PROCEEDINGS

WATER '87

THE 6TH ASIA PACIFIC REGIONAL WATER SUPPLY CONFERENCE AND EXHIBITION

BANGKOK CONVENTION CENTER

DECEMBER 11-16, 1987

CENTRAL PLAZA, BANGKOK, THAILAND

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Message from President
of the Organising Committee
of the 6th ASPAC WATER'87

It is truly a great honour that the Thai Waterworks Association, the Metropolitan Waterworks Authority, and the Provincial Waterworks Authority, have been given this privilege to host the 6th ASPAC WATER'87 in this culturally rich city of Bangkok. The year 1987 is most appropriate for two reasons. It is our 'Visit Thailand Year,' and more importantly, it is also the year that we celebrate the 60th birthday anniversary of our beloved monarch, King Bhumiphol.

Under the theme of 'Potable Water Facilities and Standards,' selected in response to the UN's International Drinking Water Supply and Sanitation Decade, the 6th ASPAC WATER'87 is intended to be the forum for experts from member countries of the IWSA/ASPAC Group as well as from waterworks communities around the globe to exchange their view and expertise in the latest developments of water technology. This event will also serve to foster close relationship and understanding among members within and without the region.

In organising the 6th ASPAC WATER'87,the members of the organising committee have made a commendable effort with their hard work and determination to ensure the success of this event. A few other public and private organisations within and without Thailand have also unfailingly rendered advice and assistance whenever they were most needed. To these people and organisations, I would like to offer my sincere appreciation for their contributions.

Last, but not least, I would also like on behalf of the three hosting organisations extend our warmest welcome to all delegates, speakers, participants and exhibitors to the 6th ASPAC WATER'87. I wish your stay in Bangkok professionally rewarding, and a totally joyful moment.

ARTHIT OURAIRAT
President of the Organising Committee
the 6th ASPAC WATER'87
President, IWSA/ASPAC Group

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PACKAGE 1

PLANNING AND DESIGN WATER SUPPLY FACILITIES

GROUND-WATER RESOURCES DEVELOPMENT IN THE ESCAP REGION

Prepared by the Secretariat of
United Nations Economic and Social Commission
for Asia and the Pacific (ESCAP)

INTRODUCTION

In view of the urgent need to provide an adequate supply of safe drinking water for the world's population, the United Nations designated the period 1981-1990 as the International Drinking Water Supply and Sanitation Decade. While the primary responsibility for meeting the goals of the Decade rests with the Governments of the developing countries, the role of the United Nations and its specialized agencies is to assist the countries in their national efforts towards achieving these goals.

The nature of the water supply problem in the ESCAP region is such that the need to provide safe drinking water is more urgent in rural than in urban areas. This is supported by the fact that out of the reported 1,128 million people without safe drinking water in the developing countries of the ESCAP region, 82 per cent live in rural areas and only 18 per cent in urban areas.

As the rural population in developing countries is scattered over large areas it is not economically feasible to provide rural areas with piped surface-water supply systems. Therefore, ground water plays a very important role in rural water supply in the region, particularly in areas where surface water resources are limited. Besides, it is observed that in many countries and areas - Bangladesh, Guam, India, Japan, and the Republic of Korea, to name just a few - ground water is much cheaper to develop than surface water.

The purpose of this paper is to provide information with regard to the status of ground-water resources development in the ESCAP region, the part played by the United Nations system of organizations in the development of the region's ground-water resources, the problems of ground-water development which are common to some countries in the region, and to draw specific conclusions on the development, management and utilization of ground-water resources in the region.

Country data on ground-water development contained in this paper were provided by the Water Resources Branch, Natural Resources and Energy Division, Department of Technical Co-operation for Development, United Nations Headquarters, which it collected from various government organizations.

A. Ground water as an important source of water supply

Tapping of ground-water resources for drinking water supply in the region dates back to ancient times and is now widely practised. For example, in the Philippines (1) the use of ground water has been reported since 1521, while in China wells of several hundred metres depth were drilled by using bamboo rods in the sixteenth century.

The main reasons for which ground water is a significant source for safe drinking water supply are: it is commonly free of pathogenic organisms as well as of turbidity and colour and therefore can normally be used without any treatment; its temperature and chemical composition are generally constant; its availability is geographically widespread over the entire region and is relatively unaffected by short droughts; and in many arid and semi-arid regions it is the only source of water supply.

The complete absence of bacteria and other micro-organisms in almost all ground-water resources under normal conditions is due to the fact that the environment of the ground-water reservoir is not conducive to the survival of micro-organisms as it is insulated, lacks oxygen and usually provides some degree of infiltration. Hence, it is rare for a newly drilled well in most types of geological units to yield water containing living organisms. Under some circumstances, however, particularly in karstic limestones or in other rocks having large openings or channels, polluted water does have an opportunity to travel considerable distances without destruction of micro-organisms. Even in such cases the movement of organisms into supplies of drinking water can be prevented by proper location of well sites and/or the removal of the sources of pollution.

In many countries ground water has proved to be the most convenient, economical and reliable (being subject to less seasonal fluctuation) source, particularly in rural areas. A recent study has indicated that ground water is one of the main factors which contributed to alleviating the famine that threatened China and India earlier in the century following the rapid growth of population in those countries.

Ground-water utilization in various sectors of the economy in selected countries of the ESCAP region is presented in table 1.

For the majority of the countries in the region, ground water is a major factor affecting their socio-economic development. In Kiribati, a Pacific island country, ground water is the only source of water supply apart from very restricted practices of rain-water harvesting. In such countries ground water is the key factor in sustaining the lives of their population. In Guam, it is a vital resource for sustaining a viable economy on the island. In Viet Nam, there are many regions in which surface water is not available and ground water is the only source of water supply. In Australia, ground water is important in augmenting short supplies of surface water. In fact, it is the main source of water for more than half the continent, where reliable surface water supplies are not readily available. In India and Pakistan, ground water is an important source of water supply for irrigation. For instance, India obtains 40 per cent of its irrigation water from ground water. In the Republic of Korea, the water requirements for its industries are satisfied mainly from ground water resources. In Malaysia, until about 20 years ago surface water was readily available in terms of both quantity and quality. However, a considerable increase in water demand has caused serious shortages in water supply, and ground-water resources have increasingly assumed an important role for supplementing the surface-water resources. In the Philippines, ground water has been used primarily for domestic water supply. About 28 per cent of the total population are supplied with ground water tapped from wells and springs. Another sector in which ground water is utilized is industry: about 50 per cent of the total industrial water requirement is satisfied by ground water. In Thailand, the expansion of national economic development programmes, which began in 1955, increased the requirements of water for domestic, agricultural and industrial needs to a level where the water demand could no longer be satisfied by the surface-water resources alone, and ground-water resources had to be resorted to in order to make up the deficit. In New Zealand, the majority of regions depend entirely on ground water. It is observed that 13 of its 40 large cities and towns currently depend on ground-water resources for water supply.

Table 1. Ground-water utilization (million m^3/year) by various sectors of the economy in selected countries of the ESCAP region

Country or area	Domestic and/or municipal	Irrigation	Industry	Total
1. Australia	1 160	1 460	180	2 800
2. Bangladesh a/	1 710	5 997	24	7 731
3. Guam	..	..	..	35
4. India	4 600	143 500	1 900	150 000
5. Indonesia	3 640	11	33	3 684
6. Malaysia	427	35	249	711
7. Pakistan	..	40 000	..	40 000
8. Philippines	1 095	500	1 000	2 595
9. Thailand	541	202	181	924

Source: Figures are based on country data provided by the Department of Technical Co-operation for Development, United Nations Headquarters, New York, except for Bangladesh.

a/ National Water Plan Project: Second Interim Report, June 1984, vol. III, Ground-water Availability (Ministry of Irrigation, Water Development and Flood Control, Bangladesh), pp. 2-4.

Note: Two dots (..) indicate that data are not available or are not separately reported.

Utilization of ground water in relation to the total water use in selected countries of the region is given in table 2. It will be observed from this table that ground-water utilization constitutes a significant portion of the total water use.

In Japan, the ratios of ground-water use to total water use in various sectors are: industrial use, 41 per cent, domestic use, 28 per cent, irrigation, 6.6 per cent, and air conditioning, 100 per cent.

Table 2. Ground-water utilization as a percentage of total water use

Country or area	Percentage
1. Australia	16.6
2. Guam	75
3. Iran (Islamic Republic of)	41
4. Japan	16
5. Kiribati	100
6. Malaysia	19
7. Philippines	35
8. Republic of Korea	6

Source: Ground-water in the Pacific region, Natural Resources/Water Series No. 12 (United Nations publication, Sales No. E.83.II.A.12), except for the Islamic Republic of Iran, which is based on data from "Water resources profile" (unpublished) prepared by ESCAP.

The development of ground-water resources is relatively inexpensive, particularly if it can be tapped at shallow depths. The average approximate cost of ground water, which includes the costs of drilling, well construction, pumps and accessories, fuel/energy, and operation and maintenance, for selected countries of the region is given in table 3.

Table 3. Ground-water extraction cost in selected countries

Country or area	Cost per m^3 at well-head (US dollars)
1. Bangladesh	0.01 (1979)
2. India	0.02 (1973)
3. Japan	0.01-0.04 (1980)
4. Malaysia	0.06-0.09 (1981)
5. Northern Mariana Islands	0.03 (1983)
6. Pakistan	0.01 (1981)
7. Philippines	0.03 (1983)
8. Samoa	0.04 (1983)

Source: Cost figures are based on country data provided by the Department of Technical Co-operation for Development, United Nations Headquarters, New York.

According to available information the approximate average costs (including treatment and conveyance costs) of surface-water supply (2) in Bangladesh and India are $US 0.10 (1978) and $US 0.08 (1977) respectively. This suggests that ground water is much cheaper than surface water in these countries. Besides, recent studies indicate that ground water is much cheaper to develop than surface water in countries or areas like Guam, Japan, and the Republic of Korea, although information on comparative cost data is not available.

B. Assessment of ground-water resources development in the Asian and Pacific region

Development of ground-water resources in the Asian and Pacific region has occurred since ancient times. However, large-scale development of ground water began only after the Second World War and has been expanding considerably since then.

In China, a major thrust in ground-water development was initiated in the 1950s and the country has maintained this momentum until now.

In Bangladesh (3), the World Bank had financed two deep tube-well projects for 7,000 wells: the first project, financed in 1973, for 3,000 wells had been completed and the second project for 4,000 wells had been approved for co-financing by the Bank, the United Kingdom of Great Britain and Northern Ireland and Australia. The Bank had also financed two shallow tube-well projects: the first for 10,000 wells equipped with diesel pumps and the second for 180,000 tube-wells with hand pumps.

Exploration of ground water was initiated in central Burma in about 1980 and, after a pilot development of about 25 wells, the feasibility of further development of ground water in this region was established. Based on the success of this pilot development, the World Bank appraised the first tube-well project in late 1982, and later approved a Bank loan for $US 14 million for the construction of 106 tube wells for irrigating approximately 7,300 hectares. In Burma (3), as of 1983, there had been no development of ground water for irrigation.

In India (3), as of 1983, the Bank had financed three tube-well projects in the State of Uttar Pradesh: the first project, financed in 1962, consisted of 800 wells with traditional design; the second project, financed in 1980, consisted of 500 wells with new improved design concepts; and the third project, financed in 1983, consisted of 2,200 wells with all the design innovations successfully tried out under the second project. The third project involved a Bank loan of $US 101 million. Virtually all Bank-financed ground-water projects have been or are being implemented by national organizations or departments.

In Maldives, Singapore and Sri Lanka, ground-water development has faced some difficulties. In some highly populated islands of Maldives, scarce ground-water resources are subjected to exhaustion, sea-water intrusion and pollution. In Singapore, ground-water resources are not significant. In the northern part of Sri Lanka, ground-water development in fractured and karstic low-lying limestones has resulted in sea-water intrusion.

In countries such as Malaysia, Bhutan and the Lao People's Democratic Republic, which had not undertaken major ground-water development programmes until recently, plans for large-scale development are now being seriously considered.

In the Pacific island countries, such as the Cook Islands, Fiji, Niue, Papua New Guinea, Samoa, Solomon Islands and Tonga, ground water exists in the form of fresh-water lenses, particularly on small islands of less than 100 km^2 in area and less than 3 km in width. In atolls (4), the fresh-water layer is quite thin and does not generally exceed one metre. Therefore, the exploitable ground-water potential on the atolls is not significant and will not be able to meet the requirements of domestic use. This is particularly true in the case of islands whose width is less than a half mile. In such islands and atolls, most of the domestic water supply is derived from rain-water catchments. Ground water in island countries is developed mostly by means of shallow dug or drilled wells which tap the fresh-water lens in its upper part. In most cases the yields have to be kept low so as to leave the fresh-water lens as undisturbed as possible.

The hydrogeological conditions of the Asian and Pacific region vary substantially from place to place. However, in general, the region is endowed with large quantities of ground-water resources. Many areas have vast ground-water reservoirs storing extensive amounts of water and receiving regular annual recharge. According to preliminary findings by a World Bank study (5), large deep underground fresh-water reservoirs exist in Bangladesh, Burma, India and Nepal, particularly in the Ganges, Brahmaputra and Irrawaddy basins, the exploration and development of which are expected to benefit up to five hundred million people living around those basins. A compilation of the estimated ground-water potential and its utilization in selected countries of the region, based on available data, is given in table 4. From this table, it will be observed that with the exception of Guam, a small island in the Pacific, the remaining countries have so far developed a very small percentage of their exploitable ground-water resources potential for utilization.

Assessing ground-water availability goes far beyond the stage of data collection. It requires an adequate and reliable ground-water investigation programme that involves the study of the ground-water flow, assessment of the hydrological balance, and of the ground-water budget of the aquifers. According to the available information few countries in the region have adequate ground-water investigation programmes.

C. Conservation and protection of ground-water resources

Given the significance that ground water holds for countries of the ESCAP region, the importance of conservation and protection of this natural resource from pollution cannot be overemphasized.

One of the effective ways to achieve conservation and protection of ground-water resources in the region is to promote national efforts to formulate and promulgate ground-water legislation as part of the general water legislation.

Table 4. Estimated ground-water potential and ground-water utilization in selected countries in the region

Country or Area	Exploitable potential (Million m^3/year)	Utilization (Million m^3/year)	Utilization as percentage of potential
1. Australia	50 600	2 800	5.5%
2. Bangladesh a/	..	7 731	..
3. Guam	70	35	50%
4. India	..	150 000	..
5. Indonesia	455 520	3 684	1%
6. Malaysia	63 000	711	1.12%
7. Mongolia b/	6 000	..	..
8. Pakistan	..	40 000	..
9. Philippines	33 000	2 595	8%
10. Republic of Korea	15 000	..	..
11. Thailand	..	924	..
12. USSR (Asian part)	279 000	..	..

Source: Figures are based on country data received from the Department of Technical Co-operation for Development, United Nations Headquarters, except those for Mongolia.

a/ National Water Plan Project: Second Interim Report, June 1984, vol. III, Groundwater Availability (Ministry of Irrigation, Water Development and Flood, Bangladesh), pp. 2-4.

b/ Vodnoye Kherzyaistva MHR (Water Economy of the People's Republic of Mongolia, in Russian), an information booklet (VIZDOK nyomda, Budapest VII, 1983).

Note: Two dots (..) indicate that data are not available or are not separately reported.

In Japan, ground water belongs to landowners, while surface water is controlled by the Government. In 1963, self-governing bodies have been established in the country to exercise control over the drilling of new wells, land development and ground-water extraction.

In Thailand, drafting of the Ground-water Act was initiated in 1972 by the Department of Mineral Resources and it became law in 1978. The underlying principle of the Act is government control of ground-water activities. This includes drilling for ground water, its use, and disposal of waste water into the aquifer through a well. Under the provisions of the Act, no one may utilize ground water from designated "ground-water areas" without an official permit.

In Viet Nam, appropriate legislation has been enacted to protect ground water against pollution, particularly by industries. However, it was indicated that at present it has not been possible to prevent occurrences of such pollution.

In this connection, it is necessary to stress that efforts should also be made to raise the level of knowledge of the public in general and water users in particular with regard to the nature, behaviour and vulnerability of ground-water resources towards achieving public acceptance of legal and administrative measures which could restrict the freedom of individual water users. Such knowledge is necessary in order to forestall any resistance or outright opposition by the public to the implementation of sound policies for protecting ground water.

D. The role of the United Nations system in the development of ground-water resources

The United Nations and its specialized agencies are actively engaged in the development of ground-water resources in the region. Some of the organizations involved are the Department of Technical Co-operation for Development (Headquarters), Economic and Social Commission for Asia and the Pacific (ESCAP), United Nations Children's Fund (UNICEF), United Nations Development Programme (UNDP), Food and Agriculture Organization of the United Nations (FAO), United Nations Educational, Scientific and Cultural Organization (UNESCO), and World Health Organization (WHO).

Based on the available information, the activities of the United Nations system in the field of ground-water resources development in the region are summarized in annex I.

Some of the ESCAP activities in the field of ground-water resources development have included providing technical assistance to developing countries through the Regional Mineral Resources Development Centre (RMRDC) in the form of hydrogeological surveys and providing advisory services aimed at achieving the accelerated manufacture of hand pumps for rural water supply in the region.

E. Problems of ground-water development

1. Problems that hamper development of ground-water resources

(a) Adequacy and reliability of hydrogeological surveys

One of the major problems faced by developing countries in the region is the lack of adequate and reliable hydrogeological surveys for the assessment of their ground-water resources.

(b) Shortage of adequately trained manpower

A serious problem common to most of the developing countries in the region is the shortage of qualified manpower in the field of ground-water resources development at all levels: managerial, supervisory, higher technician, technician and skilled worker. It is also observed that these countries, particularly the Pacific island countries, have difficulties in acquiring the necessary technical know-how as well as in building their professional institutional capabilities.

(c) Shortage of financial resources

Finally, most of the developing countries consider the lack of financial resources to be a very severe constraint in the development of their ground-water resources. In this regard, the establishment and implementation of appropriate pricing policies for the supply of ground water may be helpful as a means of full or partial recovery of fixed and recurrent costs to generate internal financial resources as well as to enhance the ability to secure credits, loans and grants from external sources.

2. Problems resulting from improper management and use of ground water

(a) Problems related to over-exploitation of ground water

Problems related to over-exploitation of ground water include declination of ground-water levels, reduction of well outputs, encroachment of sea water along coastlines, subsidence of the land surface and movement of mineralized or polluted waters into the aquifer. Generally, the declination of ground-water levels results in the increased cost of ground water owing to the expenditure involved in deepening the wells and pumping up water from the correspondingly increased depths. In some cases, over-exploitation could lower the water table to such depths that the existing wells have to be abandoned.

Countries which are facing problems related to excessive withdrawal of ground water in certain locations include Australia, China, India, Japan, Kiribati, Maldives, Republic of Korea, Sri Lanka and Thailand. For example, in Australia (1), a number of basins, such as the Great Artesian Basin, the Burdekin Delta, the Bundaberg area and the North Adelaide Plains, have their ground-water resources developed and extracted to a level reaching or exceeding that which can be sustained by natural recharge. In Thailand, increasingly heavy pumpage of ground water in Bangkok during 1955-1982 caused a decline of 45 to 50 metres in the ground-water levels. The lowering of water levels by these depths had resulted in the abandonment of old wells, increased pumping costs and encroachment of sea water.

(b) Contamination related to human settlements

Contamination of ground water may be caused by cesspools, septic tanks, leaking sewer systems, and industrial and domestic waste disposal sites. Contamination of this kind is found to be common in the vicinity of large cities and in suburban areas of India and Kiribati. For example, at Semra, India (7), many hand-dug wells were found to contain water with high concentrations of nitrate. This nitrate pollution was found to originate from latrines and animals straying in the vicinity of wells. Similarly, Kiribati has the problem of pollution of ground-water resources near human settlements. According to a recent study by the International Reference Centre (7), nitrate pollution of ground water from on-site sewage disposal systems, particularly in high population density unsewered areas, is becoming a serious problem in other developing countries as well. In New Zealand, the quality of shallow ground water in certain rural areas is observed to be deteriorating as a result of contamination from intensive stocking, factory farming, fertilizer application, irrigation infiltration and septic tanks.

(c) Problems related to coastal areas

The encroachment or intrusion of salt water is also a serious ground-water problem, particularly in coastal areas. Since a large portion of the region's population is located along the coasts of oceans and salty seas, there are many problems of this kind in the region. Some of the countries which have problems of this nature include Fiji, Guam, Japan, Kiribati, New Zealand, Thailand and Viet Nam. Basically, encroachment occurs when the water levels in a fresh-water aquifer are lowered to a point where salt water can invade beds bearing fresh water. For example, in Fiji, the majority of boreholes for water supply in Viti Levu are situated near the coast owing to the concentration of population along the coast. This has led to saline intrusion problems at Tagitagi, Singatoka and Korotongo. In Guam, the problem of increased salinity in certain wells is due to the wells located very close to the coastline rather than due to overdraught. In

Kiribati, salt-water intrusion into the fresh-water lenses is observed to be the result of over-exploitation, which is becoming a major problem, particularly on the low atoll islands. There is no problem of overdraught in New Zealand, however, salt-water intrusion has taken place in certain regions where abstraction wells have been sited unreasonably close to the interface. In Thailand, the rapid lowering of the water table due to overdraught has caused the shallow aquifers in Bangkok to become contaminated with salt water. In Viet Nam, sea-water intrusion into coastal aquifers is a major problem. For example, in the lower part of its major river basins, as well as in the coastal plains, the average salinity of ground water is approximately 3,000 to 4,000 ppm, while the maximum salinity sometimes reaches as high as 10,000 ppm, thus rendering the ground water unsuitable for drinking.

(d) Land subsidence problems

In some countries of the region, the withdrawal of large amounts of ground water has caused serious problems of the subsidence of the land surface. Some of the countries facing such problems include China, Japan, and Thailand. In Japan, from 1961 to the present time, the occurrence of land subsidence and/or sea-water intrusion was the result of over-exploitation of ground water brought about by the remarkable growth of industries and the expansion of agricultural production. Land subsidence has occurred in the low-lying land of the plains and basins where the principal cities, Tokyo, Nagoya, Osaka, Yamagata, Kofu, etc., are located (8).

In Thailand, over-exploitation of ground water exists in many locations, particularly around the Bangkok area. In Bangkok (6), the field evidence of land subsidence has been observed in the form of protrusion of well casings above the ground surface. Estimates based on the protrusion of well casings which were installed about 19 to 26 years ago indicate that the average subsidence rate in the city is approximately 1.8 to 1.9 centimetres per year. A detailed survey of ground levels carried out in Bangkok during the period 1979-1981 indicated that the existing benchmarks are 30 to 80 centimetres below their original elevations recorded 30 to 40 years ago. At present, about half of the city is less than 0.5 metres above the mean sea level (6). As in Bangkok, Shanghai, China, experienced a severe subsidence problem between 1921-1965, particularly from 1949 to 1957, during which an increase in ground-water pumpage resulted in a corresponding increase in the rate of subsidence as well as the area affected.

In this connection, it should be noted that where subsidence has occurred, it is not possible to reverse the process by any means whatsoever. In other words, even a complete cessation of pumping and the injection of new water into the ground will not restore the land surface to its original elevation. Hence, it is very important to establish and implement effective ground-water management programmes to forestall land subsidence due to over-pumping.

F. Conclusions

(1) Ground water is an important natural resource for the socio-economic development of countries in the region. The enhancement of its development is also a crucial factor in achieving the goals of the International Drinking Water Supply and Sanitation Decade.

(2) Hydrogeological surveys and hydrogeological maps are prerequisites for the effective planning of ground-water development. The lack of these basic data is one of the major constraints which hampers the development of ground-water resources in the region.

(3) Other constraints which hamper the development and rational use of ground-water resources include lack of adequately trained manpower, lack of equipment and lack of financial resources.

(4) For the optimum utilization of ground-water resources, the possibility of conjunctive use of surface and ground-water resources should be considered.

(5) The establishment of ground-water legislation is important and necessary to provide a legal basis for the effective management of ground-water resources, including its conservation and protection against contamination.

(6) The success of any legal and administrative measures for conservation and protection of ground-water resources depends to a large extent on the public acceptance of these measures which can be achieved through public education and information dissemination programmes.

Annex I

List of ground-water resources development projects in the Asian and Pacific region executed and/or financed by the United Nations system

	Project title	Year	Beneficiary country	Executing agency	Funding agency
1.	Ground-water investigation	1963	Afghanistan	DTCD*	UNDP
2.	Ground-water investigation	1971	Afghanistan	DTCD	UNDP
3.	Ground-water survey	1974	Bangladesh	DTCD	UNDP
4.	Ground-water resources development	1981	Bangladesh	DTCD	UNDP
5.	Ground-water surveys, Rajasthan	1965	India	DTCD	UNDP
6.	Ground-water in Madras State	1965	India	DTCD	UNDP
7.	Ground-water in Madras State Phase II	1968	India	DTCD	UNDP
8.	Ground-water studies in Rajasthan and Gujarat	1971	India	DTCD	UNDP
9.	Ground-water studies in Ghaggar River Basin	1974	India	DTCD	UNDP
10.	Hydrological and artificial recharge studies	1980	India	DTCD	UNDP
11.	Artificial recharge studies Gujarat	1981	India	DTCD	UNDP
12.	Ground-water studies in Kasai and Subarnabkka river basins	1984	India	DTCD	UNDP
13.	Ground-water investigation in selected areas of Baluchistan	1973	Pakistan	DTCD	UNDP
14.	Ground-water development	1980	Countries of Asia and the Pacific	DTCD	UNDP
15.	Ground-water development	1974	Sri Lanka	DTCD	UNDP
16.	Ground-water data centre	1984	Thailand	DTCD	UNDP
17.	Ground-water exploration	1979	Viet Nam	DTCD	UNDP
18.	Ground-water survey Phase II	1981	Viet Nam	DTCD	UNDP
19.	Support for tube-well command	1981	Bangladesh	FAO	UNDP
20.	Ground-water drainage research	1974	India	FAO	UNDP
21.	Ground-water reconnaissance	1982	Lao People's Democratic Republic	FAO	UNDP
22.	Ground-water development drilling programme	1974	Philippines	FAO	UNDP

	Project title	Year	Beneficiary country	Executing agency	Funding agency
23.	Pre-feasibility study for coconut irrigation with ground-water	1985	Sri Lanka	FAO	UNDP
24.	Assistance to the Irrigation Management Programme Training Activities at the Rural Development Academy in Bogra	1984	Bangladesh	FAO	UNDP
25.	Equipment for the Geophysical Wing of the Central Ground-water Board - Phase II water	1983	India	FAO	UNDP
26.	Studies for the use of saline water in the command areas of irrigation projects, Haryana	1982		FAO	UNDP
27.	Ground-water utilization for food crop production	1985	Indonesia	FAO	FAO
28.	Irrigation training	1981	Nepal	FAO	UNDP
29.	Remote sensing applications for ground-water exploration	1985	Philippines	FAO	FAO
30.	Feasibility for second tube-well project	1982	Bangladesh	ADB/IDB*	
31.	Roving seminar on ground-water development	1981	Countries of ESCAP region	ESCAP	UNDP
32.	Hydrogeological and ground-water development advisory services	1978 continuing	Regional developing countries	ESCAP/ RMRDC*	Donor country UNDP
33.	Advisory missions on accelerated manufacture of hand pumps for rural water supply	1985	Bangladesh, Burma, Indonesia, Thailand	ESCAP	ESCAP
34.	Ground-water irrigation	1962	China	China	World Bank/ IDA
35.	Tube-well irrigation	1962	India	India	-do-
36.	Tube-wells	1973	Bangladesh	Bangladesh	-do-
37.	Shallow tube-wells	1977	Bangladesh	Bangladesh	-do-
38.	Bhairawa-Lumbini I	1977	Nepal	Nepal	-do-
39.	UP tube-wells I	1980	India	India	-do-
40.	Hand tube-wells	1981	Bangladesh	Bangladesh	-do-
41.	Deep tube-wells II	1983	Bangladesh	Bangladesh	-do-
42.	Bhairawa - Lumbini II	1983	Nepal	Nepal	-do-
43.	UP tube-wells II	1983	India	India	-do-
44.	Ground-water irrigation I	1983	Burma	Burma	-do-
45.	Birganj irrigation	1973	Nepal	Nepal	-do-
46.	Irrigation VIII	1977	Indonesia	Indonesia	-do-
47.	Narayni zone irrigation	1979	Nepal	Nepal	-do-
48.	Haryana irrigation I	1979	India	India	-do-
49.	Irrigation XVII	1982	Indonesia	Indonesia	-do-
50.	North China plain	1982	China	China	-do-
51.	Chambal (MP) irrigation II	1983	India	India	-do-
52.	Haryana irrigation II	1983	India	India	-do-

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Note: DTCD - the Department of Technical Co-operation for Development, United Nations Headquarters.
ADB - Asian Development Bank
IDB - Inter-America Development Bank
RMRDC - Regional Mineral Resources Development Centre
IDA - International Development Association

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New Prognosis and Contract Adaptions for the Water Delivery to the 60 Partner Communities of the Region of Zurich by the Water Supply Authority Zurich.

by :
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Wasserversorgung

General

Water is indispensible for the existence of all living beings. The concern for this asset is, therefore, a task of the utmost importance for every community. In this sense the water supply utilities must assure that water in sufficient quantity, with adequate pressure and of impeccable quality is available at all times. The City and Region of Zurich are one of the biggest connurbations in Switzerland. For this area sufficient drinking and industrial water is to be made available. This task has now been solved covering a large area, and the required financial means for its realisation were raised by the City, by the various Boroughs concerned and by the Canton. If in the following mention is made of the Region of Zurich it concerns those 60 communities which today have, directly or indirectly via a group water supply, concluded water delivery contracts with the City of Zurich (Figs. 1 and 2). The partners are:

1. Borough of Adliswil
2. Borough of Zollikon
3. Specific Union Group Water Supply Suburbs and Glattal

(CVG), with the Boroughs of Bassersdorf, Boppelsen, Buchs, Dällikon, Dänikon, Dielsdorf, Dietlikon, Dübendorf, Greifensee, Hüttikon, Illnau, Kloten, Lufingen, Niederhasli, Nürensdorf, Opfikon-Glattbrugg, Otelfingen, Regensdorf, Rümlang, Schwerzenbach, Uster, Volketswil, Wallisellen, Wangen-Brüttisellen und Winkel. A total of 25 Boroughs.

4. Regional Group Water Supply Amt-Limmat-Mutschellen (GALM) with the 26 Boroughs of Aesch, Aeugst, Affoltern a.A., Arni, Berikon, Birmensdorf, Bonstetten, Hausen a.A., Hedingen, Islisberg, Kappel, Knonau, Mettmenstetten, Oberlunkhofen, Oberwil, Obfelden, Ottenbach, Rifferswil, Rudolfstetten, Schlieren, Stallikon, Uitikon-Waldegg, Urdorf, Wettswil, Widen and Zufikon.
5. Elevated Zone Water Supply Looren-Forch with the 4 Boroughs of Fällanden, Küsnacht, Maur and Zumikon.
6. Water Supply Co-operative Tobelhof Gockhausen (Borough of Dübendorf).
7. Water Supply Utility Walterswil-Sihlbrugg Ltd with the 2 Boroughs of Baar and Neuheim.
8. Waterworks Zug Ltd, vested right, procurement according to requirement.

General Disposition of the Water Supply Facilities in the City, the Region and in the Canton of Zurich 1971.

In 1971 a general plan of disposition for the water supply facilities in the City and Region as well as in the Canton of Zurich was elaborated. Mr Christian Maag, dipl.eng., Head of the Office for Water Protection and Water Engineering of the Canton of Zurich, was responsible for the work on the plan for the Canton of Zurich. For the City of Zurich the realisation lay in the hands of the Water Supply Authority, who engaged the engineering office of Haas and Meier. The planned target for the period 2020/2040 (Condition II) corresponds to the population density of the master plan of the cantonal Office for Regional Planning, whereby a population of 2.1 million inhabitants in the Canton of Zurich was then assumed. Besides this planning target the short and long-term objectives of the years 1985 resp. 2000 were determined, as they were naturally of great importance for the realisation of the plan. During the planning special attention was given in the City to the problem of optimum utilisation of all facilities either under construction or existing, for the Region as well as for the City.

The criterion for the dimensioning of Swiss water supply facilities are still today the population development and the specific water consumption per capita and day. For the determination of the water consumption in the Region of Zurich, these criteria are sufficient, whereas the City, however, must consider the places of work and their specific consumption. With these four criteria a very good estimation of the total water consumption for the City of Zurich was obtained. Nevertheless, for the determination of the consumption of the various municipal supply areas, such as the City, Technical University Hönggerberg etc., this data is insufficient and, therefore, the structure of the built-up area had to be considered. The water consumption of five completely built-up typical consumption zones was measured and with the results the specific amount of water in m^3 of area in ha determined. (Fig. 3). Incidently, these measurements are being continued today. From the five specific values of consumption in m^3 per ha and day, multiplied by the area of the expected building disposition, the mean water consumption of the various zones can easily be calculated. In the City of Zurich the ratio from maximum to mean water consumption in 1976 was 1.8 - 2.6 depending on the area of consumption. A factor of 1.6 - 2.5 depending on the region was assumed for the planning. With that the future maximum daily consumption was calculated which was necessary for dimensioning the lay-out of the plants.

An example shall demonstrate, how important it is to plan the facilities for peak consumption. In order that a bridge may not collapse, it must be designed for maximum load (Fig. 4). Water supply utilities face a similar situation. The difficulties which could occur in a large city during a dry period are enormous. Within a peak consumption period a water supply utility usually has no reserves. That means it works without a safety margin. Naturally it is also expected that every part of the equipment works satisfactorily and that the total capacity of the plant is available. However, the full works capacity seldom exists even in times of normal consumption. During these periods the recurrent necessary maintenance operations have to be carried out. As long as the ratio between the mean and peak consumption is not greater than 1:2, one can speak of a normal supply, which can also be fully accepted financially (Fig. 5). Detailed information about the general plan of dispositon of the water supply facilities in the City and Region and in the Canton of Zurich about the year 1971 can be gathered from a publication of the SGWA in its journal "Gas, Water and Sewage" No. 7, 1972 under the title "New Ways of Water Supply to the 55 Boroughs of the Region of Zurich by the Water Supply Utility of Zurich" by M. Schalekamp (Special Print Nr. 656).

The Numerical Values of the Disposition Plan 1971 adapted to the Present-day Condition

The general plan of arrangement for the City, the Region and the Canton of Zurich for 1971 is basically still valid today. The prognoses, however, must be adapted in the sense of a running planning. In the last 15 years the propagation of water saving measures on the one hand, and the increased environmentally protective attitude of the consumers on the other hand, resulted in a smaller growth of the mean water consumption than prognosticated. From the point of view of environmental protection this course is very welcome. For the water supply utilities, respectively for its customers, it means, however, a temporary price increase of the water.

The peak consumptions, in retrospect on 1979, were in accordance with the prognoses of the general disposition plan. Taking into account the two criteria, mean and peak consumption, then the figures for 1971 must be adapted as follows: the calculated values for 1985 will most probably occur not till 1995 and those for the year 2000 not till 2015 to 2040. These adapted values for the next 50 years are tabulated in Figs. 6, 7, 8, 9, 10 and 11.

For the City and Region of Zurich a total amount of 500 000 m^3 water per day is available. From this amount the City must be totally supplied whatever is required and additional water has to be delivered to the Region. This water comes from various sources, i.e. 370 000 m^3/day from the Lakewater Plants Lengg and Moos, 110 000 m^3/day from the Groundwater Plant Hardhof and 20 000 m^3/day from the springs in the Sihl and Lorze Valleys.

In the far future an amount of 720 000 m^3 shall be made available. This additional quantity can be produced if and when required by the following measures detailed in Fig. 12:

- raising the capacity of the Groundwater Plant Hardhof by 40 000 m^3/day to 150 000 m^3/day by means of the construction of a direct Limmat Water Treatment Facility for increased artificial infiltration

- raising the capacity of the Lakewater Plant Lengg by 25 000 m^3/day (enlarging the Limmat Zone Pumps including the necessary pipeline network

  and

- the construction of a second Lakewater Plant Moos with a capacity of about 200 000 m^3/day.

When the occasion arises that the Lakewater Plant Moos will become redundant on account of its operational age, it can easily be replaced. Should more water be required than foreseen, a second Lakewater Plant, with a capacity of 200 000 to 300 000 m^3/day can be constructed in Lengg.
The City and Region of Zurich must, also in future, depend mainly on surface water. The ratio of ground-water to lake-water is today already 3 to 10.
The City and Region of Zurich form one of the largest and most efficient regional combines of the Canton. Beside it there exist another three smaller regional supply utilities and three larger combine systems. The latter are the Region Rheinau-Winterthur, the Region Eglisau and that of the Zurich-Oberland. Between the City and the Region of Zurich and the previously mentioned regions limited amounts of water for emergency supply can be exchanged. Larger quantities are planned for exchange in the future (Fig. 13). The existing and future mains system of the cantonal combine is shown in Figure 14. The

large-calibre ring main, half of which is already constructed, namely from the Lakewater Plant Lengg to the Groundwater Plant Hardhof, is of the greatest importance to the City and Region of Zurich.

For a better and more secure supply of all parts of the City and the Region - in case one of the water production plants breaks down - it will become necessary in the near future to realise the large calibre ring main from the Groundwater Plant Hardhof to the Reservoir Lyren, respectively to the Reservoir Frauental and later right to the Lakewater Plant Moos.
Interconnected systems are today absolutely essential. Only by means of ring mains respectively interconnected systems can water supply utilities mutually be secured in an optimal manner. This is also the main reason why the City and the Region of Zurich decided in 1971 to conclude Water Delivery Contracts. The folowing further considerations were made in this respect, namely:

1. The costs for the production and transport of the water are more favourable the larger the facilities can be planned. This is valid for both partners. As an example may be mentioned that an extension of the Lakewater Plant Lengg by 90 000 m^3/day, instead of by the actually realised 170 000 m^3/day, would have resulted in an increase of the capital costs per m^3 water produced from SFr. 310.- to SFr. 450.-. In other words, by this joint action, the Region as well as the City each saved 12.6 million Swiss Francs on investment costs.

2. The water is supplied on a purely commercial basis. All involved expenses are fully charged up.

3. In the sense of a mutual assistance it will, in the near future, be possible, in case of a breakdown of a production works of the City, to feed water into the mains system of the contract partners from other supply plants of the regions of Winterthur, Zurich-Oberland and later on also from Eglisau. This is, of course, also valid conversely (Fig. 12)

4. A secure supply with water in sufficient quantity and of good quality is of the utmost importance for the further economic and qualitative flourishing of City and Region. All partners of the region have identical contracts and the same prices. Before the various points of the normal delivery contract as well as the agreed upon alterations of 1980 resp. 1985, are dealt with in detail, it is necessary to first present the exact wording of the contract (Fig. 15).

Water Delivery Contract (Fig. 15)

between

the **City of Zurich, Water Supply Utility** (in the following called "City")

and

the **Regional Group Water Supply Aqua** (in the following called "A")

Introduction

I. The City is on the point of extending its water supply facilities in such a manner that increased deliveries to places outside of the City (to corporations, boroughs, water supply co-operative societies etc.) become possible.

The "A" consists at present of the following partners:

- Group I
- Group II
- Group III
- Group IV

A total of 26 boroughs

II. The intended water delivery of the City to "A" and other out-of-town customers is founded on the following bases and objectives:

1. The principle of joint cost accounting for facilities in the city zone and performances, which serve the procurer as well as the City, holds true. Pipelines are said to be in common use if they are of 500 mm calibre or more or if they directly serve the supply of a procurer. Subject to special agreements, the City generally undertakes the prefinancing.

2. The capital costs shall, in proportion of the opted for quantity of water at the time, be charged up to the procurers. The other costs in proportion to the effective water procurement are charged up to the procurers pro rata.

3. The terms of delivery shall, analogously, be as far as possible the same for all procurers. If, at a later time, new procurers wish to partake, they may become joint users by redemption of the existing facilities in an appropriate manner. Such redemption sums are generally utilised for exceptional amortizations on the mutually used facilities.

Accordingly the Partners agree upon the following:

Art. 1: Subject of the Contract

The City delivers on the under-mentioned terms drinking-water to "A" in the same quality as is available for the supply in the City.

Art. 2: Locations of Water Delivery Facilities

1. The water delivery will be effected from a Pumping Station and Reservoir L, to be newly constructed, via a pipeline of 600 mm in diameter installed in the direction of W. The capacity of the delivery facility for "A" amounts to 55 000 m^3 per day in maximum.

2. For the delivery of larger quantities of water further

delivery facilities will have to be created.

3. The City withdraws from the pipeline L-W water for its own use via measuring and pressure reducing shafts, however, only in such amounts that the supply of the opted quantity by "A" is at all times guaranteed.

Art. 3: Commencement of Delivery

Delivery can only commence after the construction of the Reservoir and Pumping Station L, and after the installation of the pipeline and the telecommunication cable L-W, i.e. probably from 1972 onwards.

Art. 4: General Terms of Delivery

1. "A" opts for a daily quantity of (22 000) 33 **980** m^3 which should be sufficient until (1985) **2000** .

2. In case that the City extends or newly constructs water production facilities, "A" has the right, every time the City does so, to increase its optional quantity for the following fifteen years.

3. In any case, increase of the optional quantity valid always for fifteen years, can only be permitted, if the City is in a position to deliver.

4. Once an option has been chosen, it can not be reduced at some later date.

5. "A" and analogue contract partners have the right to exchange their optional quantities among themselves, insofar as the total optional amount and the capacity of the delivery points as stipulated in the various contracts, will not be exceeded.

6. Should the total quantity opted for by the bulk water procurers be exceeded by more than 10 % in three consecutive days, an additional payment is to be made by the

partner responsible for this excess. For the amount exceeding the daily opted for quantity, five times the production price will be charged for the year concerned (See Art. 5).

7. Temporary excesses of the opted for quantity as a result of operational trouble in the facilities of "A", will not be charged for, if such trouble is immediately reported to the City by telephone and confirmed in writing within a week.

8. On hygienic grounds the minimum quantity of water taken from the supply point L must be 1000 m^3 per week.

9. "A" is obligated to ensure that on the part of the associated boroughs a reservoir content for the daily equalization is always available which corresponds at least to 33 % of the maximum daily consumption, in order that about a third of the opted daily requirement can be delivered during the night from 22.00 to 06.00 hours. The procurement should be effected in a constant manner over a period of 22 hours and will be correspondingly controlled by the City in agreement between the contract partners, and as far as possible under consideration of its own production.

Art. 5: Compensation for Water Delivery

1. The water delivery is compensated for according to a twin tariff, i.e. a service price per m^3 opted for daily procurement quantity and a working price per m^3 of the actual annual quantity procured.

2. The service price is guided by the capital costs (interest and amortization) for the production, reservoir and transport facilities constructed by the City at its own expense, such facilities also serving the contract partners of the City; this price being relative to the present capacity of the lake-water, spring-water and groundwater works. Should the capacity of the afore-mentioned

works be extended, the City will, from the date of credit approval, include such capacities into the calculation. Transport pipelines will be considered if their diameter is 500 mm and more. Pipelines of smaller calibre will only be considered if they solely serve the contract partners of the City as transport facilities.
The working price is guided by the costs which the City must expend for operation and maintenance of the production, reservoir and transport facilities shared with the contract partners of the City.

3. The prices are provisionally determined 6 months prior to the commencement of a financial year. The definite settling of accounts takes place at the end of each financial year on the basis of operation results of the previous year, on presentation of detailed statements of accounts and an up-to-date layout plan of the pooled facilities.
The enclosed example of an account (including layout plan) of (December 1970) **April 1985** would be binding for the year (1969) **1984.** It serves as a basis for future accounting and in this sense it forms an element of this contract. The valid plan and accounting bases at the time are to be drawn up anew from year to year in accordance with the actual circumstances.

4. The liability to pay the service price and working price commences on 1st October 1971.

5. Invoicing to "A" will be made monthly pro rata with a grace period of 30 days, for the first time 30 days after the effective date of the contract. Interest to start 1st October 1971. Any payment of arrears or reimbursements are to be effected within 3 months.

Art. 6: Financial Obligations of the City and of "A"

1. The City constructs and maintains the reservoir and the Pumping Station L with measuring equipment. For sharing the pipeline, diameter 600 mm, and the telecommunication cable between the Pumping Station L and the City bounda-

ry, the City pays a lump sum of SFr. 400 000.- towards the costs of this equipment.

After the construction of the pipeline and the installation of the telecommunication cable, the City becomes owner and is responsible for the maintenance thereof. The expenses of the City will be included in the capital, respectively operation and maintenance costs of the pooled service and working price.

2. "A" pays the remaining costs after deduction of the lump sum paid by the City for the pipeline and the telecommunication cable between the Pumping Station L and the City boundary W. Furthermore, "A" constructs and maintains on its own account, the equipment necessary for the procurement of water from the City boundary including a remote action facility for the transmission of the necessary measuring data to the City. The planning of such remote action facilities is carried out in agreement between the contract partners.

Art. 7: Water Metering

1. The metering of the delivery of water to "A" is effected either in the Pumping Station L, whereby the supply to the City is deducted, or in a metering shaft on the city boundary. For the control of the maximum daily procurement only those readings are valid, which are taken at night between 24.00 and 02.00 hrs always at the exact time on two consecutive days. "A" also accepts the results of the peak consumption controls carried out at the Water Supply Utility by means of a computer. Should discrepancies of the meter readings to the electrically transmitted data occur, then the meter reading is applicable for accounting.

2. Observed deviations during meter controls are not considered for invoicing, if such errors are not more than ± 3 % at mean load. Should the meter, however, show higher deviations, then the accounting is retrospectively corrected from the beginning of the calender months prior to

the determination of the deviations. In addition the meter must be repaired or exchanged.

3. "A" has the right, at any time, to read the water meters for control purposes. "A" is entitled to demand a control of the meter supplied by the City. Such control to be carried out in the laboratories of the Water Supply Utility Zurich in the presence of a representative of "A". The party in the wrong shall carry the costs of such tests.

Art. 8: Failures, Restrictions and Temporary Assistance in Water Delivery

1. Operational failures of the Municipal Water Supply because of machine breakdowns, power interruptions, pipe breakage, difficulties in the treatment process or on other similar grounds, entitles the City, to act in the same way as it would act against the water consumers in the city area, by temporarily restricting or completely cutting off the water delivery to "A". Furthermore, the City may restrict the water delivery to "A" in the same measure as it would restrict supply to its own area should there be a general scarcity of water. In case of a total disruption of the water production facilities mutually shared by "A", the water delivery will be discontinued entirely. Such measures do not entitle "A" to claim compensation.

2. The City and "A" mutually undertake the obligation, to inform each other as early as possible, of any foreseeable shut-downs and to eliminate the failures as quickly as possible.

3. The City has the right to obtain water from "A" within the frame of the latters possibilities, if circumstances so require. Provided these quantities do not fall under Art. 2, para. 3, they will be compensated for by a corresponding reduction of the opted-for amount of "A" during seven days at most. For longer lasting delivery the self-

costs of "A" will be compensated.

Art. 9: Further Stipulations

The City must be informed in writing prior to the connection of new members to "A". Furthermore, "A" must also inform the City in writing of its intention to procure water from third parties.

Art. 10: Term of the Contract

This contract is of unlimited duration and is subject to a five-years notice at the end of any September, however, for the first time on 30th September 2015 to take effect on 30th September 2020. New regulations within the frame of a more comprehensive (cantonal) water supply are reserved.

Art. 11: Change of a Contract Partner

Both contract partners (City and "A") mutually declare, that they are prepared to transfer this contract, with all rights and obligations contained therein, to a possible assignee, respectively to recognise such assignee as a new contract partner.

Art. 12: Effective Date of Contract

This contract becomes effective after the approval by the City Council of Zurich and the appropriate Authorities of "A".

Date and Place

On behalf of the City Council of Zurich

Date and Place

On behalf of the Regional Group Water Supplies Acqua

Note: Text between ( ) designates the old Contract of 1971.
Boldface type designates the new Contract of 1985

Water Delivery Contract

The contracts have been in force since 1971 resp. 1973 and are valid for 50 years. Since the effective date of these contracts, considerable works constructions have been realised which brought about important changes in the operational circumstances of the Water Supply Utility Zurich. Out of economic considerations the calculation basis of the working price was newly determined and put into effect on 1st October 1980. Not only had the produced quantity of lake-water to be considered, as was usual up to now, but the ground-water and spring-water had, in addition, to be included. Thanks to this change in the contract, which proved very successful, the Water Supply Authority now has the complete freedom for he economic management of its facilities. This brings financial advantages to both partners (City and Region). According to Art. 4, para.2 of the Water Delivery Contracts, the contract partners were able, in 1985, to increase their optioned for quantity for the next 15 years, provided the Water Supply Authority Zurich realises new facilities or extends the existing ones. This prerequisite was fulfilled by taking into operation the new Groundwater Plant Hardhof, so that an increase of the options for the years 1985 to 2000 could take effect. The partners Zollikon, High Zone Water Supply Looren-Forch and the Group Water Supply Amt-Limmat-Mutschellen took advantage of this possibility. The optioned for quantity of up to then 129 000 m^3/day was increased by 14 480 m^3/day to a total of 144 280 m^3/day. With the ground-water enrichment in the City, planned by the Canton of Zurich in co-operation with the Water Supply Authority Zurich, the amount optioned for can successively be increased by a further 7 000 to 15 000 m^3/day (Fig. 2). With the increase of the total optioned for quantity, the Water Supply Authority has now also adapted the calculation basis of the service price to that of the working price. Besides the lake-water, the ground-water and spring-water will in future also be considered. Corresponding inquiries among the contract partners resulted in their unanimous acception of this change. Subsequently supplementary contracts were made, which have been in force since 1st October 1985.

The Water Delivery Contract and its Supplements gives cause for the following remarks:

Introduction

According to the principle of mutual cost sharing for the facilities located on City ground which serve the procurer as well as the City, the City undertakes the prefinancing. The mutual facilities remain thus in possession of the City. At first sight this seems to be a very "undemocratic" solution. However, as at the most only 35 % of the total municipal production is delivered to the Region, this solution is justified. It is a just costs distribution, because each partner pays only those costs which are caused by the quantity of water he has procured. Basically, each partner has to pay the same price irrespective whether he is situated nearer or farther from the production plant, or located higher or lower. It is a matter of course, that each new partner must buy himself into the partnership at the time when he is newly connected to an existing plant of the supplier. Instead of a purchase sum, however, the new partner must pay for his connecting pipeline on City ground starting from the ring main. Should later on new procurers wish to join, they must, in a suitable manner, buy themselves into the mutual share of the existing facilities. These purchase sums will be used for exceptional amortizations of the mutually shared facilities and are thus to the benefit of all partners.

Article 2: Locations of Water Delivery Facilities

As it is in the interest of both sides to conclude a contract of longer duration, the possible capacity of the delivery facilities - independent of the quantity opted for - has been given. For the provision of larger quantities further delivery facilities would have to be provided. To be free for chosing such locations when the time comes, they were deliberately not specified.

Article 4: General Terms of Delivery

The partner must, in advance, opt for a maximum daily quantity for 15 years, i.e., the ordered quantity had to be sufficient until 1985 and must be sufficient today until 2000. Only if the City would have to expand its production facilities, or if the City were in a position to increase the delivery, a further increase of the amount to be delivered for the following 15 years could be carried out in advance. Even if the City expands its facilities, the partner is not forced to increase his option. He is in future also basically free to opt wherever he wishes. However, a once opted for quantity from the City can not be reduced. This is necessary to ensure that the capital costs caused by the partner are redeemed before the contract expires. In order that the City may dimension its production facilities on the consumption for the next 15 years, the quantities required must be opted for at the commencement of construction, i.e. 15 years in advance. This means that after completion of construction the facilities must suffice for the next 10 years. The contract partners of the Region of Zurich have, in any case, the possibility to exchange their opted for quantities among themselves insofar as the total opted for quantity and the capacity of the delivery facilities determined in the various delivery contracts are not being exceeded. Should the opted for quantity be exceeded because of interruptions due to faults, such excesses will not be charged for provided such faults are reported in time. On the other hand, should the total opted for quantity be exceeded by more than 10 % on three consecutive days, the partner responsible for this excess will be charged with the five-fold service price for the amount axeeding the daily procurement.
The partners are under obligation to ensure that a reservoir

content is always available which amounts to at least a third of the maximum daily consumption. Furthermore, the procurement has to be effected as evenly as possible over a period of 22 hours in order to counteract an inordinate load on the municipal production and distribution facilities. This is valid for maximum times of procurement; for average procurement water is produced, if possible, during low tariff periods.

Article 5: Compensation for Water Delivery

The advantage of these contracts lies in the fact that the basis for accounting takes place in the so-called pool system. That means that each connected contract partner obtains the water for the same price from the city limits.
What comprises a pool price, what are its bases and how is it arrived at? These questions will now be answered. The main feature consists in employing the self-cost price for all facilities on city grounds which are in effect being mutually shared for the water delivery to the outlying boroughs. Therefore, no distribution lines, hydrants etc., are included in the pool price, but only mutually shared facilities, such as the two lake-water plants, ground-water and spring-water works, all pipelines with a diameter of 500 mm and larger, pipelines of smaller calibre if they directly serve a procurer, the remote action facilities, a third of the reservoirs and the pumping stations required to deliver the water to the partner boroughs. The pool price is thus calculated from the self-costs of the mutually shared facilities. It is composed of a service price and a working price. The service price covers the recurring annual capital costs. The basis of the service price, as previously mentioned, is the ordered quantity of water/day (option for the year 2000). The sum of all options of the partners and the City amounts to a total of 500 000 m^3. The specific service price is computed from the annual costs for interests and amortization of the mutually shared facilities, divided by the maximum possible daily capacity of the mutual production works.
The working price is utilised to balance the costs for operation and maintenance. The basis for that is the actual annual quantity procured in m^3. The working price is computed from

the annual costs for operation, maintenance and administration, divided by the annual water production, less the supply of unpaid for water in the City.
By way of illustration, an example of a calculation may serve: In 1987 the service and working price for a partner with an option of 60 000 m^3 and an annual supply of 10 mil m^3 is as follows:

The Service Price (Fig. 16)(1987)

Capital costs SFr. 21 474 000.-

Max. daily capacity 500 000 m^3 = SFr. 42.95/m^3

Total Service Price:
Option 60 000 m^3 à SFr. 42.95 = Sfr. 2 577 000.-

The Working Price (Fig. 17)(1987)

Maintenance costs SFr. 17 500 000.-

Net annual water production 62 900 000 m^3 = SFr. 0.27/m^3

Total Working Price:
Annual supply 10 000 000 m^3 àSFr. 0.27 = SFr. 2 700 000.-

The Mean Price

Service Price Working Price
SFr. 2 577 000.- + SFr 2 700 000.-
10 000 000 m^3
Annual supply

= SFr. 0.5277 per cubic metre

The prices for water are newly determined and invoiced annually on the basis of the operational results of the previous year. If in the meantime no capacity increase of the facility takes place, the service price will naturally rise with the costs for the planned and to-be-constructed works expansions of the Water Supply Utility Zurich until the year 2000. However, as the foreseen investments for the next 15 years are approximately of a similar magnitude as the amortization, the service price will remain the same. At the present time this is SFr. 42.95/m^3, by the year 2000 it will be round about SFr. 43.50/m^3 (Fig. 16).

The working price will, however, most probably rise by about 30%. At present it amounts to SFr. 0.27/m^3 and will increase to about SFr. 0.369/m^3 by the year 2000 (Fig. 17). It must here be specially pointed out that the prices detailed in Fig. 16 do not include a general price increase. The prices shown in Fig. 17 contain a general price increase of 2-3%. In order to prevent later differences of opinion in the annual accounting, the following documents are provided as an integral part to the contract: operational accounts for the years 1969 and 1985 of the Water Supply Authority Zurich including a key to the allocation of the city-owned and mutual facilities as well as a layout plan of the present and presumably future pooled works (Fig. 18).

Article 6: **Financial Obligations of the City and of the Partner "A"**

As has been mentioned already, the City constructs and pays for all facilities realised on city ground. In the sense of a redemption fee, the partner pays the costs for the connecting pipeline from the municipal ring main and of course all facilities in his own supply region. Irrespective of who pays the maintenance of the facilities, each partner assumes these costs in his own supply region. In both cases, the expenditures of the City - wherever they concern mutual facilites - will be included in the capital resp. operations and maintenance costs which are decisive for the computation of the service and working price.

Article 8: **Failures, Restrictions and Temporary Assistance in Water Delivery**

The expenditures for the protected buildings and for the emergency power aggregate of the Groundwater Plant Hardhof and of the Pumping Stations Sonnenberg and Frauental will not be charged to the partners. The City of Zurich and not the Water Supply Utility, paid for these installations.

Expenses incurred by the operation and maintenance of the spring-water facilities and the separate fountain network of the City will also not be charged to the partners. Should the lake-water production plants experience a break-down, the partners have, therefore, no right to an emergency water supply from the above-mentioned facilities. Their own emergency water supply must then be available. During a general water shortage in normal times, the water supply (from all production works) will be limited for the partners in the same measure as it is limited in the supply region of the City.

Article 9: **Further Stipulations**

In principle, each partner has the right to procure water from third parties or accept the connection of new members without any permission whatsoever. However, the City must previously be notified of such steps, as most resulting coherent problems, such as the utilisation of the option (more or less water), could cause operational changes in the City.

Article 10: **Term of the Contract** and
Article 11: **Change of a Contract Partner**

The uniqueness of the Water Delivery Contract is the fact that not until 30th September 2020 can it be rescinded. For both partners this means great security. In addition, dispositions can be made really in advance, i.e. in plenty of time. Both contract partners may, at any time before the expiration date transfer this contract to a possible assignee. If for instance, a cantonal water compound with own legal entity be formed, a transfer of this contract could be undertaken without any problem.

Article 12: **Effective Date**

All contracts of the partners of the Region of Zurich took effect on 1st October 1971. An exception is the contract with the Group Water Supply Suburbs and Glattal which, by reason of mutual interests, came already into force on 1st October 1970. All contracts were modified on 1st October 1985.

Final Observations

The Water Delivery Contracts reviewed above, regulate the rights and obligations of the City and the partners of the Region of Zurich. Through the introduction of the pool price a solution may have been found, of how a price computation equitable for all partners, also in case of larger compound solutions, could be effected. Today, more than ever before, the principle holds true that, specially in the field of drinking-water supply, solutions for regional, cantonal and international problems must be searched for. The big water shortages which appeared in Switzerland in the years 1943, 1947, 1949 and 1972 were in the first place, mainly due to an insufficient development of available water resources and lack of compound systems, i.e. for the most part the reason was found to be the low efficiency of the available water production facilities and the non-existence of interconnected networks. This situation prevented a proper management of the available ground-water, spring-water and lake-water resources. By the management of the water resources is meant that, if for instance there is a reduction of the ground-water and spring-water on account of a dry period, this period can be bridged over with surface water from the lakes. On the other hand, if the production in a lake-water plant breaks down, ground-water and spring-water can help out. Since the City and boroughs of the Region of Zurich are associated in a water compound system, they have never again experienced a water shortage, not even in 1976 which was a year of extreme peak consumption.

There have never been any problems or differences between the partners and the City on the one hand, and the Canton of Zurich on the other hand. Warmest thanks to all concerned!

A nation that lives, provides for its future. An important part of this future is surely the provision of sufficient water, in the truest sense of the word: a vital element. The City and Region of Zurich have taken every precautionary measure so that in this respect the near future may be looked upon to be secure.

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Fig. 1

The Contract Partners
of the Water Supply Authority Zurich are:

1	Borough of Adliswil	1
2	Borough of Zollikon	1
3	Group Supply Suburbs and Glattal (GVG)	25
4	Group Supply Amt - Limmat - Mutschellen (GALM)	26
5	High-Zone Water Supply Looren - Forch (GLF)	4
6	Water Supply - Coorporative Society Tobelhof - Gockhausen	1
7	Water Supply Walterswil - Sihlbrugg AG	2
8	Waterworks Zug AG Supply only when required	-
	Partner - Municipalities resp. Cooperative Societies without Zug	60

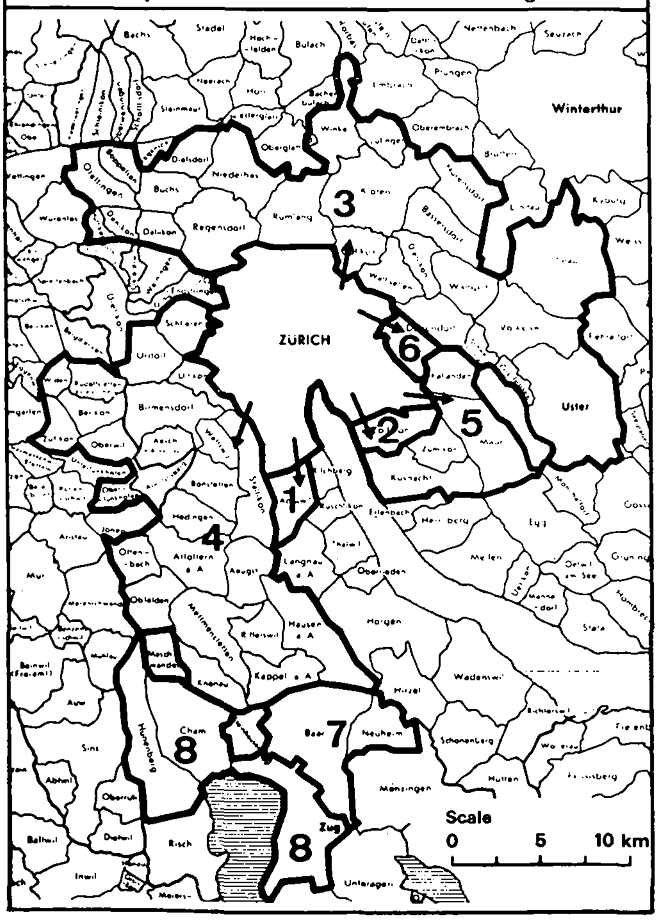

Fig. 2

Contract partners	Options m³ per day 1971	1985	1986
Borough of Adliswil	13 000	-	13 000
Amt - Limmat - Mutschellen	22 000	11 980	33 980
Suburbs and Glattal	68 000	-	68 000
Tobelhof - Gockhausen	1 200	-	1 200
Looren - Forch	8 000	500	8 500
Borough of Zollikon	17 000	2 000	19 000
Walterswil - Sihlbrugg AG	600	-	600
	129 800	14 480	144 280
Waterworks Zug AG Partner since 1900	-	-	-
Canton of Zurich plus City Enrichment (Contract pending)	-	7 000 to 15 000	15 000
Total	129 800	29 480	159 280

Fig. 3

Specific Amount of Consumption in m³, with respect to the Ground Space in ha for completely built-up, characteristic Areas of Consumption in the City of Zurich

* Reduction by means of recycling/progressive tariffs

Consumption m³ per ha/day	1971	2015/2040
1. Residential District		
Multi-storied residential buildings 100 Inh/ha		
mean/max.	33/58	30/60
Factor max./mean	2,0	2,0
Single and Multiple Dwellings with gardens 60 Inh/ha		
mean/max.	28/49	20/50
Factor max./mean	2,5	2,5
2. Industrial District		
mean/max.	290/500	120/190*
Factor max./mean	1,6	1,6
3. City Area		
mean/max.	310/540	150/240*
Factor max./mean	1,6	1,6
4. Hospitals, Hotels, etc		
mean/max.	370/650	200/440
Factor max./mean	2,2	2,2

Fig. 4 Bridge Load

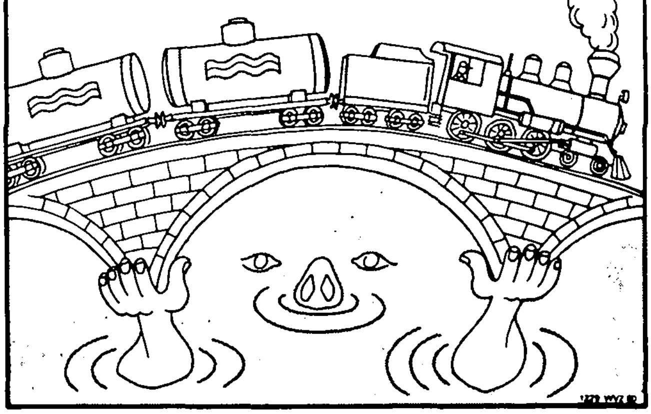

Fig. 5

Water consumption - Plant size - Security

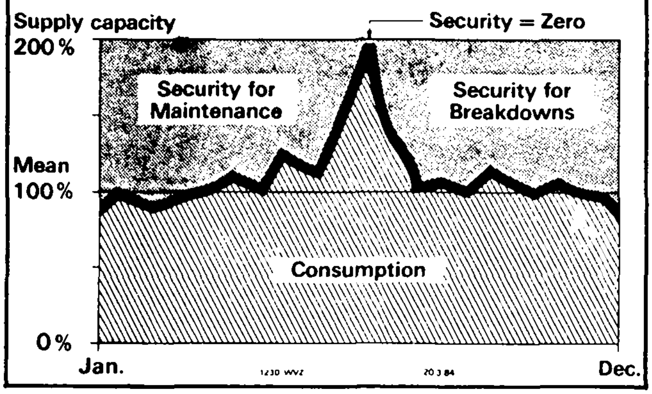

Fig. 8

Effective specific daily Consumption in m³ per Capita of the Region of Zurich

Consumption	effective 1976	estimated 1995	estimated 2015-40
Mean	0,468	0,500	0,530
Maximum	0,850	0,750	0,785

Fig. 6

Estimated mean daily Consumption of the City per day in m³

Supply area	effective 1971	effective 1976	estimated 1995	estimated 2015-40
Limmatzone	117 600	111 600	150 800	183 600
Hangzone Sonnenberg	26 700	22 600	31 400	36 300
Hangzone Albisrieden - Leimbach	8 500	7 200	10 800	13 200
Glattzone	26 000	29 600	36 200	45 900
Bergzone Orelli - Eierbrecht	3 800	3 400	4 400	5 100
Bergzonen links der Limmat	200	300	800	1 300
Loorenzone	3 200	3 600	5 200	7 100
Waidbergzone	1 900	3 500	6 400	10 500
Entire City	187 900	181 800	246 000	303 000

Fig. 9

Estimated mean daily Deficiency in m³ per day in the Region of Zurich, which should be supplied by the City

(Mean daily consumption less mean own water)
* Only half the effective deficiency
The other half required shall be covered by the regional plants of Rheinau, Zurich Oberland and Eglisau

Contract Partner	effective 1971	effective 1976	estimated 1995	estimated 2015-40
Adliswil	1 528	1 406	7 000	9 000
Galm (Amt, Limmat, Mutschellen)	-	4 440	14 000	24 000
Limmattal	-	-	-	-
Furttal	-	-	12 000*	25 000*
Vororte + Glattal	15 657	18 708	28 000*	25 000*
Tobelhof - Gockhausen	638	305	1 000	-
Looren - Forch	585	2 171	5 000	7 000
Zollikon (Zumikon, Küsnacht + Erlenbach)	3 688	3 363	8 700	24 400
Walterswil - Sihlbrugg AG	-	19	300	600
Zurich Region	22 096	30 412	76 000	115 000

Fig. 7

Estimated maximum daily Consumption of the City in m³ per day

Supply area	effective 1971	effective 1976	estimated 1995	estimated 2015-40
Limmatzone	166 200	200 400	240 800	301 000
Hangzone Sonnenberg	37 900	48 400	53 100	60 000
Hangzone Albisrieden - Leimbach	12 100	16 000	18 300	21 700
Glattzone	36 900	50 800	60 600	75 300
Bergzone Orelli - Eierbrecht	5 400	6 900	7 500	8 400
Bergzonen links der Limmat	300	800	1 300	2 100
Loorenzone	4 500	6 800	8 700	11 600
Waidbergzone	2 700	6 100	10 500	16 900
Entire City	266 000	336 200	400 800	497 000

Fig. 10

Estimated maximum daily Deficiency in m³ per day of the Zurich Region, which should be supplied by the City

* Only half the effective deficiency
The other half required shall be covered by the regional plants of Rheinau, Zurich Oberland and Eglisau

Contract Partner	effective 1971	effective 1976	estimated 1995	estimated 2015-40
Adliswil	3 200	7 650	13 000	18 000
Galm (Amt, Limmat, Mutschellen)	-	22 000	33 900	59 000
Limmattal	-	-	-	14 000
Furttal	-	-	29 000*	46 000*
Vororte + Glattal	27 000	47 750	39 000*	59 000*
Tobelhof - Gockhausen	910	860	1 200	-
Looren - Forch	870	6 940	8 000	11 000
Zollikon (Zumikon, Küsnacht + Erlenbach)	8 800	10 590	17 000	16 000
Walterswil - Sihlbrugg AG	-	170	-	-
Zurich Region	40 780	95 960	141 100	223 000

Fig. 11

Estimated maximum Water Requirement of the City and Region of Zurich in m³ per day, which shall be supplied by the City

Consumption	effective 1976	estimated 1995	estimated 2015-2040
Maximum daily consumption of the City of Zurich	326 200	400 800	497 000
Maximum daily deficiency of the Groups and Boroughs of the Region of Zurich Option	95 490	129 200 (144 280)	223 000
Total necessary water production of the Water Supply Zurich	421 690	530 000	720 000

Fig. 13

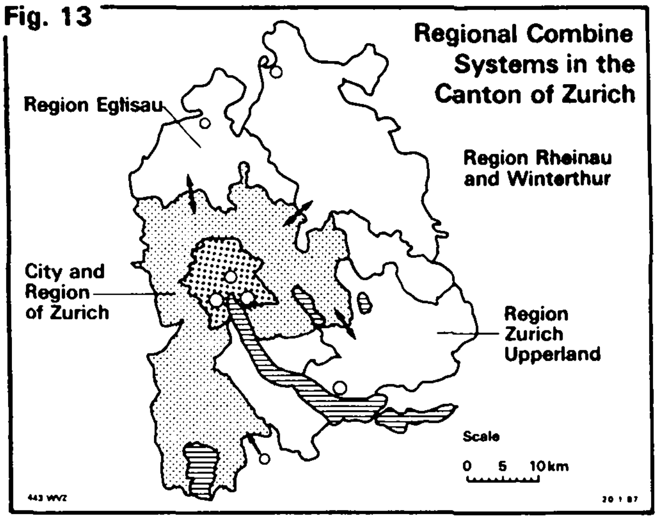

Fig. 12

Maximum and Average Water Consumption of the City and Region of Zurich shown in m³/day and the Development of the Supply Plants

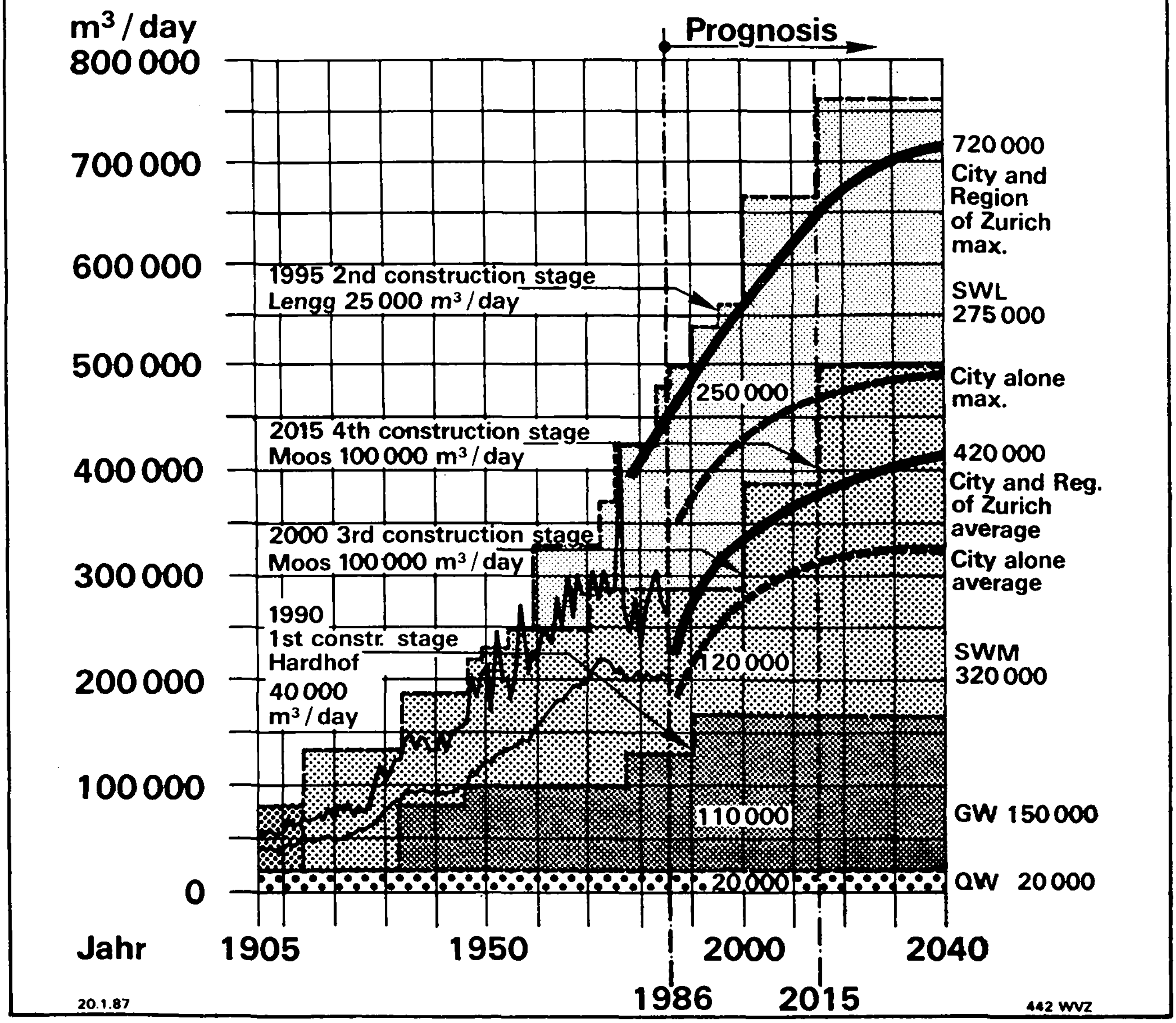

Fig. 14

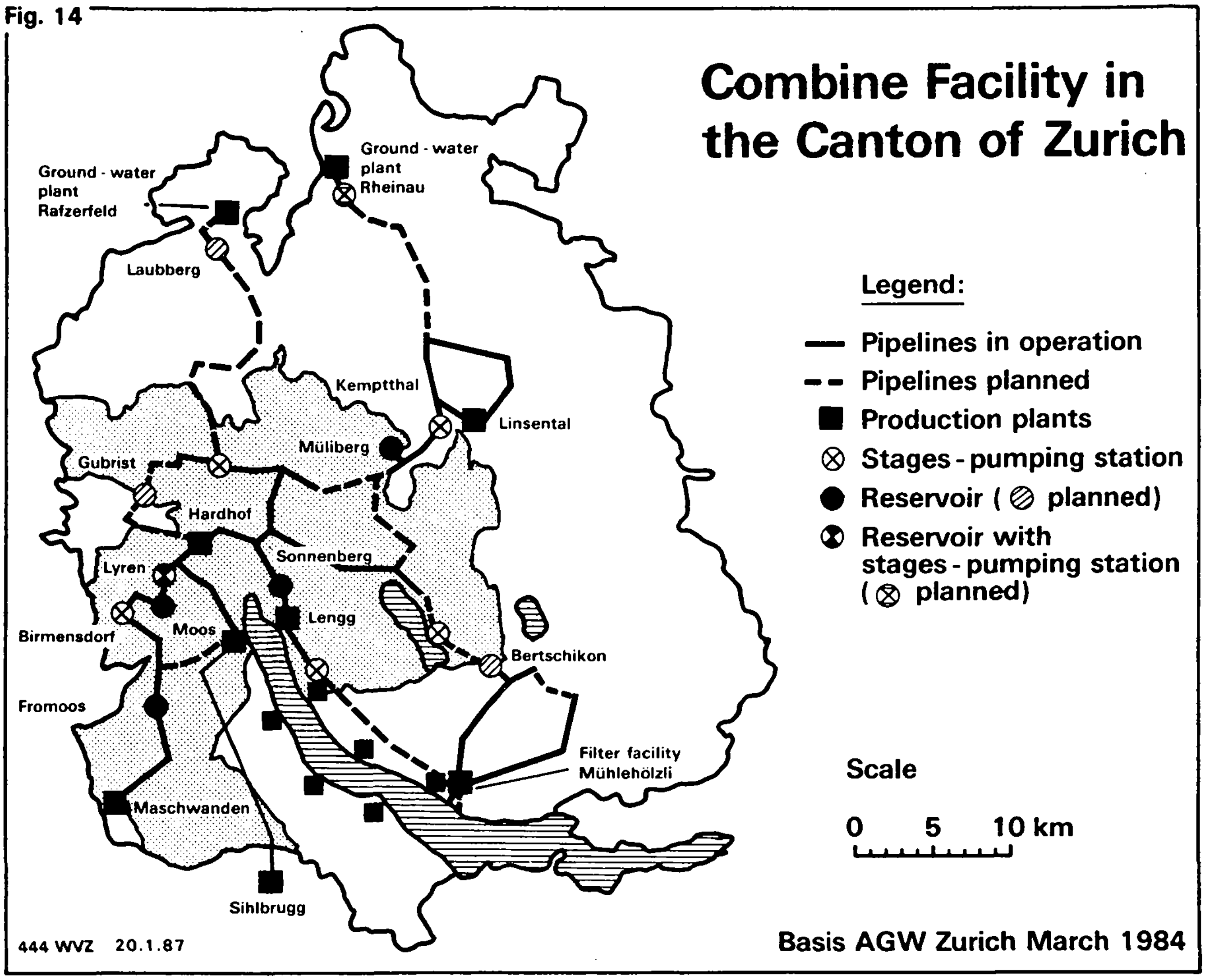

Fig. 16

Estimation of the Capacity Price Development for the Water Supply to the Partners of the Region of Zurich excluding General Price Increase

Financial year	Depre-ciation	Capital interest	Total	Daily max. produc-tion	Capacity price	Option	Receipt
	SFr.			m^3	m^3/day SFr.	m^3/day	SFr. 1 000
1986[1]	10692	10410	21 102	500 000	42,20	144 280	7610
1987	10993	10481	21 474	500 000	42,95	144 280	6 200
1988	11 248	10388	21 636	500 000	43,27	144 280	6 240
1989	11 514	10253	21 767	500 000	43,53	144 280	6 280
1990	11 796	10126	21 922	500 000	43,84	144 280	6 330
1991	12 179	10081	22 260	500 000	44,52	144 280	6 420
1992	12 563	10103	22 666	500 000	45,33	144 280	6 540
1993	12 905	10071	22 976	500 000	45,95	144 280	6 630
1994	13 170	9924	23 094	500 000	46,19	144 280	6 660
1995	13 353	9635	22 988	500 000	45,98	144 280	6 630
1996	13 522	9256	22 778	500 000	45,56	144 280	6 570
1997	13 684	8852	22 536	500 000	45,07	144 280	6 500
1998	13 847	8435	22 282	500 000	44,56	144 280	6 430
1999	14 011	8011	22 022	500 000	44,04	144 280	6 350
2000	14 174	7578	21 752	500 000	43,50	144 280	6 280

1) Change of the financial year 1.10.85-31.12.86 = 15 months
from 1.10.85 onwards take, ground and spring - water (up to now only lake water)

20.1.87 444 WVZ

Fig. 17

Estimation of the Working Price Development for the Water Supply to the Partners of the Region of Zurich 2 - 3 % General Price Increase

Financial year	Water produc-tion	Amount lost (pipeline breaks and leaks ca. 12 %)	Amount of water for working price	Costs for operation and mainte-nance	Working price	Water supplied	Receipts working price
	1 000 m^3	1 000 m^3	1 000 m^3	SFr. 1 000	m^3 / cent	1 000 m^3	SFr. 1 000
1986[1]	92 000	11 000	81 000	21 900	27,0	13 200	3 560
1987	73 500	8 800	64 700	17 500	27,0	10 600	2 860
1988	73 500	8 800	64 700	18 000	27,8	10 700	2 970
1989	74 000	8 900	65 100	18 500	28,4	10 700	3 040
1990	74 000	8 900	65 100	19 000	29,2	10 700	3 120
1991	74 000	8 900	65 100	19 500	30,0	10 700	3 210
1992	74 000	8 900	65 100	20 000	30,7	10 700	3 280
1993	74 000	8 900	65 100	20 500	31,5	10 700	3 370
1994	74 000	8 900	65 100	21 000	32,3	10 700	3 460
1995	74 000	8 900	65 100	21 500	33,0	10 700	3 530
1996	74 000	8 900	65 100	22 000	33,8	10 700	3 620
1997	74 000	8 900	65 100	22 500	34,6	10 700	3 700
1998	74 000	8 900	65 100	23 000	35,3	10 700	3 780
1999	74 000	8 900	65 100	23 500	36,1	10 700	3 860
2000	74 000	8 900	65 100	24 000	36,9	10 700	3 950

1) Change of the financial year 1.10.85 - 31.12.86 = 15 months

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Fig. 18

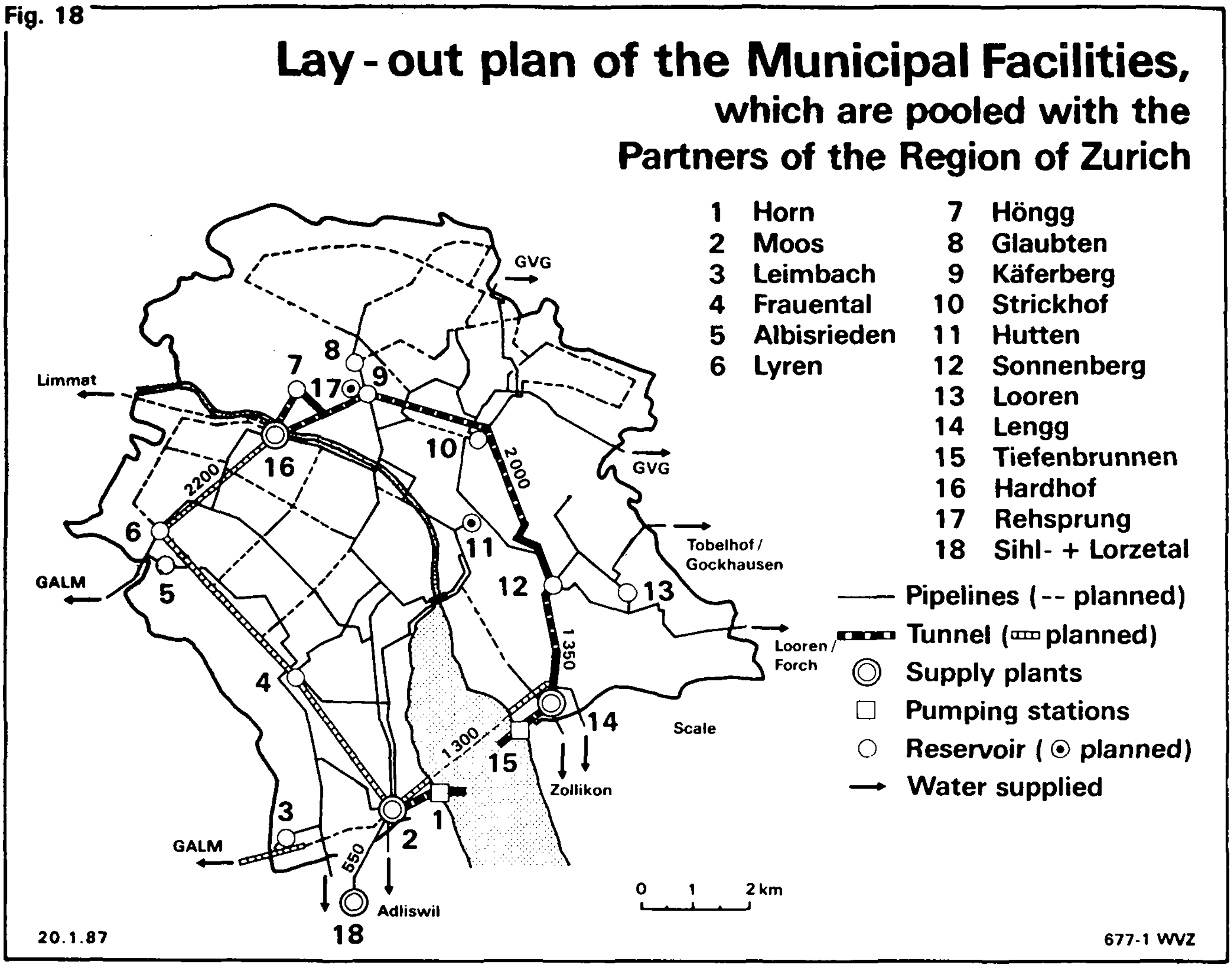

Fig. 19 The Lake of Zurich: A Drinking-Water Reservoir of the City and Region

THE STUDY OF REGIONAL VARIANCE OF WATER DEMAND IN TAIPEI CITY

by :
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ABSTRACT

This study is to survey water demand of Taipei residents. The research is going on different backgrounds of social economy and different types of land-use to search for various degrees of water demand. It is processing the survey on all categories and applying multiple variate analysis to establish the model of Taipei Water demand.

I. PRELUDE

One of the main purposes of government water department is to supply water timely, quantitatively and in the right place. But in fact, some differences usually exist between the water plan by government and the demand of residents. The main cause is planners just plan by their own knowledges without referring to various water demand types people made. Of course, the plan could not meet the need residents want.

Therefore, a careful survey before planning is necessary. From the survey, the quality of dwellers and the developing aims of areas in the near future are refered to realize different areas and different land-use dominating variance of water demand. Overcoming this variance, the plan could start the most efficient investment on the area and satisfy dwellers' demand. Then, the plan would conquer the incoordination of supply and demand. Afterwards, there will be no more one area out of water and people sad, while the other in overflow and investment squandered.

This study tries to survey water demand variance in order to shorten the distance between the government's plan and people's recognition.

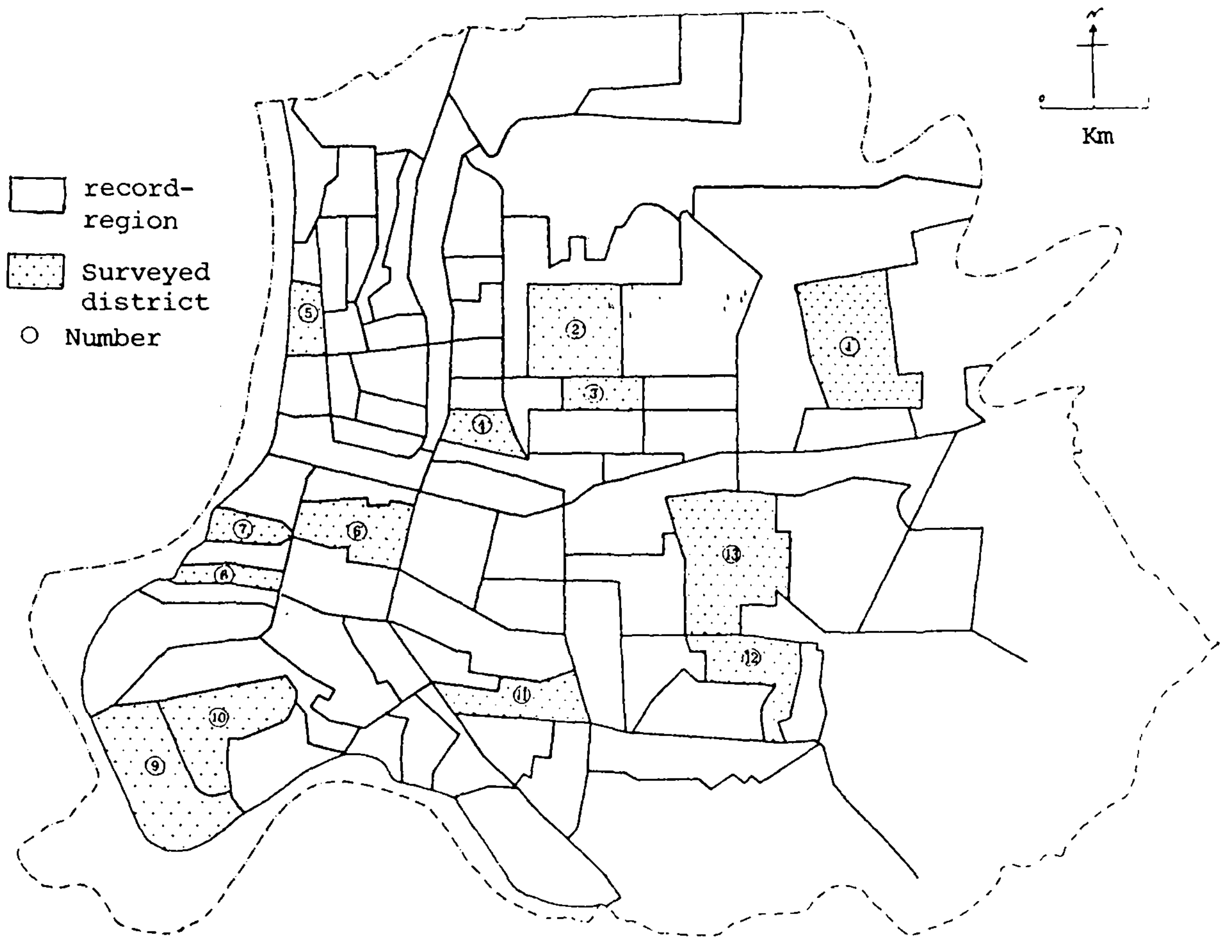
Scale

Site: The old districts of Taipei City

Reason: Taipei is the leading city in Taiwan. Its old districts have been planned carefully. The rate of water supply is up to 99%. This is a perfect sample site for study. From these old districts, the study chooses some with 90% water supply rate as objects

Research Method

As usual, water - forecast refers to total - forecast. That means to predit the total water quantity, which is demanded in the near future, as reference for expanding water resources. Seldom does it discuss



1. Ming-Sheng District (N.D.D.)
2. Sung Chiang Rd. (C.R.D.)
3. Nan Ching E. Road (C.R.D.)
4. Chiang An E. Road (C.R.D.)
5. Di-Hua St. (P.R.D.)
6. Chung-Ching S. Road (C.B.D.)
7. Hsi-Men Din (R.S.D.)
8. Guei-Yang St. (C.R.D.)
9. Dung-Yuan St. (P.R.D.)
10. Nan-Chi Chiang (P.R.D.)
11. Ho-Pin E. Road (C.E.D.)
12. Tong-Hua St. (N.D.D.)
13. Din-Hau Market (N.D.D.)

C.B.D.: Commercial Business District
R.S.D.: Recreation Shopping District
C.R.D.: Commercial Residential District
N.D.D.: Newly Developed High Class Residential District
P.R.D.: Previously Residential District
C.E.D.: Culture-Education District

Figure 1. Distribution Map of Surveyed Region

regional variance of water demand and its cause. Suppose the water - forecast is based on regional variance to predict the water demand, the forecast can not only penetrate into the cause which brings the variance of demand, but also reflect the way to distribute water reasonably under certain quantity the supply - region can offord.

Therefore, this study first is to survey current phenomena to realize factors influencing demand, then analyze the relation between water - use behavior and population quality, furthermore, establish the modle of water demand by quantitative method.

Data

Data here is derived from official statistic information and questionaire made by the author.

The method is to select 13 samples from 88 record-regions divided by T.W.D. Each of 13 ones is evident in sharp variance between water - use quantity and population density. (Fig. 1). All households in the region are surveyed by cluster sampling. (Table 1)

Table 1: Distribution of questionaire and average of water demand quantity

No.	characteries region	household	questionaire	rate	average of quant. (m^3)
1	N.D.D.	15,673	388	2.47%	69.85
2	C.R.D.	7,657	137	1.79%	66.17
3	C.R.D.	1,811	110	6.07%	76.08
4	C.R.D.	3,506	115	3.28%	70.36
5	P.R.D.	1,411	67	4.82%	60.73
6	C.B.D.	1,981	73	3.68%	76.33
7	R.S.D.	2,300	64	2.78%	75.22
8	C.R.D.	2,812	107	3.81%	63.00
9	P.R.D.	15,773	321	2.04%	54.90
10	P.R.D.	2,999	231	7.70%	54.32
11	C.E.D.	3,654	150	4.08%	61.11
12	N.D.D.	7,390	143	1.94%	61.06
13	N.D.D.	14,730	241	1.64%	72.76
Total		84,697	2,147	2.63%	60.40

II. THE CHARACTERISTICS OF TAIPEI WATER DEMAND

Though in the same water supply region, residential areas represent various water demand types due to different house - use type, water - use facilities, water - recognition and water - use behavior.

The Regional Variance of Water - use Quantity

Level all studied regions as table 2. The table shows water - use quantity of every two months in each area. We see the quantity, 0-45M^3, spreads over areas No.9 & No.10, separately of 30.2% & 31.2%. These two areas are both lower residential areas in Taipei City. Most of areas are ranging 46-60M^3 of water - use quantity. Some are more than 61M^3, such as No.13 (65.6%) and No.1, No.2, No.3, & No.6 (60%). This phenomenon reveals larger water - use quantity companying with high class residential areas or commercial - residential areas. While No.7 (42.2%) & No.6 (39.7%) are over 75M^3, it tells central commercial district and recreation - shopping district with moving population demand much more water. This condition is in contrast to No.10 with 78% under 60M^3.

House - use type and Water - use Quantity

According to house - use types, we made table 3. In No.6, 46.6% of houses are used as home - store. The second is No.7 with 32.8% as home - store. Here is a typical commercial - residential belt. The houses are used as home - office appear in No.6 (11.0%), No.4 (15.7%) and No.3 (9.1%). The exact residential areas exist in No.11 (92.7%) for being culture - education area. Other ones are No.1 (86.9%), No.13 (85.5%) and No.10 (84.0%).

Table 2. Water-use of each region

Unit: m^3/two-month

rate / region	0-45		46-60		61-75		> 75		Total	
	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%
1 N.D.D.	39	10.1	115	29.6	103	26.5	131	33.8	388	100
2 C.R.D.	19	13.9	32	23.4	53	38.7	33	24.1	137	100
3 C.R.D.	7	6.4	36	32.7	30	27.3	37	33.6	110	100
4 C.R.D.	18	15.7	43	37.4	13	11.3	41	35.7	115	100
5 P.R.D.	12	17.9	29	43.3	13	19.4	13	19.4	67	100
6 C.B.D.	5	6.9	24	32.9	15	20.5	29	39.7	73	100
7 R.S.D.	3	4.6	25	39.1	9	14.1	27	42.2	64	100
8 C.R.D.	18	16.8	40	37.4	22	20.6	27	25.2	107	100
9 P.R.D.	97	30.2	133	41.4	52	16.2	39	12.1	321	100
10 P.R.D.	72	31.2	108	46.8	34	14.7	17	7.3	231	100
11 C.E.D.	23	15.3	58	38.7	45	30.0	24	16.0	150	100
12 N.D.D.	25	17.5	53	37.1	42	29.4	23	16.1	143	100
13 N.D.D.	14	5.8	69	28.6	73	30.3	85	35.3	241	100

Table 3. House-Use types

Unit: household/%

rate / region	home		home-office		home-store		No answer		Total	
	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%
1 N.D.D.	337	86.9	14	3.6	28	7.2	9	2.3	388	100
2 C.R.D.	103	75.2	6	4.3	17	12.4	11	8.1	137	100
3 C.R.D.	82	74.5	10	9.1	15	13.61	3	2.8	110	100
4 C.R.D.	82	71.3	18	15.7	15	13.0	0	0	115	100
5 P.R.D.	42	62.7	4	6.0	17	25.5	4	6.0	67	100
6 C.B.D.	31	42.5	8	11.0	34	46.6	0	0	73	100
7 R.S.D.	36	56.3	5	7.8	21	32.8	2	3.1	64	100
8 C.R.D.	76	71.0	5	4.7	26	24.3	0	0	107	100
9 P.R.D.	260	81.0	13	4.1	47	14.6	1	0.3	321	100
10 P.R.D.	194	84.0	6	2.6	28	12.1	3	1.3	231	100
11 C.E.D.	139	92.7	3	2.0	8	5.3	0	0	150	100
12 N.D.D.	114	79.7	8	5.6	20	14.0	1	0.7	143	100
13 N.D.D.	206	85.5	15	6.2	15	6.2	5	2.1	241	100
14 Others	1,524	76.9	111	5.6	241	12.2	106	5.3	1,982	100
Total	3,226	79.1	226	5.5	532	12.9	145	3.5	4,129	100

Furthermore, compare water - use quantity with house - ownership, house - type and house - size:
No.6 demands most much water, and it is a commercial business district in Taipei. In No.7, No.2 and No.3, a lot of houses are used as home - store, No.1 and No.13 are new developed residential districts, with house - ownership and larger house - scale. No.9 & No.10 both need less water than the others, because No.9 is the old district and No.10 has newly established civic-house under 5 floors with small size for dwelling only.

In brief, the relationship between house - use type and water - use quantity is as following:
There is a close relationship between the two. House used as store - office increases water - use quantity. House - size runs parallel with water - use quantity, but water - use is not cling to house - ownership or house - type.

Sanitary Facilities and Water - use Quantity

Sanitary facilities are necessary to every family. As general, a set of facilities includes a bathtub, a washing basin, and a water closet. One and a half set means there is a bathroom without bathtub. (Table 4)

Table 4 Sanitary Facilities

Unit: household/%

range / surveyed region	>1		1.0		1.5		2.0		2.5		≥3.0		No answer		Total	
	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%
1 N.D.D.	5	1.3	145	37.4	82	21.1	137	35.3	11	2.84	7	1.8	1	0.2	388	100
2 C.R.D.	2	1.4	70	51.1	22	16.1	40	29.2	3	2.2	0	0	0	0	137	100
3 C.R.D.	5	4.5	49	44.5	18	16.4	27	24.5	4	3.6	6	5.5	1	0.9	110	100
4 C.R.D.	0	0	75	65.2	19	16.5	16	13.9	2	1.7	3	2.6	0	0	115	100
5 P.R.D.	5	7.1	40	59.7	12	17.9	2	2.9	2	2.9	6	9.0	0	0	67	100
6 C.B.D.	5	6.9	38	52.1	16	21.9	5	6.8	4	5.4	5	6.9	0	0	73	100
7 R.S.D.	1	1.6	35	54.7	8	12.5	7	10.9	3	4.7	10	15.6	0	0	64	100
8 C.R.D.	13	12.1	67	62.6	14	13.1	11	10.3	0	0	2	1.9	0	0	107	100
9 P.R.D.	13	4.1	210	65.4	57	17.8	28	8.7	10	3.1	3	0.9	0	0	321	100
10 P.R.D.	25	10.8	157	68.0	28	12.1	19	8.3	1	0.4	1	0.4	0	0	231	100
11 C.E.D.	0	0	66	44.0	25	16.7	51	34	7	4.6	1	0.7	0	0	150	100
12 N.D.D.	6	4.2	70	49.0	19	13.3	40	28	4	2.8	4	2.8	0	0	143	100
13 N.D.D.	2	0.8	56	23.2	30	12.4	131	54.4	8	3.3	13	5.4	1	0.4	241	100
14 OTHERS	87	4.3	924	46.6	290	14.6	489	24.7	52	2.6	40	2.0	100	5.0	1,982	100
TOTAL	169	4.1	2,002	48.5	640	15.5	1,003	24.3	111	2.7	101	2.4	103	2.4	4,129	100

Table 5 Per month income

range / region	1		2		3		4		5		6		7		Total	
	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%	quant.	%
1 N.D.D.	48	12.4	125	32.2	132	34.0	45	11.6	20	5.1	8	2.0	10	2.5	388	100
2 C.R.D.	27	19.7	45	32.8	35	25.5	11	8.0	6	4.3	1	0.7	12	8.7	137	100
3 C.R.D.	27	15.5	43	39.1	32	29.1	9	8.1	3	2.7	4	3.6	2	1.8	110	100
4 C.R.D.	4	3.4	41	35.7	39	33.9	20	17.4	8	6.9	3	2.6	0	0	11	100
5 P.R.D.	20	29.9	20	29.9	13	19.4	3	2.0	0	0	0	0	11	16.1	57	100
6 C.B.D.	14	19.2	25	34.2	17	23.3	8	11.0	0	0	3	4.1	6	8.2	67	100
7 R.S.D.	9	14.1	22	34.4	17	26.6	7	10.9	2	3.1	5	7.8	2	3.1	364	100
8 C.R.D.	16	15.0	39	36.4	37	34.6	6	5.6	9	1.8	1	0.9	6	5.6	107	100
9 P.R.D.	73	22.7	130	40.5	82	25.5	22	6.8	3	2.8	4	1.2	1	0.3	321	100
10 P.R.D.	58	25.1	95	41.1	49	21.2	18	7.7	5	1.3	4	1.7	4	1.7	231	100
11 C.E.D.	20	13.3	52	34.7	52	54.7	19	12.7	2	3.3	2	1.3	0	0	150	100
12 N.D.D.	21	14.7	56	39.2	40	28.0	19	13.3	1	1.4	4	2.8	1	0.7	143	100
13 N.D.D.	9	3.7	65	27.0	88	36.5	50	20.7	1	4.5	14	5.8	4	1.6	241	100
14. OTHERS	271	13.7	767	38.7	550	27.7	175	8.8	48	2.4	64	3.2	107	5.4	1,982	100
TOTAL	607	14.7	1,525	36.9	1,183	28.7	412	9.9	119	2.8	117	2.8	166	4.0	4,129	100

NOTE: 1. under NT$15,000; 2. NT$15,001-25,000; 3. NT$25,001-45,000; 4. NT$45,001-65,000; 5. NT$65,001-85,000; 6. OVER NT$85,001; 7. No answer

The above information shows:
Sanitary facilities of No.8 (12%) and No.10 (10.8%) are under one set. These two are in need of more facilities. Most areas (48.5%) have one set facilities, and among them No.10 (68%) and No.9 (65.4%) are the tops. Two sets are seen in No.13 (54.4%), No.1 (35.3%) and No.11 (34.0%).

Comparing sanitary facilities and house - size, we can find out "larger house, more sanitary facilities."

In brief, "More water - use quantity and more inside sanitary facilities" is a close relationship between the two. As to water - heater and washing machine are domestic necessities will not influence water - use quantity.

Household and water - use quantity

Income (per month) of a household is shown by Table 5. Under NT$ 15,000, No.5 with 30% is the first, and the second is No.10 with 25.1%.

The per month income within NT$15,000 - 25,000 is most popular among the ranges, and No.10 & No.9 are representives (41.1%, 40.5%). The income over NT$45,001 spreads over No.13 (31.2%), No.4 (26.9%) and No.7 (21.8%). As to the income over NT$85,001 belongs to No.7 (7.8%) and No.13 (5.8%). The two are both tops.

By income - index of each surveyed region, we find out the income is very different from the lowest to the highest. For example, 67.9% of No.13 springs over NT$25,000, but 66.2% of No.10 is lower than NT$ 25,000.

The analysis also shows that in commercial districts there are more people to stay in the day. But in residential areas, people go to work and few of them stay at home during the day. So high population appears in the night. This kind of residential area is mostly developed previously or in a lower class.

On the employment of a household:
In some high class residential areas & newly developed areas, few members support the economy of household, but remain high income. While in previously developed and low class areas, though many members get jobs, the total income is still lower than the first one. It reflects the income is still lower than the first one, as well as the income is related to the quality of population. Well - educated people get a fine job with good pay, and is able to make perfect facilities incooperating with large house. Coincidently, the water - use quantity is increasing. In previously developed areas, people would immigrate high class district after becoming rich. Those who still stay are little - educated and have a large family to be supported just by limited wages. Though many members go to work, the income is hardly increased. They are packed in an old small house. Consequentially, water - use quantity is always low.

Therefore, the index of water - use quantity is not directed by the population of a household, but by the quality of population, house - size and house - use.

The water - use quantity of commercial districts is more than residential areas is in consequence of moving population during the day. So the time of water - use is around the day. Contrarily, in the residential areas, people come home after work and use water in the night.

III. THE WATER - DEMAND MODEL

This study centers on the variables influencing water - demand to search for an index which can find out regional variance efficiently. Directed by this index, the planner can easily plan a reasonable supply and make the best of limited resources.

The water - use quantity can show the degree of water - demand. So this study uses the quantity as an index for water - demand, and its degree as a factor for deciding regional demand.

At the same time, the study is developing multivariate quantitative pattern I, which is based on the questionaire data, and apply general number rule to distribute all 13 surveyed regions into the pattern to reflex differences among them.

Factor Analysis

For inspecting all factors related to water - use quantity, the study use correlation test, χ^2 test, through the contingency table. For example, to test the correlation between water - use quantity and water facilities and make the table 6.

Table 6 The contingency table of water-use quantity and sanitary

Sanitary facilities / m^3	< 1	1	1.5	2.0	2.5	3.0	Total
under 45	27 (13)	232 (175)	51 (57)	35 (85)	4 (10)	1 (10)	350
46-60	37 (29)	452 (383)	117 (124)	139 (185)	11 (21)	9 (22)	765
61-75	12 (19)	216 (253)	87 (82)	166 (122)	12 (14)	13 (15)	506
over 76	6 (20)	174 (262)	93 (85)	179 (127)	33 (15)	39 (15)	524
TOTAL	82	1,074	348	519	60	62	2,145

NOTE: ( ) is theory frequency.

Table 7 Correlation analysis of Water-use and other variables

related variable	sanitary	education	day population	night population
degree of free	15	9	9	9
χ^2 0.05	24.9958	16.9190	16.9190	16.9190
χ^2	269.42	132.63	14.07	16.47
correlation	V	V		
related variable	**house-use**	**house-scale/ping**	**total income**	**heater**
degree of free	9	9	9	9
χ^2 0.05	16.9190	16.9190	16.9190	16.9190
χ^2	250.96	396.75	207.02	38.93
correlation	V	V	V	V
related variable	**washing machine**	**car**	**bath in winter**	**bath in summer**
degree of free	9	9	9	9
χ^2 0.05	16.9190	16.9190	15.5916	12.5916
χ^2	99.63	111.57	11.57	20.12
correlation	V	V		V

So reject hypothesis Ho "No correlation between water - use quant. and water facilities" and accept hypothesis Hi, correlation exists. Before making a contingency table, some categories with few samples should be omitted or combined. That will enable categories to reflex samples efficiently. Thus, just four categories, under $45M^3$, $46\text{-}60M^3$, $61\text{-}75M^3$ and over $76M^3$ are divided according to water - use quantity. These four catagories and other items are test by correlation analysis. (Table 7)

The Pattern

Theory

The theory used here is fist family theory (multivariate quantitative I), one of the methods of multivariate analysis, developed by Lin Chih Chi Fu at Japanese Education Ministry. We know that multiple regression analysis is to search for the linear relation among explanatary variables of objective variable and other "quantity" variables. But this pattern researches the linear relation among objective variable and "quality" variables of explanatory variable. The item of "quality" is made of several categories and every item must choose one category only (1. or 0). The pattern is explained as following: Suppose Y is objective variable, r quality of explanatory variables can influence Y, and these explanatory variables of r quality consist category p1, p2, p3...pr, then the definition of sample V can be written:

$$X_{jv}^{(i)} = \begin{cases} 1. \text{ ; If V belong to j category of i variable} \\ 0. \text{ ; If V not belong to j category of i variable} \end{cases} \quad \text{... pattern 1}$$

v = 1, 2, ..., n sample
i = 1, 2, ..., r item
j = 1, 2, ..., Pi catagory

$X_{jv}^{(i)}$ dummy variables

Here vi sample must belong to category j, and satisfy pattern 2.

$$\sum_{j=1}^{Pi} X_{(j)}^{(i)} = 1 \text{ .... (pattern 2)}$$

From the above, the table of sample - quality: (Table 8)

Table 8 Quantification-First family

Sample	(item) explanatory variable / category / objective variable	explanatory 1	...	explanatory i	...	explanatory r
		1...j...P1		1...j...Pj		1...j...Pr
1	Y_1	V		V		V
2	Y_2	V		V		V
3	Y_3					
⋮	⋮					
v	Y_v	V		V		V
⋮	⋮					
⋮	⋮					
n	Y_n	V		V		V

Objective variable Y_v is the value of sample V. If we want to know how explanatory variable influence objective variable, and we can suppose the pattern of objective variable and dummy as following:

$$Y_v = B_1^{(1)} X_{1v}^{(1)} + B_2^{(1)} X_{2v}^{(1)} + \ldots\ldots + B_{P_1}^{(1)} X_{P_{1v}}^{(1)} + B_1^{(2)} X_{1v}^{(2)} + B_2^{(2)} X_{2v}^{(2)} + \ldots\ldots + B_{P_2}^{(2)} X_{P_{2v}}^{(2)} + \ldots\ldots + B_1^{(r)} X_{1v}^{(r)} + B_2^{(r)} X_{2v}^{(r)} + \ldots\ldots + B_{P_r}^{(r)} X_{P_r v}^{(r)} + e\ldots\ldots \quad \text{(patten 3)}$$

$B_j^{(1)}$: partial regression coeficient

Y_v : Objective variable

$X_{jv}^{(i)}$: qualitative explanation variable

e_v : noise factor

Like applying multiple regression, we can use method of least square for the least squre sum of noise factor to get the best estimator $\hat{B}_j^{(i)}$ of $B_j^{(i)}$. Then, to turn the $B_j^{(i)}$ into normalization and rewrite the above pattern as pattern 4:

$$\hat{Y}_v = \overline{Y} + \sum_{i=1}^{r} \sum_{j=1}^{P_i} \hat{b}_j^{(i)} X_j^{(i)} \ldots\ldots\ldots \quad \text{(pattern 4)}$$

$$\hat{b}_j^{(i)} = \hat{B}_j^{(i)} - \sum_{j=1}^{P_i} \hat{B}_j^{(i)} \overline{X}_j^{(i)}$$

The Establishment of Model

Objective variable of this model uses water-use quantity as index. By χ^2 test, we know that quantity is related to items, sanitary facilities, house-use type, house-scale, and total income; and little related to others'. So select these four items as explanatory variables, and put into the data of the 13 surveyed sample regions to compulate. (Table 9, 11)

Table 9 Classification of explanatary variables

Sample	Water-Use quantity	Sanitary (set)			House type			House scale (ping)					total income (NT)		
		≤1	1-2	>2	home	home office	home-store	<20	21-35	36-50	>50	15,000	15,001-25,000	25,001-45,000	45,000
1	Y_1		V		V			V				V			
2	Y_2		V								V				V
3	Y_3	V			V				V						V
.	.			V			V						V		
.	.									V					
i	Y_i		V			V		V						V	
.	.														
.	.														
.	.														
2131	Y_{2131}			V			V				V		V		

NOTE: 1 ping=$3.3m^3$

Table 10

QUANTIFICATION

*** FIRST FAMILY ***

NUMBER OF ITEMS 4
NUMBER OF OBSERVATIONS .. 2131
CORRELATION FACTOR 0.95179

*** RANGES AND CATEGORY SCORES ***

ITEM	RANGE	1	2	3	4
1	13.490	-2.130	1.243	11.360	
2	12.506	-2.017	3.815	10.489	
3	20.156	-10.433	-1.363	6.979	9.723
4	11.244	-3.432	-3.297	2.549	7.811

$$Y = 64.867 - 2.130\, X_1^{(1)} + 1.243\, X_2^{(1)} + 11.360\, X_3^{(1)}$$

Sanitary

$$- 2.017\, X_1^{(2)} + 3.815\, X_2^{(2)} + 10.489\, X_3^{(2)}$$

use-type

$$-10.433\, X_1^{(3)} - 1.363\, X_2^{(3)} + 6.979\, X_3^{(3)} + 9.723\, X_4^{(3)}$$

scale

$$- 3.432\, X_1^{(4)} - 3.297\, X_2^{(4)} + 2.549\, X_3^{(4)} + 7.811\, X_4^{(4)}$$

income

..... pattern 5

Table 3.5 shows R^2=0.95179 that means the above four categories, as explanatory variables, can fully explain the correlation as well as variance of water-demand quantity. It proves that the model is available. Table 10 shows different sampling of water-use quantity.

Test and Application of the Model

Test

To test this model, we can compulat pattern 5 for 13 surveyed sample region, and get:

Table 12 Survey value and theory value surveyed region

No.	region	Survey value	theory value
1	N.D.D.	69.85	67.71
2	C.R.D.	66.17	64.87
3	C.R.D.	76.08	68.58
4	C.R.D.	70.36	66.28
5	P.R.D.	60.73	64.00
6	C.B.D.	76.33	70.11
7	R.S.D.	75.22	69.15
8	C.R.D.	63.00	62.55
9	P.R.D.	54.90	60.43
10	P.R.D.	54.32	57.41
11	C.E.D.	61.11	65.23
12	N.D.D.	61.06	65.49
13	N.D.D.	72.76	72.03

Table 12 and Fig. 2 shows that survey value and theory value are quite similar, and again verifies this model can fufil application.

Application

The function of the model is to forecast. In a new developing urban, regional water demand can be easily predicted first by surveying the percent of these four objective variables in all categories, then refers to pattern 5 and get the possible water demand quantity of the region.

Table 10 The diffent sampling of water-use quantity

Sample	Water-use quantity	Sanitary(set			House type			House scale(ping)				total income (NT)			
		≤1	1-2	>2	home	home office	home-store	<20	21-35	36-50	>50	15,000	15,001-25,000	25,001-45,000	45,000
1	46.85	V			V			V				V			
2	46.99	V			V			V					V		
3	52.83	V			V			V						V	
4	58.09	V			V			V							V
5	58.92	V			V				V			V			
6	56.06	V			V				V				V		
7	61.09	V			V				V					V	
8	67.16	V			V				V						V
.															
.															
.															
50	50.36		V		V			V					V		
.															
.															
.															
.															
144	104.25			V			V				V				V

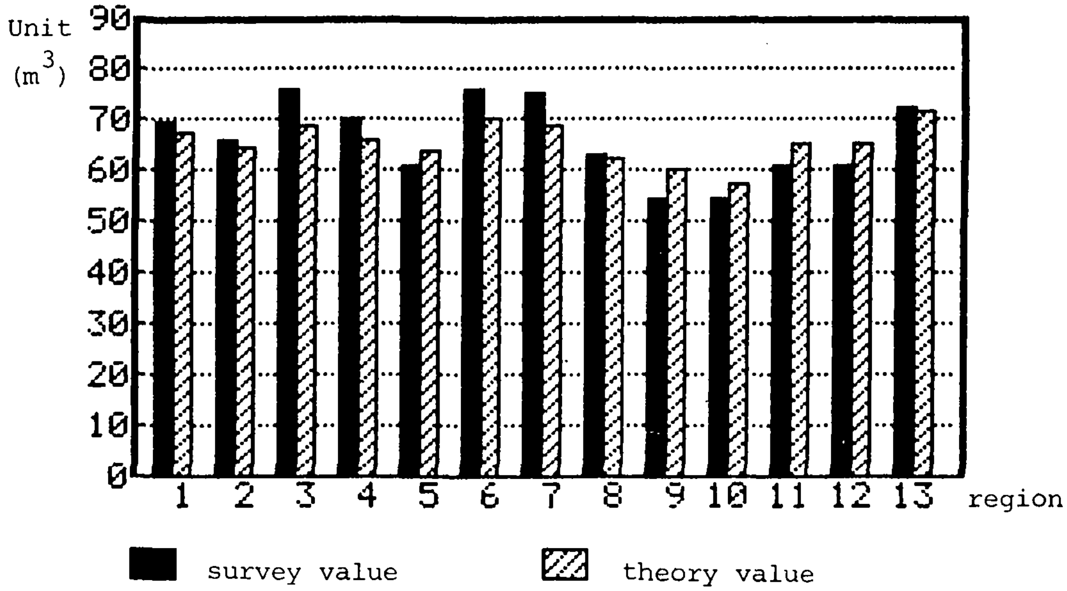


Figure 2 comparison between survey value and theory value

V. CONCLUSION

1. The water-use quantity is changing with house-use type, water-use facilities, and population quality.

2. House-use type is related to water-use quantity. The water-use quantity of a household is less than the quantity of home-office or home-store. House-scale and water-use quantity are in proportion. Large house needs more sanitary facilities and increases water-use quantity.

3. The education and employment of the head of a household is related to water-use quantity. If the head is little educated and employed to work with wages, the water-use quantity shall be decreased.

4. To estimate water-use quantity of the region, one should plan according to its different ranges in house-scale, sanitary facilities, house-use type and possible income of a household. Don't just follow the current rule to plan by numbers of population. Then, the plan could achieve the correlation between the supply and demand.

5. This study uses quantitative I of multivariate analysis to establish the water-demand model. The model selects four categories, which are most related to the water-use quantity, house-scale, sanitary facilities, house-use and home-income as explanatory variables. The correlation coefficient is up to 0.95179. It proves the model available. The model:

$$\begin{aligned} Y = 64.867 &- 2.130\,X_1^{(1)} + 1.243\,X_2^{(1)} + 11.360\,X_3^{(1)} \\ &- 2.017\,X_1^{(2)} + 3.815\,X_2^{(2)} + 10.489\,X_3^{(2)} \\ &- 10.433\,X_1^{(3)} - 1.363\,X_2^{(3)} + 6.979\,X_3^{(3)} + 9.723\,X_4^{(3)} \\ &- 3.432\,X_1^{(4)} - 3.297\,X_2^{(4)} + 2.549\,X_3^{(4)} + 7.811\,X_4^{(4)} \end{aligned}$$

6. For considering the quality of each explanatory variable, this model is durable and flexible. The inner type of region will change,but the change is quality-change. Therefore, the variance of regional water demand in the future depends on the inner-change to apply this model compulating the estimated water demand quantity.

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THE REHABILITATION OF CURRENTLY OPERATING WATER PURIFICATION PLANTS

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1. General

It has been 100 years since the first modern Japanese water supply system was put into operation in Yokohama City in 1887. During these ten decades the population served in Japan has increased more than 93%.

Many municipalities have managed to set up and expand their water supply systems to meet this increased water demand, especially since the early 1950's.

In general, rehabilitation projects for the older water facilities were carried out in cojunction with expansion projects. For instance, many big cities expanded their water purification capacity by replacing their slow sand filtration systems with efficient rapid sand filtration systems due to deterioration of the raw water quality and increasing difficulty of land acquisition.

In Nagoya City, the Waterworks Bureau has implemented 8 expansion projects in the last 75 years and now has enough facilities to supply water in quantity. Today, rehabilitation of old water facilities, efficient operation of systems and simplification of operational works are the major concerns for the Bureau. The facilities should be strengthened and modernized not only to improve the water supply capacity but also to be strong enough to function in the face of unforeseen disasters and deterioration in the quality of water sources.

Against this background, the worn-out facilities of the Oharu Water Purification Plant (544,000 m^3/d), which covers 40% of the city water supply, has emerged as a major issue for the Waterworks Bureau.

A rehabilitation program for the Nabeyaueno Water Purification Plant (290,000 m^3/d), which has a 75 year history, is also expected to be made concrete.

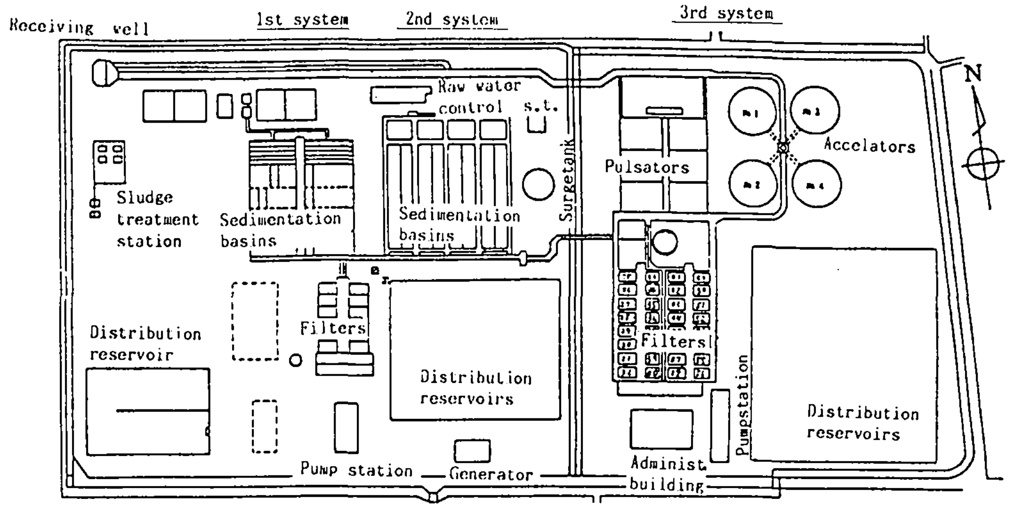


Fig. 2 A plan of the Oharu Water Purification Plant

reservoir was rebuilt in the 1st phase of the 8th expansion project (1972-1984). But the 1st filter and the 1st pump station were abandoned due to worn-out equipment and uneven land subsidence. The sludge treatment system was added in the 8th expansion project. The authorized capacity is 544,000 m^3/d.

Alum is used as a coagulant and soda ash is added as a coagulant aid when the raw water is highly turbid. Liquid chlorine gas is used for the water disinfection, but the chlorination system needs to be reinforced against earthquake disasters.

The supervisory control systems of the plant are central monitoring systems with large graphic panels, sequential controlling equipment with analog-instruments and relay units. These instruments were manufactured from 1959 through 1974. A data logger is also applied in the system.

The operation systems of the plant is divided into three stations with constant monitoring systems, i.e., for raw water management, rapid sand filters and pump stations.

3.2 Necessity of rehabilitation of the plant

The natural ground of the plant is composed of fine sand and silt layers (alluvial deposits) and is not strong enough to keep the structures in good condition. Uneven subsidence of the facilities causes water leakage from the basins and decreases the water purification efficiency.

The mechanical and electrical equipment and instruments are worn-out due to long use and numbers of the troubles have increased. The reduced availability of spare parts makes it more difficult to maintain daily operations. The old-fashioned instrumentation system requires a lot of man power for operation and man power saving is given high priority by the Bureau.

The distribution pumps, which employ a changing operating number of units, require a constant monitoring and controlling by the operaters.

Safe and reliable operation against the deterioration of the raw water quality and system reinforcement against unforeseen disasters are other important requirements. Man power and energy saving are required to reduce operation expenses.

For these reasons, the Bureau set up an overall rehabilitation and remodeling program for the plant in 1979.

3.3 Processes and procedures of rehabilitation planning

(1) Setting up the planning committee (1st stage)

Detailed investigation, analysis and evaluation of the existing facilities, detailed planning and careful process control of the construction works and wide knowledge of new techniques in water purification plant are the main requirements for the planning, designing and constructing of the rehabilitation of the plant.

Therefore, the waterworks set up a planning committee for the Oharu Water Purification Rehabilitation Program. Members of the committee are planning, designing and construction engineers from various fields. Under the committee, 2 working groups are organized to implement the practical work.

(2) Investigation of present conditions (2nd stage)

The following items are investigated to build up a picture of present conditions:

a) Facilities;

Age of the main facilities and equipment.

Operation systems, places and indicated items of the mechanical and electrical equipment.

Past records of improvement of the facilities.

Characteristic-points of the facilities or the main equipment.

b) Operation system;

Flow diagram of the water quality control, examination items and points of the water quality management.

Sections and numbers of the operaters.

Points of maintenance.

Items and contents of periodical checking.

c) Troubles;

Frequency of water quality troubles.

Frequency of power failures.

(3) Basic policy for the improvement and rehabilitation of the facilities (3rd stage)

Throuth a comprehensive analysis of the existing facilities together with a consideration of recent advanced technology applicable for the water purification plant, basic policies for improvement and rehabilitation of the plant are decided as follows:

a) The authorized capacity of the plant shoud be 544,000 m^3/d.

b) The existing 3 operation stations should be integrated into a centralized operation station by utilizing advanced computerized instrumentation systems for man-power saving.

c) The improved facilities and equipment should be simple, maintenance-free and troubleless.

d) The improved facilities should be able to treat safe water in quality and stable water in quantity.

e) An optimal flow control of the plant should be considered for energy saving.

f) Measures for emergency (power failure,system trouble, raw water pollution, etc.) should be considered.

g) Countermeasures against unforeseen disasters, like earthquakes, should be in the plan.

(4) Implementation of the planning (4th stage)

Information gathering and experimental practices are ordinary procedures for system planning. Engineers need practical information re. treatment effects and points of construction and O&M concerning the unexperienced water treatment techniques such as manganese removal, pH control and declining rate filtration.

Other information needed are : actual conditions of the recently rehabilitated supervisory control systems, points of the construction planning, construction troubles and solutions.

Data collected from similar water purification plants of other cities and results of the practical experimentations conducted at the plant were the main solutions to the problemes. The comprehensive plan was made through alternative studies and evaluations of these data.

3.4 Operation system

(1) Integration of the operation system

The Integration of the operation system is one of the major objectives for the rational operation of the Waterworks Bureau.

New supervisory equipment was installed on the 2nd floor of the existing administration building and the old 3rd floor instruments were removed after completion of the experimental operation of the new system. The office room for the plant management was moved from the 2nd floor to the 1st floor.

The new supervisory control system is divided into two functions, i.e. a controlling function at the site and a comprehensive management function. Both functions are connected with a data way (high speed data transmission loop) and these systems are called a centralized operation and distribution control system. A schematic diagram of the system is shown in fig.3. An operation console, centralized by 4 units of a visual display terminal (VDT), is employed to perform a high-efficiency of man-machine-interface. All of the data can be speedly displayed on the VDT by means of figure, graph, character, digit and sound. The field control unit, a kind of loop controller equipped with a digital controller, perfoms process controls of the individual equipment by feed-forward control system at the site. A duplex central processing unit (CPU) is employed to minimize the operational troubles and for maintenance work, i.e. , 2 units of CPU share the load ordinarily, and one of the pair takes over all of the functions of the other on real time when the other has trouble. Off.line functions like data analysis, statistic calculation can be performed when the system is normal.

All of the systems need a step-construction because an overall stoppage of the plant can not be allowed. The system is designed to be extendable for future step rehabilitation.

(2) Optimal operation in water quantity

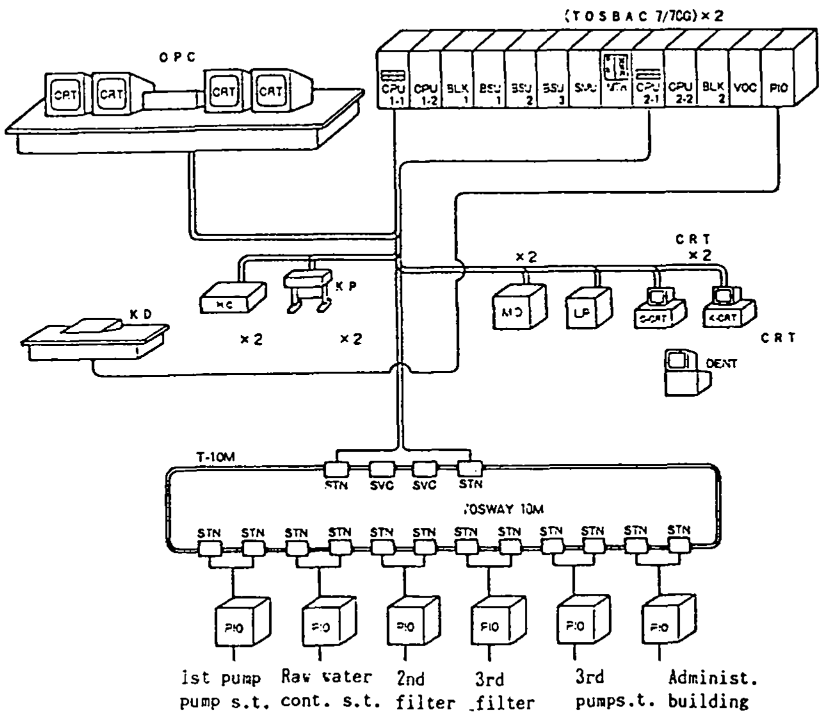
Rational water quantity control is an important factor for the waterworks not only for energy saving but also effective use of water source. A correct water demand forecast is always a matter of concern for the operaters.

In this system, the CPU forecasts a pattern of water demand in advance by analysing the results of distributed water in quantity, weather forecasts, etc. The operator moniters actual water level of the distribution reservoirs and changes the conveyance water quantity when the level differs from predicted patterns displayed on the VDT.

The water distribution control system is improved with variable speed control motors for the new pumps to control the water pressure in the distribution mains.

(3) Water quality optimal operation

The improvement and stability of purified water quality are other important objectives for the waterworks. Several measures taken are: A new employment of efficient coagulant (poly-aluminum chloride; PAC), and coagulant aid (caustic soda), automatic chemical dosing (feed forward control), water quality monitoring with on-line water quality analyzers and a centralized water sampling system. The existing chemical dosing building is restored and the equipment is replaced with new automatic dosing equipment. Replacement of the worn-out mechanical equipment and improvement of the weir loading (2nd sedimentation basins) and new installation of sludge removal system (3rd sedimentation basin), etc, are other strategies designed to guarantee the safe water supply from the plant.



CPU : 32 bit, 6 mega byte
BLK : 15 mega byte
MD : 157.2 mega byte
CRT : Cathod Ray Tube
PIO : Process Inp. Outp.
STN : Station
SVC : Supervisory Cont.

Fig.3 Supervisory conrol system

(4) Simplification of the control system

Improvement of flow control system of the filter is another issue for planning engineers, because the system is a conventional constant outlet flow control type. This system is used by many water purification plants in Japan. The system needs a complex electrical or pnewmatic control devices for each individual filter. Therefore, the engineers paid attention to a declining rate filtration method.

Declining rate filtration needs a simple control system with a manual control valve and a flow meter to limit the maximum filtration speed. The flow rate of an individual filter declines with operating hours and the water level of the filter gradually increases. The total flow rate of the filters is almost constant and the water level fluctuates. Threfore, water depth above the sand bed and surface water area before the filters are the keys of the system.

After several investigations of the reference data from other plants and field experiments at the filters, the efficiency and availability of declining rate filtration are confirmed from the following data:

a) The filtration efficiency on the basis of total filtered water quality,
b) Filtered water quality,
c) Relationships between the water level and flow rate and,
d) The conditions of declining flow rate.

Results of experiments are shown in table 1.

In the applied system, the total flow rate of the filters is controled by changing the operating numbers of the filters from the CPU. The time of back washing is controled automatically by monitering the defined minimum flow rate or operating hours of the filters.

Table 1 Experimental comparison of filtration process

Declining rate filtration						Constant rate filtration		
Initial Q m^3/h	Final Q m^3/h	Ave.decli. rate $m^3/h.h$	Ave. Q m^3/h	Accumu. Q m^3	Filter run hour	Ave. Q m^3/h	Accumu. Q m^3	Filter run hour
770	530	2.64	707	64,300	91	500	55,500	111
910	660	5.21	804	38,600	48	500	39,000	78
610	440	1.91	545	48,500	89	500	46,500	93

(Area of the filter : 119.5m^2)

(5) Reliable and safe system in emergency

Reliable and safe water supply in emergencies (power failure, system failure, etc.) and reinforcement of the system against unforeseen disasters like earthquakes are necessary measures to ensure the citizen's life-line.

Several measures taken on planning of the improvement and rehabilitation of the plant are:

a) Duplication of the main facilities and equipment (power mains, important sensors, etc.),

b) Installation of an emergency power source,

c) Duplication and failsafe system for the operation (central and field) and,

d) Earthquake proofing through reinforcement of the structures and pipes.

A one way surgetank solved the problems of water hammering and discolored water incidence in the distribution pipes. The dimensions of the tank was planned through several simulations of pipe network analysis.

4. A basic policy for the renewal of the Nabeyaueno Water Purification Plant

4.1 Historical and specific features of the plant

The Nabeyaueno Water Purification Plant was the first water purification plant in Nagoya City. It was inaugurated in 1914 with a capacity of 51,200 m^3/d. The plant has been expanded and improved through several expansion projects and the capacity is now 290,000 m^3/d.

It is composed of 2 series of filtration systems, i.e. a slow sand filtration system with 14 slow sand filters and a rapid sand filtration system 4 with chemical basins and 14 rapid sand filters. Many citizens have enjoyed its beautiful view with water, green and ancient architecture, because the plant is located in the middle of the City.

Although the slow sand filtration system is much older than the rapid sand filtration system, its water purification performance in water quality is evaluated as superior to that of rapid sand filtration systems.

The waterworks has made a great effort to maintain the plant through operation and maintenance, but most of the key mechanical and electrical equipment is worn-out through the long use. Water leakage from the pipes and inefficient water purification performance indicate the need for overall rehabilitation

4.2 Basic policy for plant renewal and upgrading

The waterworks is developing an overall rehabilitation plan for the Nabeyaueno Water Purification Plant based on the experience of the Oharu Water Purification Plant Rehabilitation Program. Several ideas have been submitted and discussed by planning engineers and senior officers. Among them are : planning capacity, effective use of the existing architecture, management planning for the proposed facilities.

After detailed investigation of the facilities and alternative studies from various view points, a basic policy for the renewal and upgrading of the plant was decided as follows :

a) The slow sand filters should be repaired with replacement of some pipes to ensure maintenance of a water purification capacity at 140,000 m^3/d.

b) All of the rapid sand filtration systems should be replaced by up-to-date compact rapid sand filtration facilities with a maximum daily water purification capacity of 150,000m^3/d.

c) The operational management should be conducted by a centralized supervisory control system for rational operation and man power saving.

d) The construction should be done through a partial stoppage of the plant within 7 years.

5 Conclusion

As a result of rapid increase of water facilities, Japanese water supply departments are facing serious problems of deteriorating water facilities, especially, pipes and mechanical and electrical equipment of key facilities.

Theoretically, rehabilitation practices should be carried out considering the economical life and frequency of the troubles of the equipment. But, increasing requirements and construction costs make it difficult to undertake rehabilitation as ordinary maintenance work.

In general, waterworks departments can not be allowed to stop all of the facilities for rehabilitation work. To install temporary equipment and continue parallel operations for a certain period require a large budget. Reliable and cooperative relationships between the construction engineers and O&M engineers are essential for the optimal solution. A practical guideline for the evaluation of existing equipment and accumulation of data in the operation and maintenance are important factors for rational implementation.

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THE PRIVATIZATION OF WATER SERVICES

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We have noted that the influence of the private sector in several countries shows signs of extending to more and more fields of economic activity.

The example that comes at once to mind is that of overland and air freight, toll roads, large-scale civil engineering constructions, telecommunications, etc.

The supply of drinking water and often the related waste water systems are also concerned by this tendency.

France is the country in the world where for long past there have been the greatest number of privatized water facilities. At the present time, about 65 % of the French population is supplied by private companies, proving that the privatization of water utilities is a well founded policy. It is also a brilliant example of its success at a time when certain states in South East Asia, as in Europe and the American continents, contemplate ventures of this kind.

This paper is divided into two main parts :

- *The first presents and describes the privatization of water utilities as practised in France,*

- *The second explains the advantages of such a system.*

I.1. THE JURIDICAL FRAMEWORK OF WATER DISTRIBUTION IN FRANCE

The success that France's private water suppliers have known is based on two essential conditions without which it would most certainly not have been possible to achieve the aforementioned positive results. The first of these two conditions, unanimously recognized by the upholders of privatization, is the efficiency of management that the private company procures, since its results depend directly on it. The second is less obvious at first glance but just as indispensable : the legal framework governing the management of such a company should be carefully adapted to the motivations of private firms. In this respect the provisions of French law have developed in a consistent manner that meets the desired objective.

Given this context, we feel it would be appropriate to begin by considering the principles and mechanisms, whereby in France the responsibilities of the public utility in charge of distributing drinking water devolve on a privately-owned company. We should first point out that supplying a city or county with water is always, technically speaking, a local problem because water is a heavy and voluminous product that is not easy to transport over long distances. Therefore, it would appear preferable for the management of water services to be decentralized and carried out not at the national level but by local authorities responsible for areas of a certain size, depending on the country. In France, the responsibilities of supplying drinking water are incumbent upon the Communes or, should they group together for reasons of necessity or simple convenience, groups of Communes known as Syndicats de Communes (Water Boards). Our country is thus divided into over 36,000 communes and includes approximately 12,000 independant water utilities.

The commune, or water board as the case may be, thus must make a choice. Responsible for supplying its population with drinking water, the commune may manage the water utility itself, a system known as "régie directe" or direct management, or it may contract management and operation out to a private water supply company, a system known as "gestion déléguée" or delegated management. In either case, the government agency in charge at the national leval will obviously exercise the same controls, whether involving resource protection by the Department of the Environment or supervision by the Health Department of the quality of drinking water supplied to customers.

Direct management of a municipal water utility can function in a highly satisfactory manner when technicals problems are not too tricky to resolve and if the municipal staff includes trained personnel. In terms of finance, the commune's "water" budget must be exactly balanced by taking into account expenditures for sufficient maintenance and suitable amortization of the water facilities. For technical reasons and, perhaps to an even greater extent, for political questions, a balanced budget is often difficult to attain or is balanced only in appearance.

Delegating the management of a water utility to a privately-owned firm may make it easier to resolve both technical and financial difficulties. Delegation may also strike municipalities as the most convenient solution as their tasks in all fields become increasingly heavy and complex. Before the seminar examines in greater detail the advantages the elected officials of a commune can procure from privatizing their water utility, we should explain how the general framework governing the devolution of a service to a private company is fixed by French law. Devolution takes the form of a contract agreed to by the commune and the private company in question ; the most common agreeements are the concession contract and, most of all, the lease-hold contract.

I.2. THE CONCESSION SYSTEM

The concession contract, which is the earliest contract, grants the private firm the exclusive rights to and complete responsibility for the water service, that may have to be built at the beginning of the contract. The statutory company must accordingly build the service's entire infrastructure and generally make all investment outlays. The company must also manage and operate the service for the duration of the concession and hand it over in good wrking order upon termination of the contract to the municipality involved (commune or water board), which then takes over ownership of the service. In return, the private distributor is remunerated from the sale of water at a price stipulated in the contract. The duration of concession contracts is necessarily long (a minimum of 25 years) to ensure the repayment of funded capital to the statutory company. The company's results will depend on its ability to manage the service with the minimum outlay enabling it to fulfil its contractual obligations, under the control of the municipality.

We should point out that the French system of concessions differs greatly from the franchise system practised in the United States, which makes the private American water supplier the perpetual proprietor of the facilities and distribution network, giving him a monopoly over water supply. To avoid any adverse effects *for the consumer as a result of this monopoly situation, the sale of water from this type of franchise service is closely supervised by a public utility control board, that tends to limit the water company's profit to the strict return on its funded capital and nothing more. And so, in many instances, the privately-owned American company has no incentive to increase productivity since a potential rise in productivity will not benefit it and, in the final analysis, will only lead to a drop in the water rate. What is more, the same American company will think twice before making any additional investment outlays, even though they be called for, lest it should not obtain sufficient return on its funded capital from the public utility board. The flaws of the American franchise system make French management especially attrative for the United States.*

In the late 19th/early 20th centuries when water distribution networks had not yet been laid, concessions for water utilities were frequently granted in France. Nowadays, supply networks are a reality and as concessions were terminated, have become the property of the communes. Concession contracts continue to predominate in other areas such as toll-road management, which is currently enjoying a boom in France. For water distribution, however, it is now the lease-hold system that accounts for the bulk of delagated management and operation.

I.3. THE LEASE-HOLD SYSTEM

Under the terms of lease-holding, the commune retains ownership of the water facilities it has either created itself or received upon termination of a concession contract. It delegates no more than the operation of its service to a privately-owned water distributor through a lease-hold contract. The contract specifications stipulate all the water distributor's obligations regarding the operation of the service and the maintenace of facilities, with oversight exercised by the commune that retains not only the ownership of the facilities but also the right to define the water supply policy throughout the area under its jurisdiction. In particular, the specifications set forth the company's responsibilities relative to the quantity, pressure and quality of the water supplied to consumers.

The company manages and operates the service at its own risk ; its remuneration is stipulated in the leasing contract in the form or an option of the sale prive of the water paid by consumers. To yield a profit, the company must keep operating expenses below the income received from the sale of water. As owner of the facilities, the commune must bear the burden of all new investment outlays, which must also be financed through the sale of water. The price of water is accordingly *divided into two parts : the "company" part and the "municipality" part. In practice the company bills customers for the water and in turn pays the commune its share.*

A leasing contract generally covers 12 years, and its various clauses may in some cases be modified during the life of the contract. Tarification of water is indexed on the basis of prevailing economic conditions.

This dual aspect of the leasing contract which draws a sharp distinction between investment outlays and operating costs is therefore especially flexible : on the one hand, the company manages and operates the water service at its own risk with the income it receives from the users of the service ; on the other hand, the municipality disposes of a part of the price of the water for financing its investments. Thanks to the income it receives from the sale of water, the municipality can either locally obtain the loans needed for building new facilities or conclude an investment contract with local private investors and international organizations (ADB, World Bank,...) that then retain temporary ownership of the facilities. The regular income from water sales enables local authorities to guarantee local investors a satisfatory return on the capital they have invested, including an indexation of annual revenue and tax reductions due to the public charity, aspect of the operation.

It is thus evident that the private management of a water distribution service encourages the raising of local capital for needed investments.

I.4. THE NECESSARY DISPARITY IN WATER TARIFFS

In France, the application of the various contractual provisions means that the sale price of water varies with each water service, since the price level is voted each year by the city council in the case of direct management, or stipulated in the contract between commune and private distributor in the case of delegated management. The result is an unavoidable disparity in prices which is to be expected since a given price reflects differences in ressources, structure and geography, all of which may vary widely from one utility to another.

We feel this disparity in water prices ought to be maintained because it reflects the reality of the costs involved. From the point of view of efficiency and overall profitability, it is not advisable to standardize the price of water. The fact is that for reasons of equity if we wish to standardize the price of water on a national *or regional scale, we end up encouraging through subdisies the consumption of water with a high cost price, while discouraging consumption in those areas where water is abundant and cheap.*

Such are the main points of the mechanisms governing the management of water services by private companies in France. I should reiterate that private firms supply water to 65 % of the French population, that is 35 million people. And so I should like to wind up this presentation by describing two recent examples of privatization, the Paris and Versailles Water Utilities.

I.5. TWO RECENT EXAMPLES OF PRIVATIZATION : VERSAILLES and PARIS

The Versailles Water Service, supplying the city proper and 19 neighbouring communes, was somewhat a victim of its own excessive fame. The city that was once home to the kings of France with their magnificent estate, including the château and its world-renowed, surrounding grounds, has produced a one-of-a-kind water distribution sytem that, managed by a government body since the days of Louis XIV, had fallen into a state of disrepair over the years. The utility was badly in need of a thorough ongoing program of modernization and more efficient management and operation if 350,000 inhabitants were to be supplied with good quality water under sufficient pressure. Thus in late 1979, a new water company was founded : the Versailles and Saint-Cloud Water Company, which is a subsidiary of Compagnie Générale des Eaux. Over the last five years, the new company has overhauled the production and distribution facilities. Today the newly implemented treatment processes ensure excellent quality tap water while renewal of the distribution network means improved water pressure and reliability. All the operations involved were performed to the complete satisfaction of the consumers.

The second example involves Paris where the mayor and his staff decided that privatization was the only way to overhaul the distribution network and reduce water losses that were approximately 20 %. Since the beginning of 1985, the Paris Municipal Water Service has limited its activities to the production of drinking water. The private distributor buys the water wholesale and transports it under the streets of the capital to the customer's service connection ; the distributor then resells the water at a retail price. The distributor's profits will depend on the difference between sales and expenses, in other words they will be the direct result of increased productivity in management and operations as well as of increased network ratio. Improved network ratio can be achieved gradually through thorough maintenance of system pipelines and the replacement of the oldest mains.

ADVANTAGES OF PRIVATIZING WATER UTILITIES

The management of water utilities by private specialized contractors is suitable in every way to the practical needs of local authorities and consumers alike, providing it is kept within a legal framework adapted to the motivations of private companies. The advantages that delegation of management procures are numerous and we feel it is necessary to devote a little time to examining these advantages, the interest and usefulness of which are well worth pointing out.

II.1. AN EFFECTIVE UTILITY AT THE LOWEST COST

Management by a private contractor is an efficient and reasonably priced solution. The competition of other distributors in the field forces them to improve productivity constantly, for only in these conditions can they arrive at the lowest selling price per cubic metre of water while making a normal profit. Furthermore, when the contractor is a very big firm, each utility is incorporated in a far wider organization and therefore several benefit from the many scale effects that entail a reduction in costs.

II.2. FLEXIBILITY AT THE FINANCIAL LEVEL

From a financial point of view, delegating management gives the granting local authority great flexibility. This is obvious if you recall the simple mechanisms of the leasehold contracts that were described before. Operating and maintenance costs are taken over by the private company in exchange for a part of the price paid by subcribers for water. On the other hand, the local authority can easily find the investment funds required by the utility, since it also disposes of a part of the revenues from the sale of water. Thus, when plant is to be built, the necessary capital will be obtained either by a government loan issue, of which the redemption annuities will be covered by the water earnings, or by calling on private, local investors in the form of an investment agreement. In the latter case, investors receive the twofold guarantee, first of temporary ownership of the plant and second the earnings derived from the sale of water. Finally, it can be said that the flexibility connected with the management of a water utility by a private company encourages local investors to put up the capital.

II.3. PERMANENT OBLIGATIONS AND GENERAL RESPONSIBILITIES OF THE PRIVATE COMPANY

In addition to financial flexibility, the local authority derives many practical advantages from privatization. First of all it is relieved from the worries of daily management while conserving the right to exercise strict control on the Company's results and to define the guidelines of water distribution policy in its jurisdiction. As a consequence it can keep a certain distance between itself and consumers and their various complaints, justified or otherwise. Relations between the private distributors and subscribers are in fact excellent, because they remain on a commercial basis, better suited than official bureaucracy to solve the problems likely to arise.

Moreover the local authority relies on its leasehold contractor to solve all operating problems. The Company, as manager of the whole utility, is responsible night and day for the quantity, pressure and quality of the distributed water. It is the contractor who must keep watch on catchments, supply lines, potable water works, water distribution up to each subscriber connection and water meter. It is also the contractor's job to watch out for leakages and illegal connections and see that all consumption is invoiced.

The quality and safety of the service provided by private companies is a proven fact, as is illustrated by the daily success of such arrangements in many countries. Their success is due to the competent staff they know how to recruit and the efficient techniques they apply and relentlessly develop.

II.4. RICHNESS AND DIVERSITY OF HUMAN RESOURCES TRAINING

The personnel of private water distribution companies is carefully recruited and permanently retrained as required by the jobs they are called upon to do. This qualified personnel, available night and day can, if necessary, be backed up by specialists to solve temporary difficulties. The big private water companies dispose of a wide range of experts in all fields able to intervene very quickly and effectively in their particular spheres. This combination of local, all-purpose personal and regional specialists proves to be remarkably efficaceous in the field, especially in the frequent cases when modifications or up-grading are comtemplated. The assistance given then comes from an experienced team of designers particularly keen on bringing the proposed changes successfully from the drawing board to completion.

II.5. APPROPRIATE TECHNICAL MEANS

In the same way as for human resources and in the same proportions, the technical means used by private water contractors are adapted to the size and complexity of the utility. In the simplest cases, the technologies adopted and the material used are both conventional and modern, meaning that a constant call is made on old, proven methods that can, at the same time, be made to optimize the performance and efficiency of management.

In other utilities however, if circumstances so require, an effort is made to innovate in order to solve the finer problems of supply, treatment, distribution or administrative management.

The difficulties encountered by the biggest water companies are very numerous indeed. To overcome them we must be forever improving existing methods and implementing new technologies.

CONCLUSION

To sum up, the French system of water utility management by private companies, could serve as an example for the many privatization initiatives currently unfolding in every part of the world. Your presence at this 6th ASIA-PACIFIC REGIONAL WATER SUPPLY CONFERENCE WATER 87 testifies of your interest in our efficient management methods and to the willingness of southeast Asian countries, to implement more efficient and higher performance procedures in the best interests of water consumers. I am thoroughly convinced that together we can do good work and I thank you for the confidence you have shown in us.

IMPROVEMENT OF WATER TRANSMISSION AND DISTRIBUTION SYSTEMS

by :
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1 . INTRODUCTION

Tokyo Metropolis is located approximately in the middle of the Japanese Archipelago which belongs to the Asian Monsoon climate zone, with annual precipitation around 1500 millimeters. Tokyo, with a population of about 12 million, which is approximately 10 % of Japan's total population, is the center for important political, economic and cultural activities.

The Tokyo Metropolis can be roughly divided into the following three areas:

(1) The heavily urbanized area of 23 Ku (special wards) districts with an area of 592 square kilometers which lies within the southern part of the Kanto Plain and borders on Tokyo Bay.

(2) The Tama district with an area of 830 square kilometers bordering the west part of the Ku area. It is divided administratively into cities, towns and villages.

(3) Islands in the Western Pacific Ocean to the south of Tokyo Bay. These are administrated as towns and villages.

The Bureau of Waterworks of the Tokyo Metropolitan Government is responsible for the management and operation of water supply in the Ku area and throughout most of the Tama district.

In order to catch up with the rapid increase of water demand, which has been increasing together with the development of Tokyo, the Bureau of Waterworks of the Tokyo Metropolitan Government has planned and implemented some expansion projects during the years since its service was inaugurated in the year 1898 as a modern waterworks. As a result, at last, the water supply capacity has reached 6.63 million cubic meters per day, which has been adequate in meeting the demand for water; however, the water supply pervasion ratio has now reached almost 100 %.

At present, waterworks are one of the most important basic urban facilities of Tokyo Metropolis. They are indispensable as a support for urban activities and citizens' lives. Consequently, the damages citizens receive because of suspension or decline of water supply might be beyond measure.

For this reason, the most important social mission to the Bureau is to keep water supply stable and reliable, not only now but also in the future. The Bureau has to develop many measures in order to accomplish this goal.

The future water demand in Tokyo is estimated to be constantly increasing due to the improvement of living standards and the progressive urbanization of the circumferential district, and to be reaching approximately 6.90 million cubic meters per day in the year 2000. Consequently, it will be necessary to build up the capacity of purification plants and the transportation channels.

Because Japan is part of the Pacific ring of fire and has been one of the world's most earthquake-prone nations since ancient times, it is necessary to implement a variety of disaster-prevention and emergency relief measures to safeguard the lives and property of citizens. In addition to these, it is necessary to implement a variety of countermeasures to provide a supply of water whenever there is trouble with a facility or with water quality.

In short, there are two important subjects. One is a quantitative subject: how to expand the capacity of the water supply. The other is a qualitative subject: how to improve the reliability of facilities.

In this paper, we intend to introduce an outline of the improvement scheme of water transmission and distribution systems and its policies.

2. PRESENT WATER TRANSMISSION AND DISTRIBUTION SYSTEMS

2. 1 Outline of Tokyo's Waterworks

2. 1. 1 Water Sources and Service Area

Tokyo's water supply depends mainly on river water—the Tone River System, the Tama River System and the Sagami River System. (Fig.1)

The service area consist of the 23 Wards in the Ku area as well as 22 cities and 3 towns in Tama district which were integrated into the Tokyo waterworks. (There are a total of 32 cities, towns and villages in the Tama district, and in the past, waterworks in these municipalities were administrated by each municipal authority respectively.)

The service area is about 1150 square kilometers, and its population is about 11 million. Four municipalities, which have not integrated, are currently obtaining water from the Tokyo Waterworks under a water-sharing arrangement.

In the year 1985, the volume of total supply of water, which included the shared water to nonintegrated municipalities, was approximately 1.72 billion cubic meters, and the maximum daily supply was approximately 5.72 million cubic meters.

2. 1. 2 Supply and Demand Project and Capacity of Facilities

Table 1 shows the supply and demand project and capacity of facilities. It is estimated that the maximum daily water demand will reach approximately 6.90 million cubic meters in the year 2000, but the capacity of total facilities is only 6.63 million cubic meters at present, as shown in table 2. The Bureau is planning to expand the Misato purification plant to compensate for the deficiency of capacity. Figure 2 shows the changes of the water supply volume, the capacity of facilities and the volume of water source. In case of a shortage of the facility's capacity, the Bureau has managed to supply water by dint of overload to these purification plants, and in case of a shortage of the water source, by the stored water in reservoirs which are in the Tama River System and are used exclusively for Tokyo's potable water.

2. 1. 3 Water Operation Systems for Mutual Connection between the Tone River System and the Tama River System

Figure 3 shows the locations of water mains of Tokyo Waterworks, and the linkage of some of the principal purification plants and major pumping stations by water mains in order to exchange purified water.

In addition to this, raw water can be exchanged between different river systems, the Tone and the Tama, by using the raw water connecting line and reservoirs which are in the Tama River System and are owned by the Tokyo Waterworks. (Fig.4) This can be called the most important function of the water operation system in Tokyo Waterworks, as it ensures reliability of water supply. In fact, the Bureau has demonstrated the reliability of this system many times in the instances of drought and accidental pollution of river water.

2. 2 Functions Required of Water Transmission and Distribution Systems, and Problems in the Present State

2. 2. 1 Functions required of Water Transmission and Distribution Systems

As was the case with the above-mentioned, in the severe situation when the Bureau had to plan and implement some expansion projects for many years in order to meet rapid increase of water demand, the Bureau has made great effort to develop a more rational waterworks system—one which is as suitable as possible for the topographic and hydrographic conditions in Tokyo. As a result, the present waterworks system can be called a large-scale waterworks which has a rational frame in its fundamental facilities; however, there are some points which are inadequate in maintaining the stability and fine handling of all the facilities and every operation.

For this reason, a great deal of consideration should be given to the importance of a water transmission and distribution system in Tokyo. The Bureau believes the following functions are necessary in order to keep water supply more stable.

(1) The ability to transport necessary volumes of water with suitable pressure and to keep water quality secure, as the fundamental service functions.

(2) The ability to utilize water-rights effectively.

(3) The reliability of transportation within the transmission and distribution systems, for instance in facility related accidents, earthquakes and aridities.

(4) The reliable operation of facilities

2. 2. 2 Problems of Existing Facilities

As a result of review and examination of the existing facilities in Tokyo Waterworks, in consideration of the above-mentioned desirable functions, some needed improvements were brought to our attention.

(1) Necessity of improvement in water distribution districts

Each distribution system of Tokyo Waterworks has been organized by its dependence on a particular water source system since the first period. Consequently, some distribution systems, which have a large water source, used to take charge of a large distribution area, and many pipe lines of the distribution system used to be directly connected with other systems' pipe networks without mutual connection through a distribution station. Because of this, these large water systems can support their own large capacity to supply water under the ordinary situation, but in the case of an accident, the results of the accident will spread over a large area. In the case of a back-up from another system, it is feared that there may be a risk of spreading turbid water over a large area because the flow of water will change the flow direction in both pipe networks which are connecting each distribution system. In addition to these matters, it tends to be difficult to cope with accidents because of the large number of valves that would have to be handled.

In the case of large scale transmitting water mains, these defects have already been solved to a certain extent by equipping the mutual connective functions, but there are these sorts of problems in other water mains yet. In the large scale distribution system which takes charge of very undulate land regions, not only a lot of energy is consumed, but also unneeded high pressure occurs because it is necessary to run pumps with high pressure for these high land regions.

(2) Ambiguity of separating transmission functions from distribution functions

Some large scale transmitting water mains directly pour water into the distribution system's pipe network at many connecting points, without connecting through the distribution station.

There are also other cases where some mains have many branch pipes to pour water into the distribution system's pipe networks on the way, in spite of having a transmission system with connection between distribution stations. In the case of mains like these, when the Bureau copes with accidents, there are risks of spreading turbid water because of the sudden changes of the flow direction and of the hydraulic gradient which exists in pipe networks. Sometimes these tend to hinder expedient measures.

Because the flows of water in the pipe networks affect each other, it is difficult to predict how the flow will change. Due to this unpredictability, it is almost impossible to control facilities by rational means; that is, by a pre-determined, systematic use of pipes, valves, pumps and service reservoirs.

Another problem exists in the case of a water main serving both transmission and distribution functions. The water main will be operated with unnecessary high pressure since the pressure for distribution is higher than that for transmission. This becomes an even greater problem when water distribution is to a higher land area. In all cases the amount of increased pressure varies with the hourly change of the water demand.

(3) Shortage and unbalanced location of reservoir's capacity

Even though the Bureau has a capacity of reservoirs which is founded on the Standard of Waterworks Design in Japan, it is not enough to cope with accidents affecting the support of urban activities and citizens' lives in the heavily urbanized Tokyo Metropolis.

In some distribution systems, reservoirs are not located appropriately due to the difficulty in obtaining sites for constructing reservoirs. The location and size of the reservoirs are not always in balance with the needs of a particular area. As a consequence, it is difficult to control transmission and distribution in some districts. Some large scale water mains needlessly share the change of the water demand and they are made to run pumps inefficiently and irregularly. In addition to this, the daily potential rate of discharge of transmission water line is restricted by hourly peak-flow demand.

(4) Necessity of strengthening pipes against earthquakes

All the pipelines, conveyance, transmission and distribution systems are classified into three groups according to the importance of their function in an emergency situation; however there are quite a bit of pipelines which are inferior in resistance to earthquakes because of old type joints and materials.

(5) Problems in Tama district

The waterworks in Tama district are composed of two sorts of systems. One group are the systems which have been managed by the municipal bodies of cities, towns or villages. The other is one which has been constructed by the Bureau to supply water widely from the Tokyo Waterworks.

In the past, waterworks in municipalities were administrated by each municipal authority respectively. However, population growth and other factors have boosted demand, making it increasingly difficult for these authorities to cope. As a result, these municipalities began to lag behind the 23 Wards in terms of the water supply pervasion ratio and the cost burden to consumers.

In the year 1971, the Tokyo Metropolitan Government developed a plan to integrate the 30 waterworks systems of these municipalities into the Tokyo Waterworks. Presently 25 municipal waterworks systems have been absorbed into the Tokyo system. The municipalities which have not been integrated are currently supplied wholesale water from the Tokyo Waterworks under a water-sharing arrangement.

This wide area system has not been completed by way of a network pattern; it is still using a branching pattern and is short of mutual connecting pipelines and service reservoirs. This situation is a result of historical course, undulation of land and scattered locations of urbanized regions. In addition to this, with respect to waterworks of municipalities which have been integrated, they have not yet been completed, and service reservoirs are short of capacity.

Because of these reasons, it can be said that establishment of a wide back up system to cope with accidents is the most important concern of the waterworks in Tama district.

3. QUALITATIVE IMPROVEMENT OF TRANSMISSION AND DISTRIBUTION SYSTEMS

The Bureau has decided to implement the systematic improvement projects concerning transmission and distribution systems on the basis of the results of reviews and examinations of the systems.

3. 1 Basic Ideas of Improvement Projects

The following basic ideas were adopted to improve and reorganize the systems in order to maintain and enhance their functions, making them more reliable, manageable and efficient.

3. 1. 1 Reorganization of Distribution Districts and Adoption of the Method of Distribution, called the Water Distribution Base Plan.

(1) Reorganization of distribution districts

Up to now, the Bureau has been able to set up distribution districts, without being restricted by volume and location of water sources, by implementation of projects such as the mutual connection between different water systems. The Bureau decided to reorganize all Ward areas' water distribution districts, which have some historical backgrounds, into appropriate scale and shape by considering topography, location and function of existing facilities.

(2) Establishment of water distribution bases

A water distribution base, which will take charge of its own area, will be established in each reorganized water distribution district by taking advantage of an existing pumping station or by constructing a new one. As a rule, a water distribution base distributes water only to its own district in order to separate transmission function from distribution function, to keep pumps running stably, and to better control distribution.

(3) Enlargement of service reservoir capacity

Water distribution bases will generally consist of service reservoirs and pumping systems. Each reservoir will have the capacity not only to handle hourly variation in water demand, but also to cope with accidents in its own district and to back up other districts in case of accidents. Actually, the Bureau has aimed to make the capacity of the reservoir correspond to one third of the daily maximum water consumption of the year 2000.

(4) Improvement of water distribution functions

Each water distribution base will be made able to receive water from at least two different water transmission mains. Also the functions of pipeline systems and pumping systems to transmit will be separated from the functions to distribute as completly as possible, in order to develop rapid response capabilities to deal with accidents.

3. 1. 2 Improvement of Pipelines

(1) Improvement of pipelines is needed to adopt the Water Distribution Base Plan.

The Bureau has planned to construct a comprehensive transmission network system linked with each distribution base by improving water transmission mains and interconnecting purification plants with water distribution bases.

With respect to large scale water mains, which have both transmission and distribution functions, the water distribution mains' network will be improved in order to separate both functions and to be able to distribute from its own base.

On the occasion of improvement of the water distribution mains' network, it will be endeavored to keep adequate water pressure in the whole area by considering topography, but in the case of parts in which it will be difficult to keep adequate pressure, small scale pumping stations or pressure-reducing valves will be adopted.

(2) Intentional renewal of old pipeline to prevent leakage and turbid water

An explosion of a water pipe in the city has the potential danger of causing substantial secondary problems such as obstacles to traffic and inpouring of water into basements. The prevention of leakage is one of the most important priorities for the Bureau, not only from the viewpoint of the shortage of supplied water as a financial problem, but also in terms of ensuring that Tokyo's limited water resources are used effectively.

The occurence of turbid water, such as red water due to secular changes of pipeline, hinders the expedient change of distribution. For this reason, the Bureau decided to replace old distribution mains and sub-mains, such as initial cast iron pipes (grey iron pipes), cast iron pipes,and asbestos cement pipes, with ductile cast iron pipes.

(3) Promotion of earthquake-proof measures for pipelines

In order to provide the maximum possible water supply after a major earthquake disaster, in order to safeguard the lives and property of Tokyo's citizens, it is necessary not only to found the systems for emergency restoration and emergency water supply, but also to promote earthquake-proof measures of waterworks' facilities.

With respect to these subjects, the Bureau has endeavored to construct and maintain the best possible facilities of every kind; however, it is anticipated that there would be widespread and substantial damage to pipelines, because there is quite a bit of old type pipes (in material or joint) or secularly changed pipes.

For the purpose of promoting earthquake-proof measures of pipeline, there are two means to consider. One is to construct an efficient and interacting pipe-network system by adopting the Water Distribution Base Plan, the other is to reinforce the pipeline itself in resistance to earthquakes.

In terms of these, the Bureau classified all the pipelines as the life-line of the city into three groups from a viewpoint of emergency restoration and emergency water supply, and decided to replace old pipes with ductile cast iron pipes according to priority.

3. 1. 3 Improvement of Facilities in the Tama District

Since it is necessary to carry on the expansion of facilities, because of the above-mentioned, it is difficult to systematically operate the existing facilities as a wide area system.

(1) Construction of water distribution stations

In the Tama district, the Bureau has planned to construct water distribution stations with service reservoirs. It is especially important to provide for a system to supply water to areas which are difficult to replenish due to topography and other situations. These areas should have a service reservoir large enough to manage to supply about half of the daily maximum water consumption.

When deciding the location of the new water distribution stations, consideration should be given to intricate and undulate topography as factors in reorganizing the distribution districts. It is also important that major stations be able to receive water from at least two different systems.

In addition to these, if possible, wide-area and large-scale service reservoirs, which are equivalent to several service reservoirs, will be constructed, rather than small scale reservoirs.

(2) Improvement of pipelines

The old type pipes will be replaced with ductile cast iron pipes in order to prevent leakage and promote earthquake-proof measures.

It is also planned to increase water supply positions by constructing wide area and interacting systems.

3.1.4 Control of Facilities

It is not only important to operate an efficient water supply system during ordinary situations, but it also necessary to react expediently to emergencies and accidents, and to ensure fair and equal distribution of water after an accident or disasters such as earthquakes and aridities. In order to provide smooth and efficient operation of Tokyo's waterworks in the future, it is necessary not only to improve facilities of all kinds, as is the case with the countermeasures mentioned above, but also to establish new facility operation systems in order to realize our plans. For this reason the Bureau has planned to establish the operation system which displays both dispersion management and integration management, as described below.

(1) The total water supply, the water distribution bases, and the major facilities are comprehensively controlled by the Water Supply Operation Center which was established to ensure that the facilities are used for maximum benefit and that Tokyo's limited water resources are utilized effectively.

(2) The vice-operation centers will be established at some water distribution bases to combine and control a group which includes several water distribution bases.

(3) Each vice-operation center controls not only its own water supply, but also several bases' water supplies which are combined.

(4) A remote control system is fundamental to this scheme. In addition to this, a double source electricity method and pluralized function idea will be adopted to ensure reliability and safety of systems.

3.2 Outline of the Improvement Scheme of Water Transmission and Distribution Systems

At the conclusion of this paper, we intend to introduce an outline of the improvement scheme which is founded upon the above-mentioned ideas.

Some parts of this scheme have already been undertaken in 1984 as the Distribution Facilities Comprehensive Improvement Project, and the Bureau intends to implement this scheme for about ten more years. The Bureau plans to carry out this scheme with the intention of not suspending the wide area water supply. This will be accomplished by making shifts with existing facilities because this improvement plan involves facilities which are currently operating.

3.2.1 Construction of Water Distribution Bases

The Ku (23 special wards) area's water distribution districts, which are still separated into historical districts, will be newly divided into 31 distribution districts, and 29 water distribution bases will be established by new construction or by making use of existing pumping stations. Only two bases will take charge of two distribution districts respectively. The capacity of service reservoirs, which will be enough to supply the water demand of the year 2000, will also be constructed and expanded.

3. 2. 2 Improvement of Pipelines

The pipelines which are expected to improve with the adoption of the Water Distribution Base Plan are as follows.

transmission mains	: 900mm—2600mm, l= 60km
distribution mains	: 400mm—1500mm, l= 50km
distribution sub-mains	: 75mm— 350mm, l= 300km

With the respect to replacement of pipes, the pipelines which are planned to promote earthquake-proof measures are as follows.

transmission mains	: 800mm—1800mm, l= 15km
distribution mains	: 400mm—1500mm, l= 30km

And the pipelines which are planned to be replaced because of secularly change areas follows.

distribution mains	: 400mm—1500mm, l= 30km
distribution sub-mains	: 75mm— 350mm, l=1850km

3. 2. 3 Construction of Facilities in the Tama District

In the Tama district, 13 service reservoirs will be improved and the pipelines will be constructed or replaced as follows.

construction of transmission and distribution mains	: l=220km
construction of distribution sub-mains	: l=560km
replacement of secularly changed pipes	: l=170km

4. CONCLUSION

In Tokyo, the period of quantitative expansion, during which the Bureau has been making great effort to meet the rapid increase of water demand, seems to be over in a fashion. The subject which the Bureau has to work on now is a plan to keep the water supply stable as a basic urban facility in the highly urbanized Tokyo Metropolis. That is to say, Tokyo's waterworks are entering a period of qualitative progress. The reliability of the transmission and distribution systems certainly will be increased by this improvement project.

However, there are still many problems which the Bureau must come to grips with in order to provide a stable supply of clean water. We are now laboring to provide solutions for these problems. Hopefully, in the near future our goal will be reached.

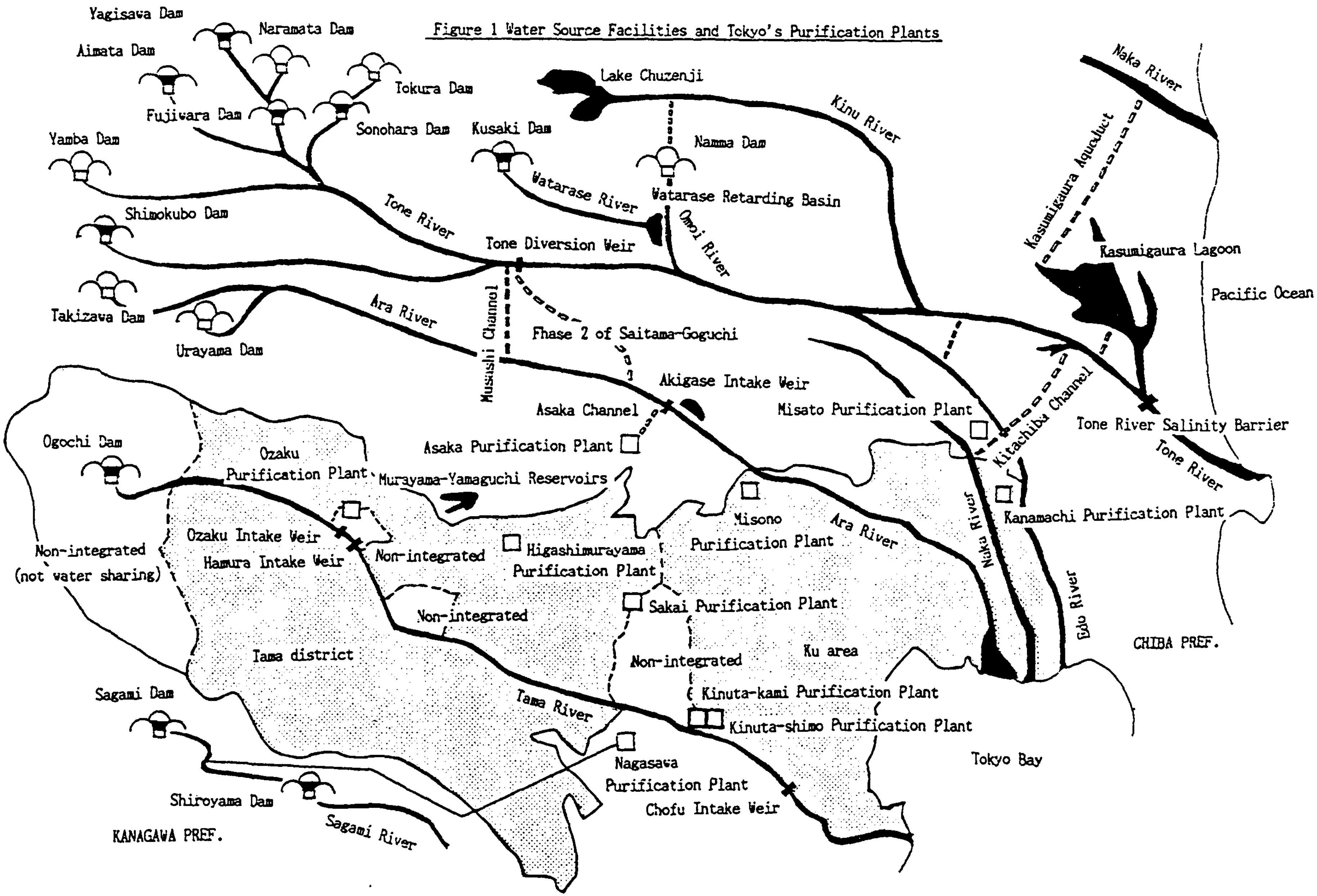


Figure 1 Water Source Facilities and Tokyo's Purification Plants

Table 1 Supply and Demand Project, and Capacity of Facilities

Item / F.Y.	Population Served	Maximum Daily Supply (m^3)	Facilities: Capacity (m^3/day)	Facilities: Expand Plan (m^3/day)
1985	11741000	5898000	6630000	Fase 2 of Misato Purification Plant, in 1993
1990	11952000	6400000	6630000	
1995	12152000	6700000	7180000	550000
2000	12292000	6900000		

Table 2 Purification Plants

Water System	Name	Capacity (m^3/day)	Contribution (%)		Treatment Method
			Plant	System	
Tone River System	Kanamachi	1820000	27.5	79.2	Rapid Sand Filtration
	Misato	550000	8.3		Rapid Sand Filtration
	Asaka	1700000	25.6		Rapid Sand Filtration
	Misono	300000	4.5		Rapid Sand Filtration
		880000			Rapid Sand Filtration
Tama River System	Higashimurayama	385000	19.1	17.6	Rapid Sand Filtration
	Ozaku	280000	4.2		Rapid Sand Filtration
	Sakai	315000	4.8		Slow Sand Filtration
	Kinuta-Kami	114500	1.7		Slow Sand Filtration
	Kinuta-Shimo	70000	1.1		Slow Sand Filtration
	Tamagawa	(152500)	------		--------------------
Sagami River System	Nagasawa	200000	3.0	3.0	Rapid Sand Filtration
Underground Water	Suginami	15000	0.2	0.2	Slow Sand Filtration
Total		6629500	100.0	100.0	

Note:The supply of water from the Tamagawa Purification Plant in the Tama River system has been suspended due to the deteriorating quality of the raw water, and the facilities have been excluded from the capacity statistics. They are currently used to supply industrial water.

Figure 2 Capacity of Facilities and Volume of Sources

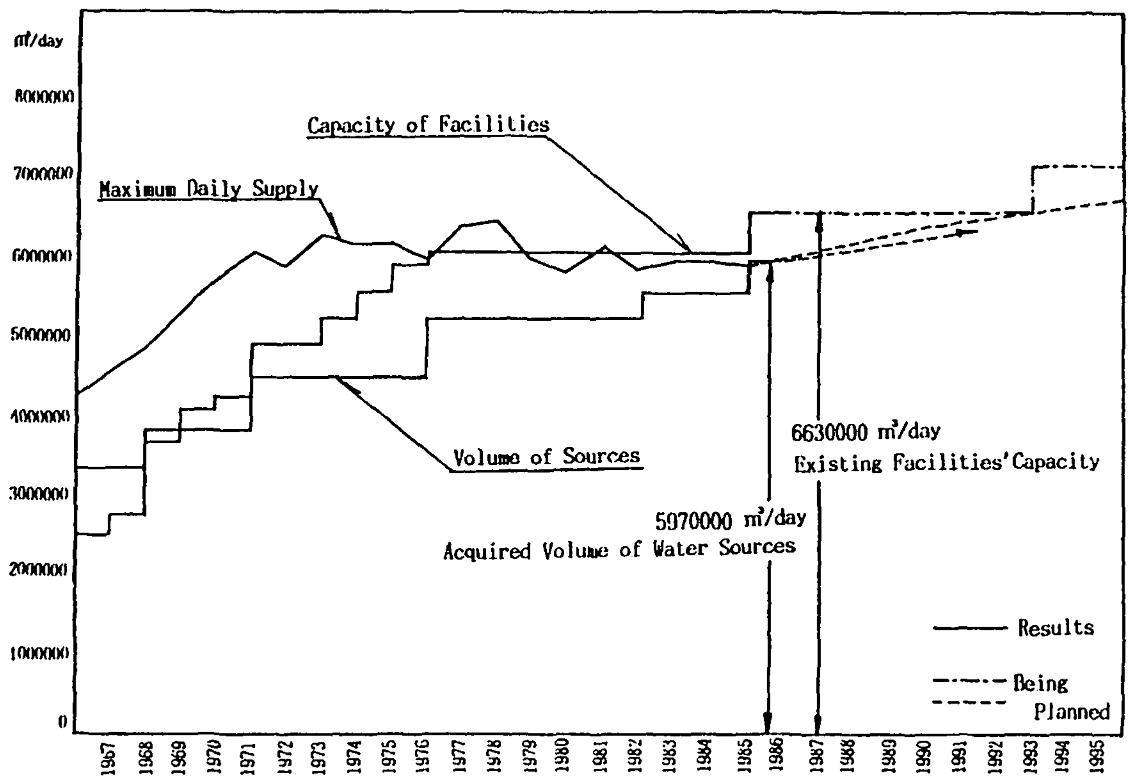


Figure 4 Mutual Raw Water Connection

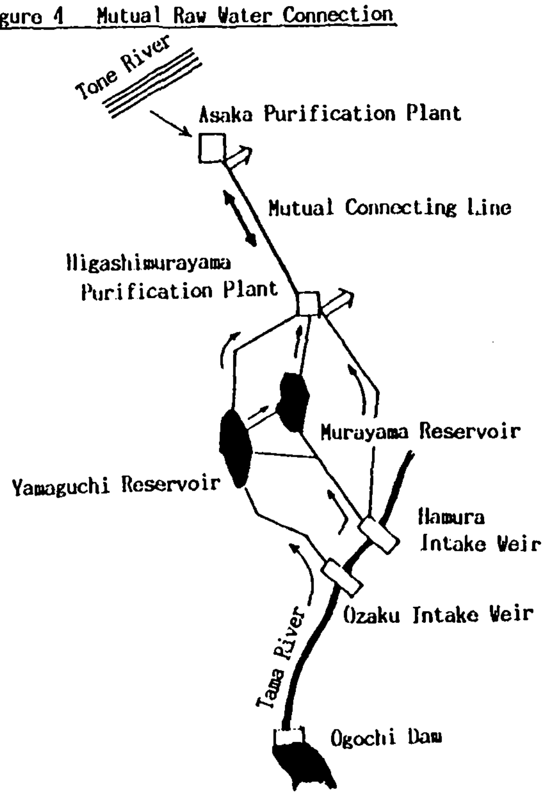


Figure 5 Concept of Controling Facilities

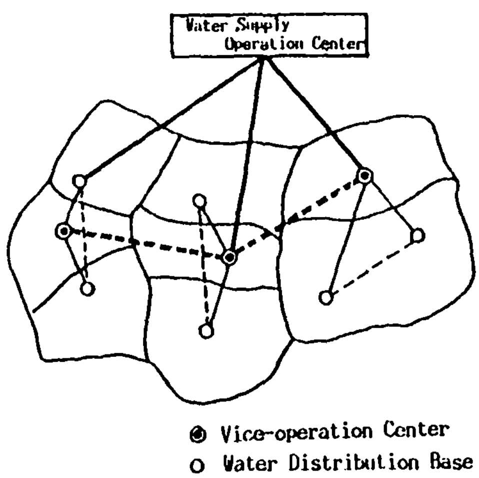
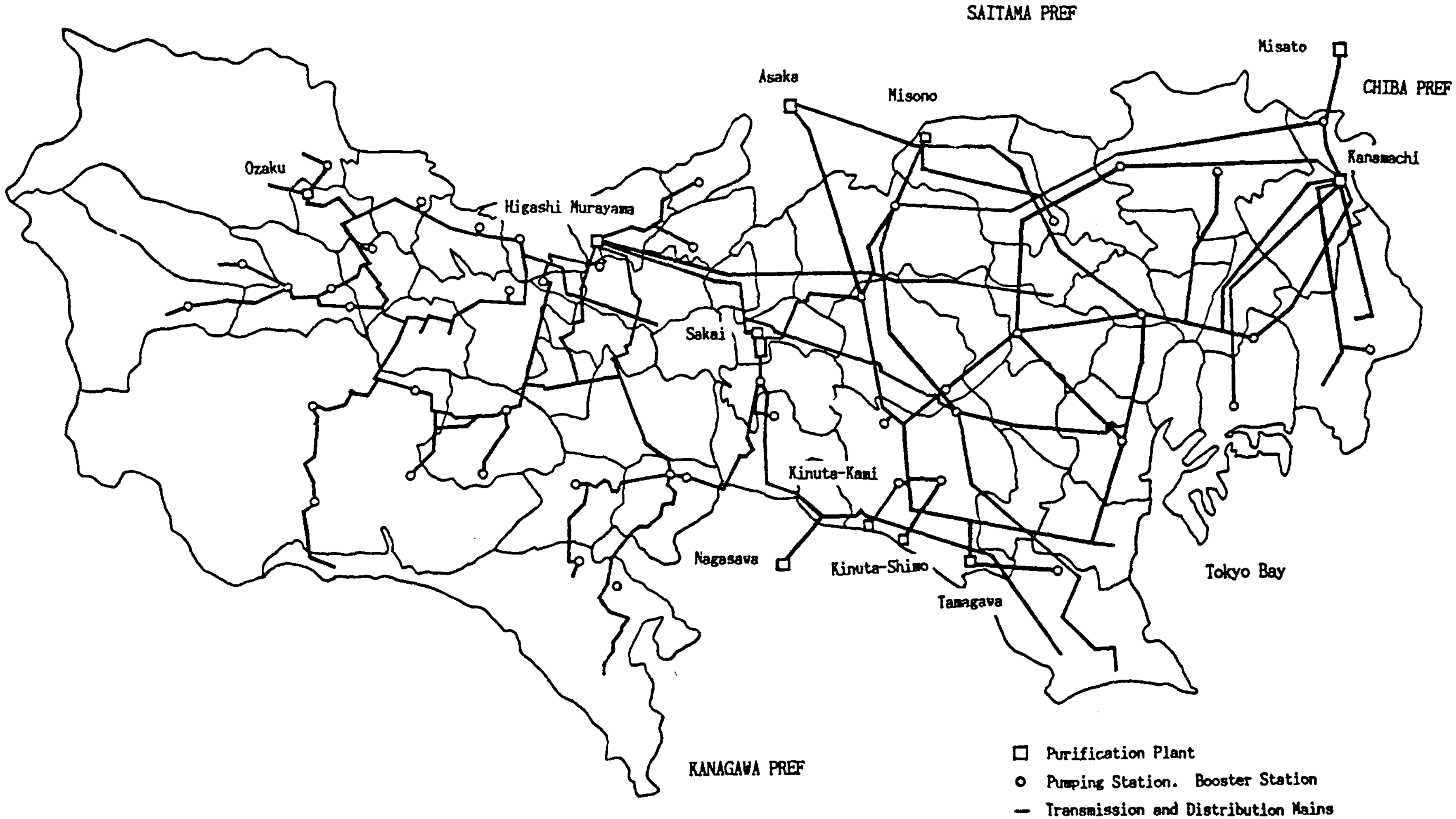


Figure 3 Principal Water Mains



POTABLE WATER FACILITIES AND STANDARDS : SMALL WATER SUPPLY SYSTEM

by :

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INTRODUCTION

The management of a water distribution network involves ever-increasing responsibilities connected with captation, any eventual treatment and distribution.
Within this spere, the limitations which in general define nearly all small systems, can be summed up as follows:

- reduced number of workers;
- prevalence of generalised professionalism;
- run along "artisan" lines;
- scarce economic/financial availability;
- difficulty regarding changes in organisation;
- administrative ties preventing development.

These factors must not in any way jeopardize the quality and, above all, the constancy of distribution.
Technology, instrumentation and professionalism, even if not acquired directly by small systems should, however, be at their disposal through suitable structures, so that as far as safety and the guarantee on drinking water is concerned, there is no difference at all between small or large systems.

1. QUALITY STANDARDS

The establishment of standard values is necessary to maintain a balanced equilibrium between people, social structure elements and their environment, whenever this balance is threatened or is already upset, and must therefore be re-established.
Establishing standards for a specific factor always presents a number of difficulties; these can only be defined by the existing Authorities, that must consider all those aspects which regard the problem in question, therefore avoiding too much

concentration on one particular factor at the cost of another. Therefore, the legal situation in various countries has considerable influence from the technical point of view, on the standard values or on the stipulations regarding the required quality.
The finalizing of quality standards on an international scale has come about until the present day, following two different methods.
The first, followed by the WHO, concentrated on giving suggestions, not compulsory values, keeping in mind the issue of national laws compatible with local, technical and economic possibilities, according to a cost-benefit balance, with a liberal type of interpretation including trust in people's honesty and common sense.
The second method, adopted by the E.E.C. probably influenced by greater scepticism, justified by centuries of experience has, however, tended towards compulsory rules, attempting to tackle the problem on a vaster scale orientated towards the protection of the natural water environment, the surface water and underground water, thus trying to create conditions so that the prescribed standards may be truly respected in the various countries of the Community.
For small water system wishing to survive or to become independent with water resources with no alternative water supplies and with technical and economic availability, the limited standards both suggested or imposed cannot have great significance except for controlling actual or potential pollution with the aim of taking more efficient, corrective or preventive steps.

1.1 SUBTERRANEAN WATER

The small systems seldom exploit sources apart from springs or wells which can both be classified as subterranean waters and which normally constitute water utilized as it is, with limited conditioning processes.
Its characteristics depend on the ground which it passes through during the filtering and underground flow.
As far as the chemical characteristics are concerned, some substances must be absent, others can be tolerated within a certain degree of concentration while others give the water particularly valuable qualities.
Among the components which must not be present because they are considered pollution elements owing to decomposition of organic matter (faeces, urine, animal carcasses), not forgetting ammonia, nitrites and nitrates.
Other substances which indicate a state of water pollution owing to deteriorating organic matter are i.e. sulphidric acid and total organic substances or there is contamination from domestic waste, i.e. detergents, chlorides, and industrial waste, i.e. chloride solvents, heavy metals, ets., or from agriculture - phosphates, nitrates.
We must particularly take into consideration the hardness which gives water particular characteristics and can cause some inconvenience in sanitary and domestic use.
The limits for organoleptic and chemical charactetistics are established by taking into consideration the fact that the composition of water varies greatly from one area to another in the world and that the supply capacity from sources is often limited.

The values fluctuate between those permitted under exceptional conditions and those normally acceptable. These are sometimes influenced by unforeseen circumstances or by unsurmountable economic barriers.

1.2 SURFACE WATER

The formulation of quality standard values of surface water must be made taking into account its various eventual uses. The quality requirements for surface water which is meant for drinking purposes, are established taking into consideration, above all, safeguard requirements and wherever possible, the quality improvement of water supplies (checking of waste) and the quality standards thus obtained are classified according to the type of necessary processes in order to obtain drinking water (Tab. 1).

1.3 CONCLUSIONS

Therefore, quality standards represent one common reference point for both large and small systems as far as checking is concerned. However, here we are not going to deal specifically with mixed or drinking water distribution systems because regarding this topic, systems of all types should be equipped with autonomous structures (instruments, staff, technology), so as to be able to check the quality of the water from the point of intake to when it is distributed throughout the network.
As regards untreated natural water, it is sufficient to say that periodical checks carried out by the authorities responsible will guarantee the quality of the water distributed.
Therefore we will deal with the most frequent occurence concerning small systems distributing only ground water which for chemical and bacteriological reasons undergoes disinfection i.e. with chlorine (Tab. 2 - 3).

Both guarantee and safety, once the constancy of the characteristics of the water to be distributed have been ascertained, are verified by chemical and bacteriological checks, keeping in mind the speed with which there controls can be carried out in an emergency.
The obstacle which basically must be tacked is the time factor.
In order to overcome this problem, one must be able to:

- carry out frequent checks on chlorine residue in the network;
- take correct samples;
- carry out minimal estimates;
- transfer to the structures proposed above, as soon as possible, in case of necessity, the samples taken.

2. CHECKING THE RESIDUAL CHLORINE IN THE WATER DISTRIBUTION NETWORK

This procedure is of the utmost importance because chlorination must be considered not as just bacterial disinfestation but as chemical oxidation as well.
For example, chlorine and ammonia react stoichiometrically causing mono-di and trichloramine leading to the formation of molecular nitrogen, thus obtaining the complete elimination of ammonia following the classical procedure of breakpoint chlorination (Tab. 4).
Nitrites, like most of the possible organic substances present, are oxidized following the principle of oxidoreduction, and therefore it can be observed how the finding of chlorine residue, if it is correctly interpreted, may be an indicator of some deficiency or excess of chlorination and also partially explain

the possible causes which have brought about this situation. For instance, it is possible to make an induced qualitative test of ammonia utilising as indicating reactives of residual chlorine both DPD (NN-Diethylphenylenediamine sodium sulphate) and the well-known ortho-tolidine. The latter reactive is without doubt the simplest and quickest to use; in fact, by just observing the velocity of the formation of the typical yellow colour, it is possible to determine whether there is combined chlorine or not (and therefore ammonia). Consequently it is possible to rectify the chlorination immediately.
It is known, however, that as ortho-tolidine is a suspected carcinogenic agent, in many countries it has been taken off the market and it is getting more and more difficult to find. Therefore we are obliged to use DPD which entails a longer analytical process which is not complicated but gives results over a longer period of time.
It is important to underline that this indirect analysis, though technically and scientifically supported and widely used, is not sufficient in itself to give a 100% guarantee. In fact only through specific laboratory tests is it possible to trace the causes of increased and diminished chlorine demand.
These analyses, which will later be included in detail, will result as being minimal regarding both the amount to be carried out and the difficulty involved, but so that they may reach reliable conclusions it is necessary that sampling procedures should be absolutely correct.

3. SAMPLING

It is worth keeping in mind that for practical purposes, the check points regarding chlorine residue coincide with sampling points and that they will be distributed at the exit of the chlorine station and throughout the network, in particular at its terminals or at the most extreme points.

In case there are reservoirs, there should be sampling - and therefore checking-points - at both the entrance and exit, in order to be able to exclude any eventual pollution, and there is also a by-pass line for inspection procedures and correction, if this is necessary.
Sampling is too often underestimated while in reality it is an essential part of the entire analytical process, so much so that any errors which could be made during this procedure inevitably reflect on the results, not making them plausible. Therefore sampling must be most meticulous and carried out by highly trained staff with extreme care, respecting the principle of casual selection. If this is not respected, the analysis will have no statistical value. We will now distinguish between chemical and bacteriological sampling, adding however that for practical purposes, the same sampling point is preferred, having a tap made of heat- resistant material (necessary for bacteriological samples), preferably stainless steel, water-tight and with good quality washers, as the water will always be turned on. The tap must be situated in a closed place and not accessible to unauthorized staff. As the regards the chemical side, there are no particular techniques to follow except that the container used, previously already carefully cleaned, should be rinsed with the sample water several times.
The collecting containers should be quite large and made of pyrex glass, polyethileneor stainless steel.
They should also be suitably identifiable with labels where, besides showing the place and date of the sampling, other useful

information should be added for statistical knowledge (air temperature, atmospheric pressure, the percentage of humidity relative to the general meteorological conditions).
As far as transport is concerned, it is necessary to be as rapid as possible from when the sample is taken to the point of its analysis, because an analytical result is held valid when sinergisms in the time lapse, do not bring about chemical, physical and bacteriological changes.
If this is not possible, it is therefore necessary to refrigerate the sample, and should be treated according to universally adopted tables.
Instead, the bacteriological sample requires a particular technique which entails extremely accurate care and methods described as follows:
"The sampling tap (which is on), is turned off when sampling begins and is heated persistently. Turned on again, the water is allowed to run for a few minutes. Keeping the burner very close, the sample is taken using a sterile bottle and being careful to lightly heat the neck and the lid if it is of frosted glass. The bottle must not be filled right up, in order to fausur the homogeneity of the sample at the time of analysis.
If the tested water is chlorinated, the sterile bottles will have to contain a few drops of 100% solution of thiosolphate which will have been put in the bottles before sterilising.
The sample thus collected, refrigerated in the suitable thermic case, is sent to the laboratory where it will be analysed on arrival or within a period of 12 hours if further refrigerated".
It goes without saying that sampling and checking will not only be carried out in emergencies, but also will a frequency that, when not subject to fixed regulations, will depend on:
- the number of inhabitants supplied;
- the general condition of water resources;
- the analytical potential of institutions carry out analysis.

4. EQUIPMENT

As mentionned above, the analyses which should be carried out in a small network are minimal and in fact include checking:
- pH;
- temperature;
- colour;
- odour;
- taste;
- conductivity;
- organic matters (kubel);
- ammonia;
- nitrites.

The relative equipment required is therefore extremely limited. In fact, normal laboratory glassware will be sufficient, plus a normal reagent (concentrated sulphuric acid, Griess and Nessler reactives which are manufactured ready for use as is the case with Seignette's salt or EDTA).
The number of instruments to be utilised is also limited.
Just one multi-use instrument is all that is required to check the pH temperature and conductivity. As far as the colorimetric analyses are concerned, it is unnecessary to employ sophisticated spectrophotometers - a filter photometer will do. There are vartypes on the market which are particularly useful because they provide, for instance, a direct concentration reading, giving also the possibility of observing the calibration curve using the permanent standards provided. Furthermore they are generally

available, on option , with a twin supply flow so that they can also be used in the field. The reasonable cost and simple utilisation have caused them to replace the old optic comparators when measuring, for example, the residual chlorine when processing drinking water.
An analytical and semi-analytical balance plus equipment to produce double-distilled or deionized water complete the items mecessary to equip a chemical analysis laboratory able to carry out not just the basic checking mentioned above but also, after acquiring the necessary experience, more detailed analyses, which do not require complex techniques or a particular type of equipment may be undertaken.
Information can be made more complete by equipping the laboratory with a few items in order to take a bacteria count. In fact, a vacuum pump or a water ejector, funnels for vacuum filtering, an incubator at 37° ± 1, an autoclave at 200° for dry sterilising will be sufficient to determine·

- total bacteria count;
- fecal streptococcus;
- total coliforms.

The technique employed entails using filtering membranes incubated in a selective medium and does not require any particular skill apart from great care during handling to prevent contamination. This procedure is exact and above all pratical due to the fact that membranes, Petri capsules and culture mediums are today manufactured and supplied in sterile packs, thus eliminating glassware and reagent material in a bacteriological laboratory, not forgetting also the long preparatory procedures previously required.
It is obvious that more specific or complex controls, i.e. tracing salmonellosis (in the bacteriological field); atomic absorption or gas chromatography analyses (in the chemical field), will have to be handled by efficient health authorities which, in any case, should follow up and guide any controls undertaken by small networks (Tab. 5).
To conclude, it should be underlined that if on the one hand chemical, physical and bacteriological checks are of fundamental importance, on the other it is necessary to guarantee the constant high quality of the water supplied.
This is a maintained by the correct hydraulic management of the water distribution network. Parameters relative to pressure, flow, levels and velocity must not be neglected, thus avoiding the following phenomena:

- the deterioration of the entire system;
- increase in bacteria;
- the accumulation of dust and organic substances;
- pollution through the water mains.

5. ECONOMIC ASSESSMENT OF THE PROJECT AND COSTS-BENEFITS ANALYSES

As far as the feasability of the project outlined is concerned, the economic verification cannot be separated from a series of political considerations entailing judgement values of an unquestionable nature. In other words, the choice made by the disciplinary body regarding the best organisation and set-up in the chemical laboratory previously described, can only be decided upon following accurate costs-benefits or cost-efficiency analyses.
The fundamental principle which has to lie at the root of this

methodology is that those responsible for the running of the water board should be interested in social well-being, following a concept and using methods which must necessarily be based on the situation found in the organisation at the present time.
Through the choice of suitable assessment parameters and by a system of prices and distributive demands, which reflects the interests of the community, plus the alternative use of the resources, costs-benefits analysis allows the aims of the project to be carried out, its feasability being decided by a public body.
It goes without saying that the investment procedures have different economic advantages fot those who take up, undertake and estimate the suitability of creating a bacteriological chemical laboratory whose utility is naturally of common interest.
Therefore, the bemefits and costs of the projects will vary, depending on:

1) the social groups which gain the benefits or pay the costs of the project;
2) the different times when the above-mentioned benefits and/or costs will materialise;
3) the different degree of possibility with which the project could be undertaken.

The basic requirement of costs-benefits analyses is to distinguish between financial and social analysis. Even though these two factors have the same objective - quantifying the actual flow regarding benefits and costs - they differ as regards the receiver of this flow: the managing body in the case of economic financial analysis, the community in the case of social analysis.
The systematic consideration of costs and benefits principally has the objective of excluding the projects which are not so satisfactory and to diminuish the possibility that the public administration might undertake uneconomical enterprises which could put pressure on the contributors without a valid reason from the social benefits angle.
Within this context, an assessment table, (Tab. 6) is included which could easily apply to the situation in waterworks interested in organising a bacteriological chemical laboratory.

Example of analysis
Without doubt there is great difficulty when defining benefits in a general social sense. However, in this case it is possible to tackle the problem starting with the "costs" element.
The problem is to establish which part of the costs can substitute or limit the extent of the benefit. This is an issue that really upsets the conjecture that economists are familiar with: finding oneself facing the hypothetic construction of two projects, A and B, it is confirmed that the cost of A is the benefit lost by not constructing B.
The example, starting with the following assumptions:
a) the singling out of the alternative project,
b) which combination of projects is compatible
c) which institutional rulings decide project selection,
d) the quality and number of services supplied by each project,
sets out to underline the alternative cost which may substitute the benefit rate.
Among the rules regarding selection, it will be useful for practical purposes, to provide the public body with two possibilities, so that it may have priority or pre-emption in any eventual conflict arising when choosing between a public and

private project.
The choices are usually made from a number of clearly specified alternatives (esplicit alternatives).
Once it has been established that the deciding public body intends to maximize the net benefits, the objective function will assume the following form:

$$\text{Net Benefit} = Bo - Co + \frac{B1 - C1}{1 + r} + \ldots + \frac{Bn - Cn}{(1 + r)^n}$$

where B and C represent the benefits and costs within the considered time span and "r" the social discount rate.
The project may only be undertaken if the net benefit has positive value.
Besides the necessity to correctly assess costs and benefits in various periods, it is indispensable to choose the social discount rate with great care.
Leaving aside the technical considerations linked with the fixing of the social discount rate, here it is sufficient to point out that as regards the investment - like the one in question - relatively low discount rates should be used, this being motivated by the fact both present and future generations will get a lot of advantages from the above-mentioned investment.
Finally, it must be underlined that particular care should be used when singling out methods able to confer, above all, social benefits - not exclusively in terms of quality but also in a quantitative dimension, using methods to determine social aspects which are not always easily monetized.

TABLE 1

SURFACE WATER

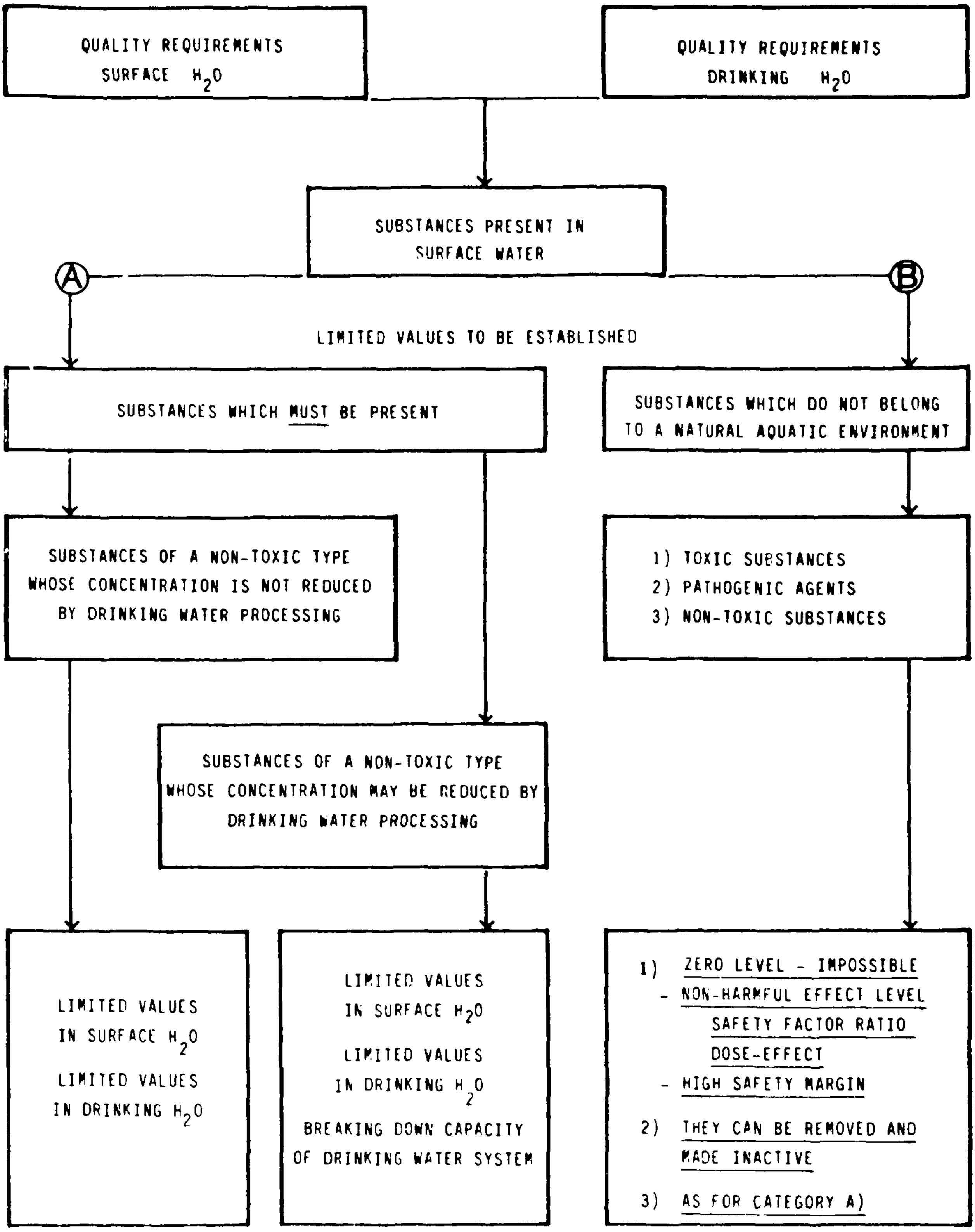


TABLE 3

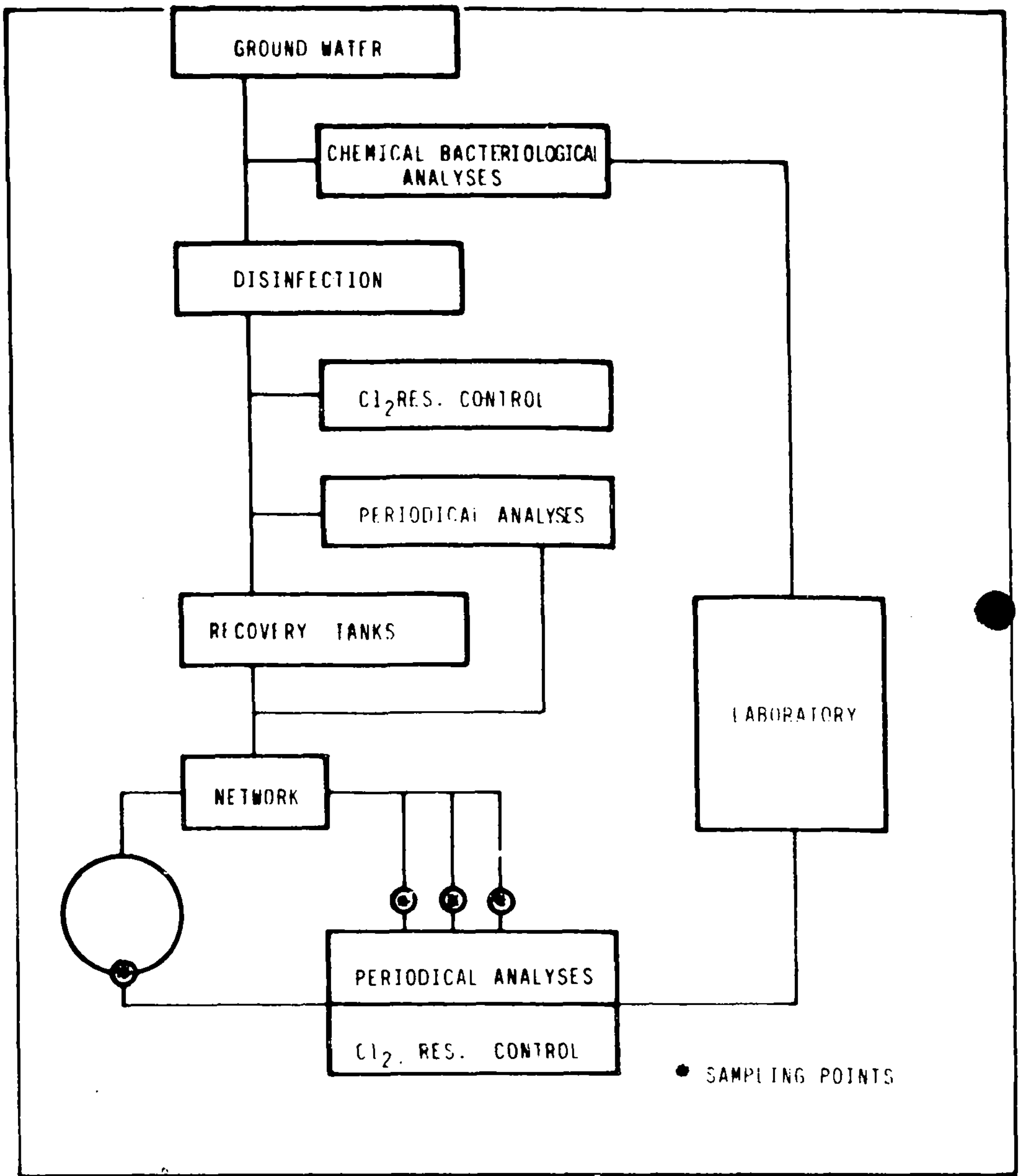


TABLE 2

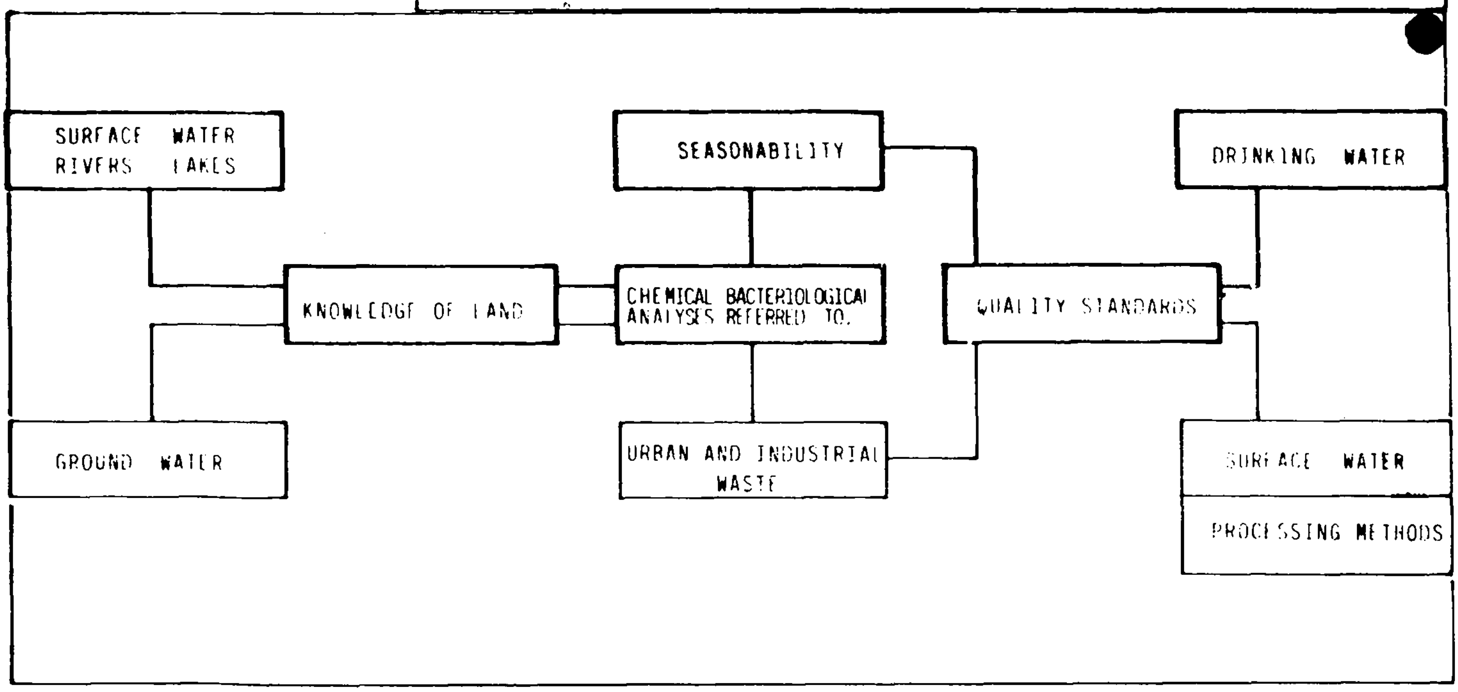


TABLE 5

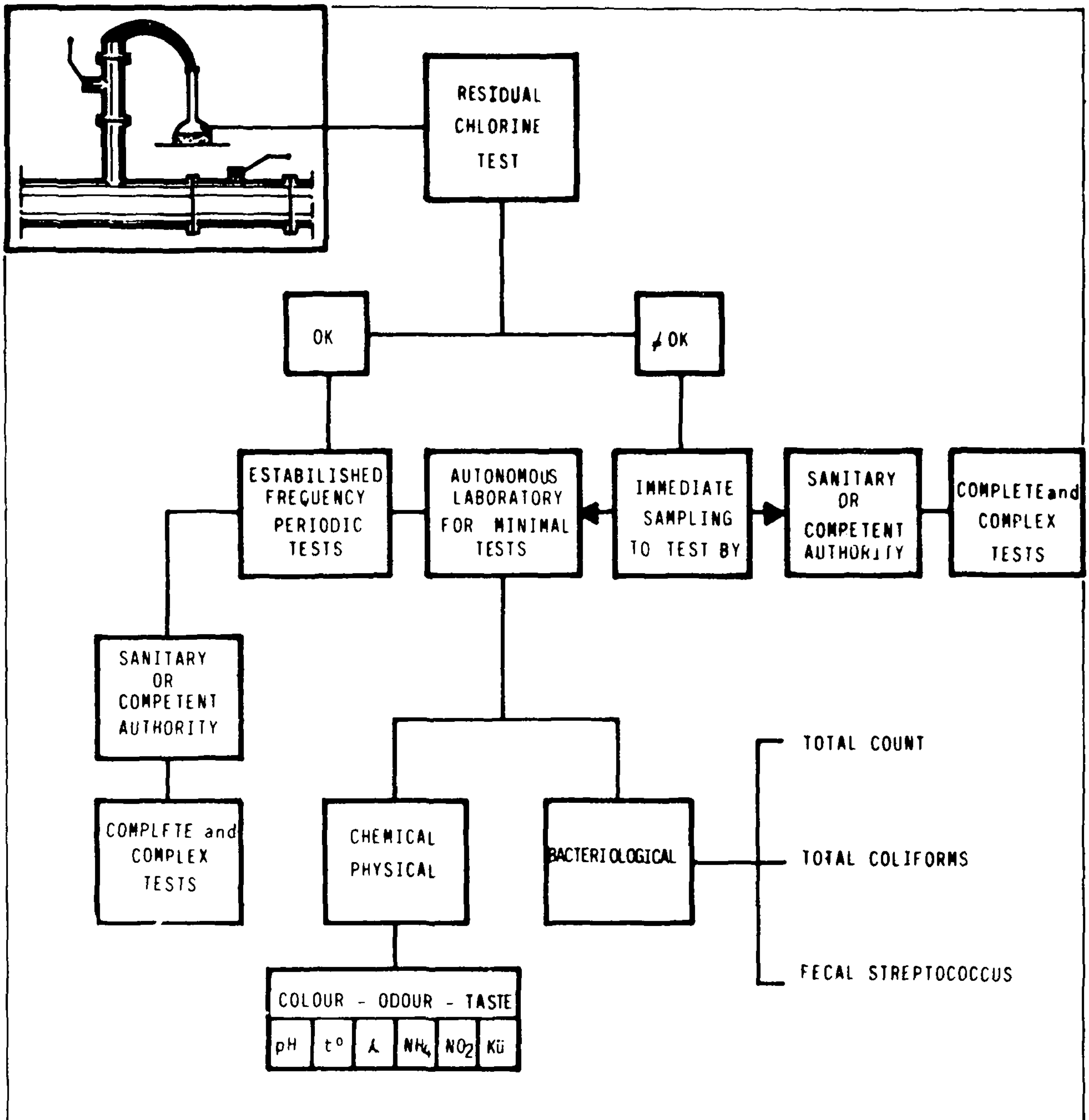


TABLE 4

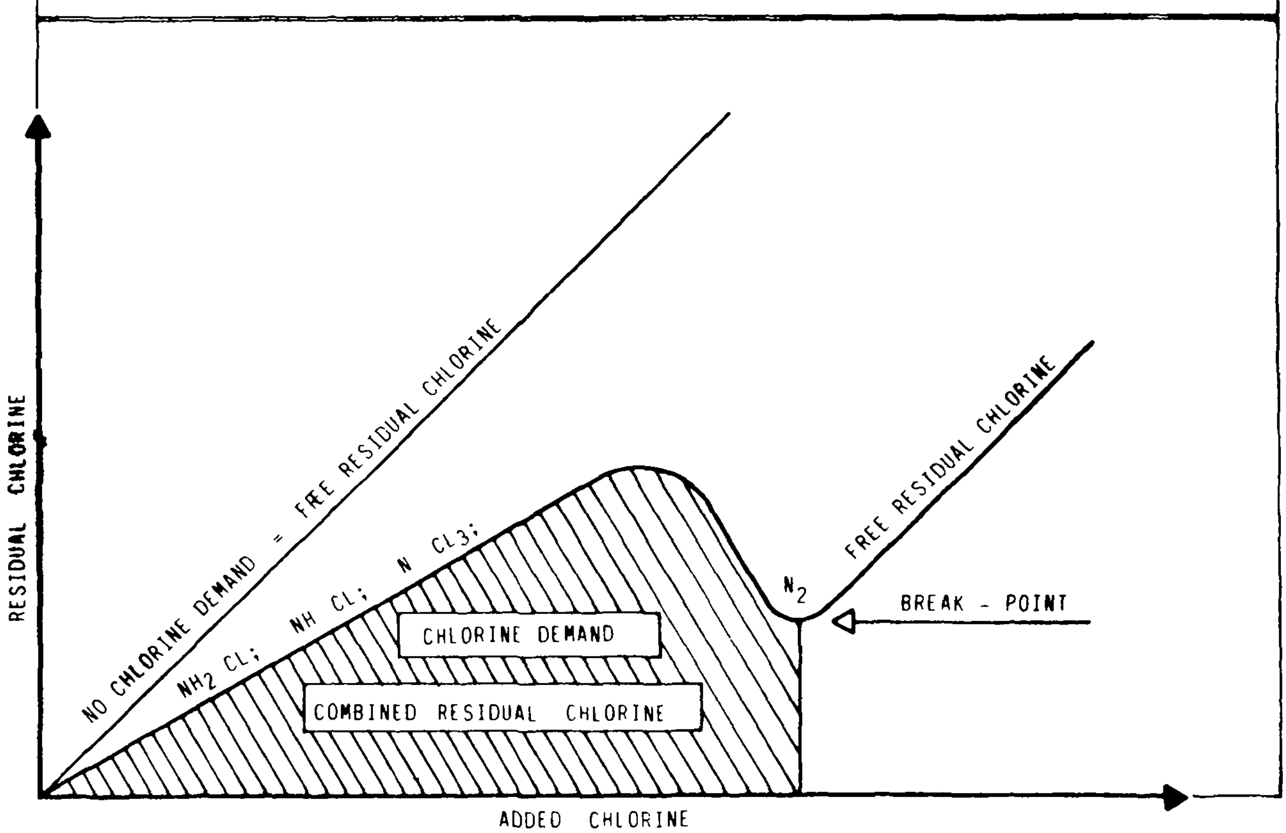
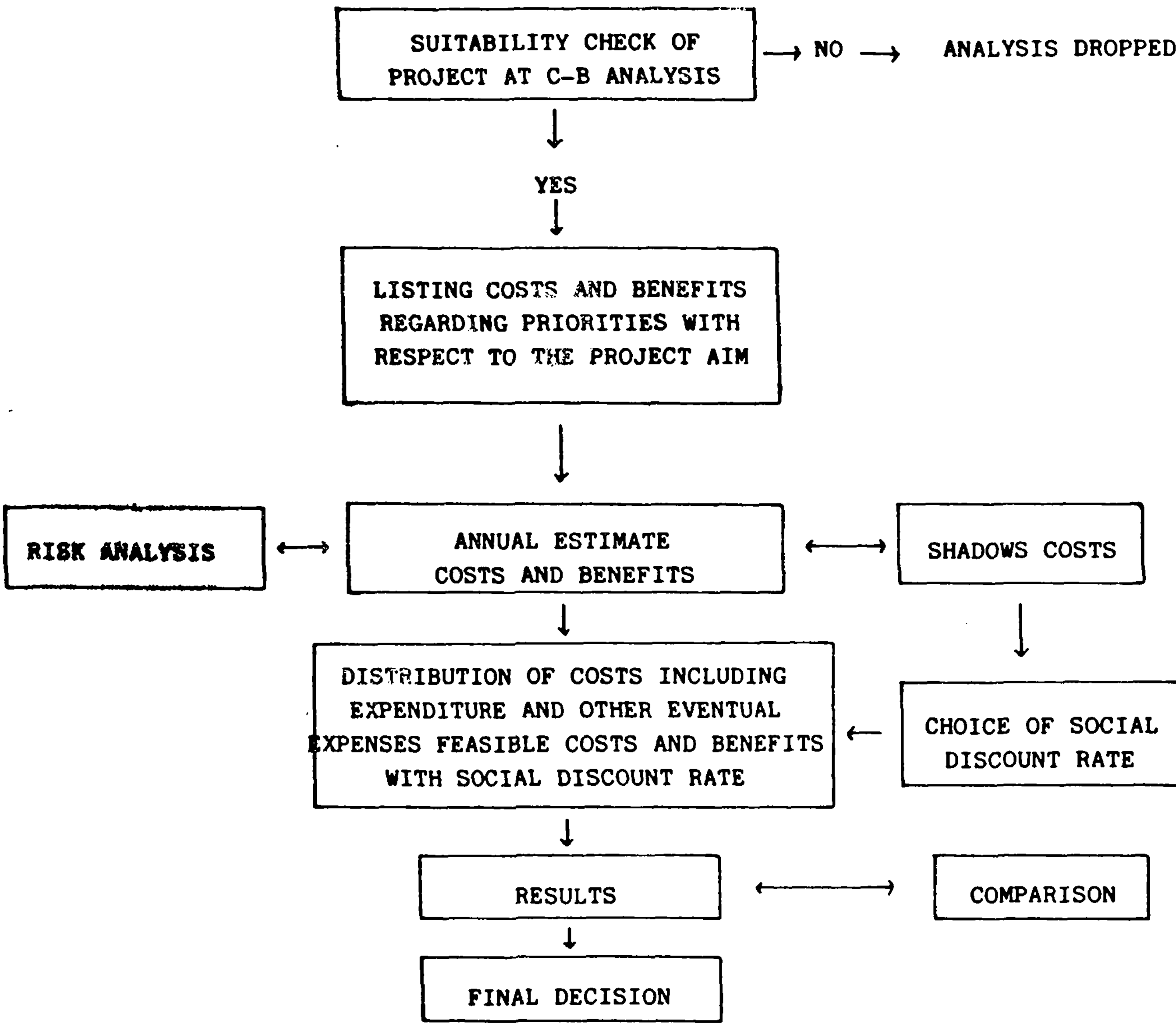


TABLE 6

FUNCTIONAL COSTS - BENEFITS ANALYSIS



DEVELOPMENT OF WATER SUPPLY FOR SMALL TOWNS AND VILLAGES (IN WEST JAVA, INDONESIA *)

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Summary

This paper sets out to provide a framework for institutional development in the rural water supply sector, using West Java as a frame of reference. First, a general overview is given of the Dutch-Indonesian cooperation in the field of water supply and sanitation projects. The development of concepts and approaches over the last ten years is explained and starting points for further sector development are presented. Then, the focus of the paper is directed to rural water supply, especially to the institutional aspects. The dilemma of rural water supply is explained : safe water is provided to combat water borne diseases and to avoid the burden of fetching water of doubtful quality from afar. However people are apparently unable or not willing to maintain the facilities provided properly although these facilities may be considered as sufficiently simple.

To provide a way out of this dilemma it is proposed to establish management systems especially for operation and maintenance and to developed the involved institutions accordingly. Rural water supply facilities have been divided into three categories to allow for a more flexible institutional development approach. The first and largest consists of dug wells and bored wells (handpumps). The second category consists of small village systems and the third category consists of full-scale piped systems.

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The paper concludes that large scale institutional development programs are called for, but that these should be attached to ongoing implementation programs. Special attention should be paid to rehabilitation programs with a strong institutional development component.

These programs for which there is a great need, safeguard available infrastructure from further deterioration, while valuable experience is gained with institutional development.

To achieve the desired situation, policy changes are required for which several recommendations are given. Additional foreign aid funds are considered essential for the implementation of the institutional development programs, but also self-help and private sector initiatives will have to be stimulated.

1. Water Supply and Sanitation Sector Development; a review of Dutch - Indonesian cooperation

Three main focal points in water supply and sanitation sector development are planning, implementation and institutional development.

In the past ten years these aspects have been addressed in the Dutch-Indonesian cooperation, with, from time to time, some difference in emphasis. Initially, the main attention was focussed towards the implementation (design and construction) of water supply systems. However, during the late seventies/early eighties the accent gradually shifted towards the institutional development aspects while in recent years the planning aspect became more and more visible.

2. Urban Water Supply Development

As to urban water supply, initially great emphasis was laid on speedy implementation and standardization. This resulted in a package approach, and in design criteria based on general standards. Experience showed, however, that the advantages of this approach did not fully compensate the disadvantages caused by, for instance, widely differing consumer interest. It was therefore decided to give more attention to project selection and to execute consumer surveys ("socio-economic") before designing and implementing systems. In a number of cases in which during earlier years a standard approach was chosen it was decided to apply more tailor made solutions.

The water supply facilities in small urban and semi-urban areas were implemented according to the Basic Need Approach (BNA) which comprised, basically, the supply of water to 60% of the urban population through house connections and public taps on a 50/50 basis.

In the early eighties a similar approach was initiated for the supply of water to subdistrict capital towns (IKK's). Both the BNA and IKK approach have been set-up as a standardized mass-approach in order to reach the national targets. Particularly the IKK approach was to be "low cost-high speed", and various batches of systems have been implemented according to these concepts.

The first BNA water supply projects started in 1976 while the systems were completed in the early 80's. At present some 300,000 people are supplied with potable water through house connections and public taps, while the installation of additional service connections is still going on. In general, the systems are financially self-supporting, and are managed by a water enterprise. Although the results seems promising, assistance is required in further technical/institutional development of systems and enterprises.

The first batch of IKK systems was less succesful, due to various reasons of conceptional and technical origin. The main reason was that the program was initially set up as a standardized mass approach, with emphasis on the quantitative targets, leaving no room for sufficient pre-surveys and feasibility studies. The IKK concept has been evaluated and modified ever since.

Main recommendations were, a.o. that increased attention should be given to the selection of IKK's, the involvement of the community, the water source selection and to institutional/financial aspects. Most of the recommendations have now been incorporated in the third batch of IKK.

A similar process of development occurs within the Small Towns/BNA approach : instead of maintaining the rather rigid BNA design criteria, new and more flexible criteria are being applied now within the new progranm, adapted to the felt need of the population concerned and their willingness/ability to pay for the future services.

An interesting development during the last few years has been the renewed interest in viability as a criterium in project selection. Both the financial aspects (cost recovery, cash flow) and the institutional aspects (absorption capacity) play an important role in this concept.

In two fields further developments seems to be called for.

In the first place water supply and sanitation for low-income consumers is still a problem. In some areas considerable success has been achieved with a great number of people using the facilities and even contributing to their costs. In other areas, however, acceptance is very low and water supply companies are forced to shut down the facilities because of the high costs compared with the low demand.

In the second place there is the problem of supplying water to small urban centres. The present small scale piped systems still encounter too many obstacles for appropriate operation, and means are still being sought to remove them.

From the above it becomes clear that development of urban water supply in Indonesia is not only taking place in a quantitative sense, but that it is accompanied by a continuous process of re-evaluation and improvement of technologies, procedures and implementation methods.

3. Rural Water Supply and Sanitation Development

In 1976 it was still generally believed that rural water supply development was a question of installing large numbers of handpumps, rainwater collectors and small water treatment facilities.

It became clear, however, that the appropriate technology to tackle the problem did not exist. This resulted in the development of handpumps, ferrocement rainwater collectors, and pilot small scale treatment systems. At the same time it became clear that existing institutions were at that time not geared towards executing this type of program. Greater understanding has been reached on the role of community involvement and institutional development, and to any observer it is obvious that West Java is now on the threshold of large scale introduction of facilities that are not sowed at random but bedded in the society, both institutional and local. This last point has proved to be the prime determinant of effective and continuous operation of the facilities.

A remarkable change in policy is the transfer of the responsibility of piped rural systems from the Ministry of Health towards the Ministry of Public Works; it is believed that this decision has been triggered by the experiences where it proved to be extremely difficult to ensure the operation and maintenance of piped rural systems towards the appropriate institute, leading to a state of disrepair of many of the facilities. Surveys and studies have now been carried out to upgrade these systems and to place operation and maintenance in the hands of the District Water Enterprises.

4. Starting points for further sector development

The major objective within the sector is to create durable lasting improvements of the water supply and sanitation conditions in villages and towns in accordance with the felt need of the population and at acceptable costs.

In order to achieve success in the longer run it is of extreme importance that the responsibility for the future operation of the facilities is transferred to appropriate organizations at a decentralized level without the necessity of a significant permanent support from the Central Government. For simple non piped water supply and sanitation facilities the operation and maintenance could be placed, at desa level, in the hand of village committees.

The more complicated piped water systems will, in general, be transferred to the District Water Enterprises (DWE). These DWE's should, wherever possible, be financially self supporting, meaning that recurrent costs (operation, maintenance and replacement) should be recovered from water sold within the District.

In order to meet the aforementioned basic conditions for further sector development, some criteria for project selection will have to be met.

First of all, the community should be involved in an early stage of project planning in order to find out whether the villagers are really interested to improve their WS&S facilities and, if so, whether they are willing to participate actively in the operation and maintenance of the facilities and/or to contribute financially (payment of water fees).

Secondly, the systems should be designed in such a way that operation and maintenance can be executed at village level (for simple systems) and/or at DWE level, both from a technical as well a financial point of view (recurrent costs coverage).

Finally, as an overall condition, an optimum use should be made of available resources (water resources, human resources and financial resources), in particular in the densely populated coastal plains of West Java where projects cannot be executed on an individual basis.

5. The Rural Water Supply Management Problem

The Ministry of Health gives a high priority to the provision of safe water supply and sanitation facilities for the rural population. It is a means of improving public health by tackling the cause of diseases, rather than the symptoms. The program has a social character. Facilities are provided free of charge to the communities. People don't have to pay for the services, they are only requested to utilize and maintain the facilities properly. It is assumed that operation and maintenance of these systems is so simple that special organizations to manage them are not required. The community, through its traditional ways of cooperation, through its leaders and through its available institutions in the village, is supposed to be able to take care of this task independently. But this is just where things seem to go wrong. Government handpumps for public use are usually not maintained and eight out of ten pumps are either totally out of order or show serious defects. Rainwater collectors are found dry, due to either leakages, damaged gutters or clogged strainers. Piped systems depending on mechanical pumping are generally abandoned, and only some gravity fed piped systems may still produce water through a few leaking or permanently opened public taps. In most of these villages the community obtains its daily water from its previous water sources, although they may appear in the statistics as people being served by a safe water supply system.

But how can such a situation arise? It would be too easy to accuse the population of laziness or ignorance, nor would it be right to put the blame on the Government or on the contractors who construct the systems. It may also be argued that the technology is not appropriate, or that the designs are wrong, and that the population has not been involved sufficiently. Each of these reasons may be valid in some way or another.

It is the objective of this paper to further analyze the above mentioned problems based on the situation in West Java, and to put forward some suggestions for improvements in the field of institutional development. Institutional development is understood here as the continuous process of improving the planning, preparation, implementation, operation and maintenance, utilization and monitoring of water supply systems. The emphasis in this paper will be laid on the operation and maintenance function and on the utilization of the system by the consumers. It is beyond the scope of this paper to describe the institutional framework of the sector in detail (for more details, see ref. 1 and 2).

6. *Existing Management Systems*

Urban, semi-urban and in some cases rural piped water supply systems are managed by Water Management Boards or Water Enterprises at kabupaten level. Water Enterprises in turn, are monitored and supervised through specialized agencies at Provincial level, and are supported by a National training delivery system. In the Water Enterprises accounting systems, maintenance systems, management information systems and operation control systems have been introduced, and although not yet functioning perfectly one may say that the institutional framework for urban water supply is more or less established. It is a framework exclusively focussed on the management of water supply.
For the rural (non-piped) systems the situation is different. These systems are usually transferred to the LKMD, the Village Community Resilience organization. The LKMD however, is only a platform for community development in the desa. It has no separate budget and consists of volunteers. Without external support in the form of funds, training, organization development or technical guidance, the LKMD remains powerless. Most LKMD's therefore do not take part in management of the water supply facilities in their village.

In addition, the Puskesmas (Public Health Centre) is responsible for supervision and guidance concerning the operation and maintenance of rural water supply facilities. More specifically this is the task of the Environmental Health Section of the Puskesmas, in which one or two sanitarians are employed. A Puskesmas however may have to cover as many as twenty villages. Sanitarians are burdened with all aspects of environmental health control, while facilities and budgets are very limited. The Puskesmas therefore, is in the present situation insufficiently equipped to perform the task of supervising and guiding the operation and maintenance of rural water supply and sanitation facilities.

It can be concluded that the institutional framework for the management of rural water supply facilities is not sufficiently established, although the basic structure is available through LKMD and Puskesmas. It is however still a weak structure with also many, perhaps even more important responsibilities in fields outside water supply and sanitation.

7. The scope of Institutional Development for Rural Water Supply

It is the experience that in West Java it is not always easy to motivate the rural population to organize an improved drinking water supply. Apparently, water supply is not considered a main problem. The provision of water from traditional sources is often quite adequate, and in many places plenty of water is available within a distance of 100 m from the house, and the supply is free of charge.

Under such circumstances rural water supply projects are not likely to succeed. Projects may succeed only in those places where the fetching of water is a problem due to scarcity or distance. But then a solid organization is required, and of course a reliable service.

In the cities the situation is different. Here water supply is just one of the public facilities which have to be provided sooner or later. The purchasing power is available to pay for the service (among higher income groups), while the need is also higher, due to limited traditional sources.

Therefore implementation of water supply systems and the subsequent operation and maintenance pose less problems in urban areas than in rural areas. Although still far from perfect, basic management systems for urban water supply are available through the water enterprises. Also semi-urban water supply systems (IKK program) and even rural piped systems, implemented in the larger rural centres are transferred to kabupaten water enterprises for operation and maintenance and thus benefit from the guidance of an established managing agency.
The non-piped systems (handpumps) and the small communal systems such as gravity supplies, artesian wells and slow sand filters, supplying water through public standposts only, remain outside the scope of the water enterprises. For these facilities it is imperative that a local capacity

be created where the population they serve participates in planning, operating and maintaining its own system. This poses rather different challenges in terms of organizational development, as compared to urban water supply (ref.3).

The scope for institutional development in rural water supply may be derived from a classification of technical systems to be managed on the one hand, and from an inventarization of available management options, on the other hand.

A possible classification of rural water supply facilities is the following :

I. Facilities consisting of in general only one public water distribution point, with a coverage of up to 100 people and no piping (dug wells, bored wells and rainwater collectors);

II. Facilities consisting of more than one public water distribution point, with a coverage of up to 500 people, a small distribution network covering only part of a village and sometimes mechanical pumping (spring protections, artesian wells, slow sand filters);

III. Facilities consisting of both public water distribution points and private connections, with a coverage of up to 5,000 people (or more), a distribution network covering one or more villages and in many cases mechanical pumping (rural piped systems).

8. Available Management Options

Available management options are given in table 1. These range from the single household to the Kabupaten Water Enterprise. Options 3, 4, 5 and 6 refer to experiments carried out in the framework of various rural water supply projects in Indonesia and cannot be considered as readily available management options. Options 1, 2, and 7 are the established ones but especially option 2 is underdeveloped, while option 1 pertains to the private sector. Although very relevant, option 1 will not be elaborated further in this paper. The description of a system of appropriate credit schemes, subsidies, technical support and promotion requires a separate contribution. Option 6 will also not be considered further because of its extra-structural character.

9. Proposed Institutional Framework

Elements of options 3, 4, 5 and 7 have been used for the design of an institutional framework for the management of rural water supply facilities. The institutional framework which is represented in figure 1 takes into account the different requirements of the three categories of facilities:

a. Category I type facilities should be managed through a 3-tier system consisting of :

- handpump mechanics, pump supervisors and water user-groups at village level, organized and coordinated by the LKMD;
- spareparts distribution, supervision, guidance and monitoring by the Puskesmas;
- training, central spareparts distribution and water quality control by the kabupaten Health Department;

Table 2: Management options for rural water supply systems

MANAGEMENT OPTION	DESCRIPTION
1 Individual household	The majority of the rural population fetches its water from shallow dug wells, equipped with a handpump or bucket and rope system.It is estimated that 90-95% of these facilities are private property.
2 LKMD (Village Community Resilience Org.	Water supply facilities provided in the framework of INPRES or Health projects are usually transferred to the LKMD for O&M,since they are meant for community use.
3 Caretaker & inst./ techn. support	LKMD's are insufficiently equipped to perform O&M of water supply systems. Therefore some projects have introduced O&M systems with appointed caretakers who have been trained previously and are supported by the Puskesmas (Health Centre)
4 Water user groups	Some projects developed water user groups, who manage water supply systems. These groups rely on some outside support from paid community organizers and so-called "suka-relawan" (village extension workers), who are paid as well.
5 Village water supply org.	Systems covering a part of a village or a whole village, are sometimes managed by a village water supply organization. It appears that if systems are sufficiently simple, not too big, and if there is good informal leadership, this management option may be feasible.
6 Kabupaten rural water supply org.	In 2 kabupatens in West Java such organizations were established for the management of newly constructed rural piped systems.Due to the extra-structural character of the organizations and the very small financial basis on which they have to operate they gradually decline.

7	Kabupaten water enterprise	Bigger piped systems must be managed by a kabupaten water enterprise.

b. Category II type facilities should be managed through a 2-tier system consisting of :

- a village water management unit, carrying out daily operation and maintenance, and governed by the LKMD;
- supervision and monitoring of the village units by the kabupaten Water Enterprise using a supporting service agreement. Water quality control is done by the Health Department.

c. Category III type facilities should be managed like an IKK system through a desa unit of the Water Enterprise. The LKMD functions in this setting as a platform for consumer organization and representation.

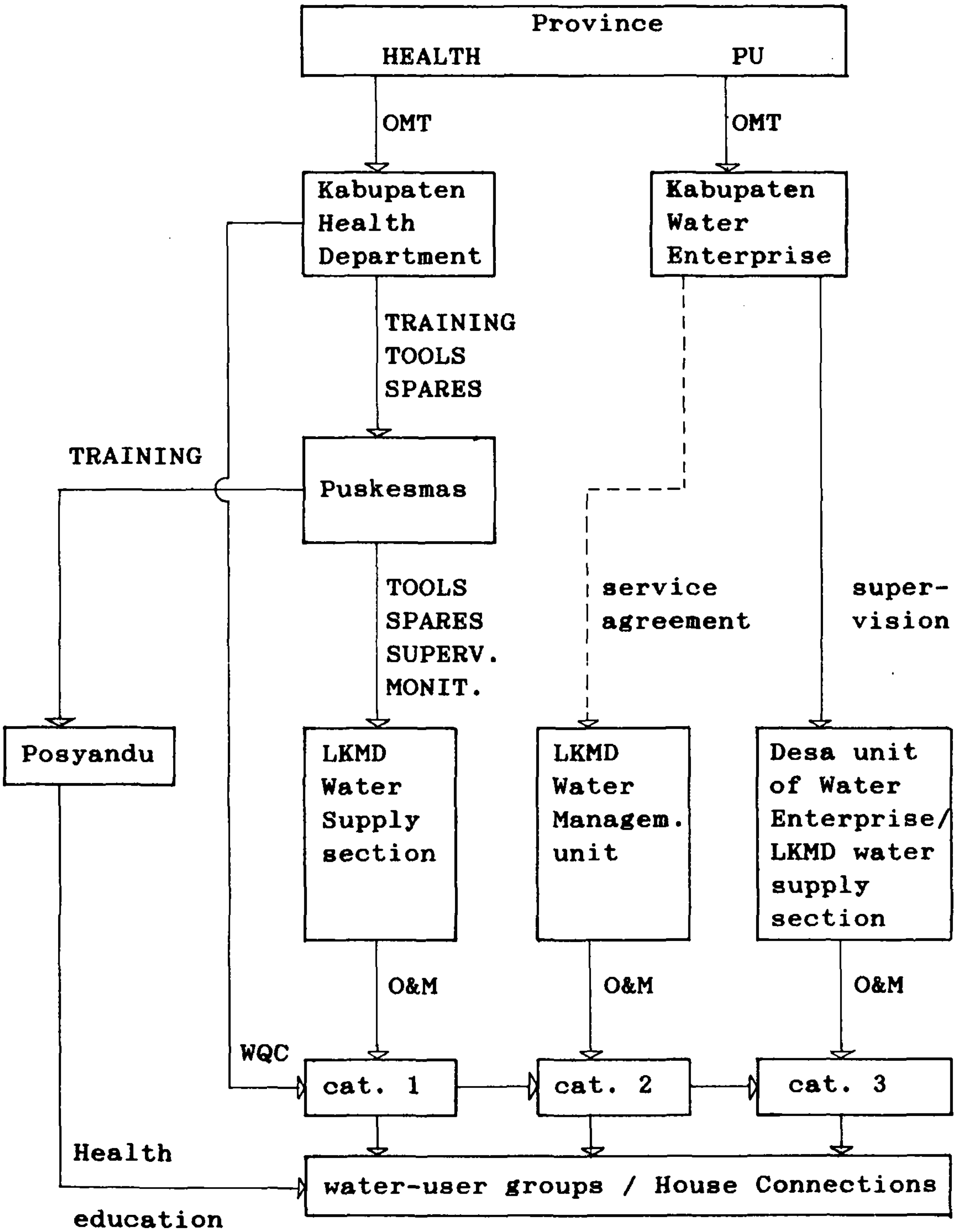
Special attention is given to the health aspects of water supply. It is proposed to develop the Posyandu (village health post) for this function.

Support and guidance from the Provincial level is of course required, first of all for the development of the proposed institutional framework, but also for a smooth absorption of new water supply systems by the involved agencies. In urban water supply projects, so-called OMT programs (Organization, Management and Training) accompany the implementation of the systems. The communities which will be served by the system have to be informed and involved, new staff has to be recruited and trained, maintenance systems, operation control systems and administrative systems have to be introduced, and last but not least, assistance with the starting up of systems has to be provided. Such OMT activities ought to be integrated in rural water supply programs as well.

10. Requirements for Institutional Development

To establish the institutional framework as described above, institutional development programs have to be formulated and implemented.

Figure 1 Institutional framework for the management of rural water supply facilities



The majority of rural water supply facilities can be found in category I. Handpumps and shallow wells are still the main facilities in rural areas. Institutional development programs for this category should therefore have priority, but need not necessarily be tied to ongoing implementation projects. There are already thousands of handpumps installed, and most of them are in immediate need of rehabilitation, overhaul and more permanent care. The proposed maintenance systems can therefore be implemented anywhere.

More or less this is also the case for category II and III type systems. Many of those systems which were formerly transferred to the *LKMD's without further guidance* and support, now require rehabilitation. This rehabilitation work deserves high priority to avoid further deterioration of the available infrastructure and equipment. With accompanying OMT programs most of these systems can be revived and generally kabupaten Water Enterprises are ready to take over the management of the systems.

It is recommended that more funds are made available for rehabilitation work, but also for the accompanying OMT programs. In such projects the knife cuts more ways; available infrastructure is safeguarded against further destruction, communities earlier planned for water supply are at last being served, and experience with institutional development is gained.

11. Conclusions

It can be concluded that there is indeed a wide gap between rural and urban water supply as far as institutional development is concerned. It is therefore clear that one of the major conditions for achieving the Repelita IV target of 55% coverage in rural areas will not be realized. The number of facilities to be constructed may be increased, but this is a waste of money if a year later only half of the facilities are functioning. The published coverage percentage is than a fallacy. A major policy change would be required. Instead of continuing the present large scale implementation programs (such as for handpumps), these might be slowed down in favour of rehabilitation projects with a strong institutional development component (OMT). On the other hand it is of course extremely important that Indonesia achieves its targetted coverage. Implementation of water supply systems therefore should be continued. But if more funds are required for rehabilitation and institutional development projects, implementation budgets might have to be reduced. It is therefore recommended that Indonesia finances rehabilitation and institutional development activities largely from additional foreign aid funds and to leave domestic and already allocated foreign aid funds for implementation unimpaired. This should also apply to essential supporting programs, such as research, masterplanning and human resource development. To pave the way for the implementation of the abovementioned programs, clear terms of reference should be made while the necessary policy decisions should be taken.

This paper does not do justice to the many small scale private and self-help activities aimed at the improvement of water supply, and triggered by motivated individuals, community leaders or non Governmental Organizations.
Only Government programs have been taken into account. It will be clear however that the Government alone will not be able to supply the millions in the rural areas with safe water in the forseeable future. Self-help activities and private sector initiatives should therefore be stimulated as much as possible. Issueing of guidelines and formulation of programs for technical and institutional support for these types of activities is therefore also recommended.

References

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Glossary of terms and abbreviations

Bappeda	- Regional Planning and Development Board
Bappenas	- National Planning and Development Board
DWE	- District Water Enterprise
INPRES	- Presidential subsidy
IKK	- Subdistrict capital town
Kabupaten	- Regency (district)
LKMD	- Village Community Resilience Organization
O&M	- Operation and Maintenance
OMT	- Organization, Management, Training
PU	- Public Works
Puskesmas	- Public Health Centre
Posyandu	- Village Health Post
Repelita	- 5 year plan
WQC	- Water Quality Control
WS&S	- Water Supply and Sanitation

MINAM : A COMPUTER MODEL FOR DISTRIBUTION SYSTEM MANAGEMENT AND UPGRADING

Robert H. Fitzgerald
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The Metropolitan Waterworks Authority (MWA) of Bangkok, Thailand is currently undertaking an ambitious project to rehabilitate the water distribution system to reduce leakage and unaccounted-for-water, and to improve customer service. The Mapping, Inventory and Network Analysis Model (MINAM) was developed to support some of the data management and data analysis needs of this project, and to help improve distribution system management generally.

The MWA currently serves an area of approximately 600 sq. kilometers within the Bangkok metropolitan area, which has a population of 7 million people. Current rate of water production is approximately 2,000,000 CMD reaching 700,000 metered customers. The primary source of supply is the Chao Phraya River. River water is clarified, filtered and disinfected at three major treatment facilities before being pumped into the distribution system. A number of deep wells are also utilized for water supply, but these are being phased out to mitigate land subsidence.

Processed water enters the distribution system from two treatment plants and five pump stations located throughout the service area. A 25 km system of deep tunnels, ranging from 2.0 m to 3.4 m in diameter, transmits water to the pump stations (see Figure 1). An additional 24 km of transmission conduits connecting four new pump stations is currently under construction.

The distribution system consists of some 7,800 km of pipe, ranging from 1/2 inch service mains to 1,800 mm trunk mains. A variety of pipe materials are in use including steel, cast iron, concrete, asbestos cement, galvanized iron, PVC, PB and PE. A system-wide inventory of distribution piping by size and material is shown in Table 1.

Organizationally, MWA is divided into ten Branches, each responsible for distribution system maintenance and customer services within its own area. The Branches are further divided into 550 Blocks. The Block subdivisions were selected primarily as isolatable units for waste metering and leak detection, but also function as convenient units for inventory and identification of pipes and valves as well as planning for system upgrading.

The MWA Pipe Rehabilitation Project has the overall objective of reducing UFW (Unaccounted-for Water) to 30 percent by 1990, a significant improvement when compared to UFW of 46 percent in 1982 and 41 percent in 1986. The project includes replacement of 1,000 km of galvanized-iron (GI) service mains and 250,000 GI service connections, and more intensive efforts in system mapping, waste metering, leak detection and leak repairs.

Model Applications

A number of computer model applications were envisioned to support the pipe rehabilitation project as well as distribution system planning and management. Generally, **MINAM** was developed to provide data management and analysis support for :-

1. Distribution system rehabilitation - in particular, prioritizing the replacement of pipes by material, age, location, etc. to reduce leakage.

2. Distribution system maintenance and record keeping, especially for valves.

3. Planning operating procedures for pump stations and throttling valves.

4. Planning and design of new facilities such as pipelines and pump stations.

5. Computerized mapping for the Bangkok Metropolis.

Distribution System Rehabilitation

Some particular **MINAM** functions related to distribution system rehabilitation are as follows:-

1. Compile and maintain a complete and up-to-date inventory of pipes and valves, including all significant and available attributes. Inventory data are made easily available in both tabular and graphical (map) form for any particular locations and pipe/valve characteristics of interest. Data input must be as efficient as possible, making maximum use of currently available data.

2. Compile and analyze leak repair data in conjunction with the distribution system inventory. For making decisions concerning pipe replacement it is obviously very useful to know the relative frequency of leak repairs for different classifications and locations of pipes. It should be possible, in fact, to look at individual pipe segments in this manner.

3. The effectiveness of acoustic and electronic noise correlation techniques for locating underground leaks depends significantly on there being sufficient line pressure in the survey area. The mapping and hydraulic modeling features of **MINAM** should be useful for planning distribution system operations to ensure that pressures are sufficient in areas where leak survey operations are to be performed. Modeling results should be graphically output for ease of interpretation.

Distribution System Maintenance and Record Keeping

Using **MINAM**, it should be possible to conveniently keep records of the maintenance, condition and accessibility of valves in the distribution system.

Planning Operating Procedures for Pump Stations and Throttling Valves

Hydraulic modeling of distribution networks is an effective tool for optimizing schedules of pump station pressures and discharges, designing pressure control with throttling valves, locating unintentionally shut valves, etc. **MINAM** will link network analysis software with the pipe/valve database to expedite the modeling process.

Planning and Design of New Facilities

MINAM's hydraulic modeling capabilities should also be applicable to planning new distribution system facilities, ranging from new pump stations and major trunk mains to simple interties between adjoining pipelines. It will provide hydraulic modeling capability at different levels of detail appropriate to the project under consideration.

Computerized Mapping for the Bangkok Metropolis

Initial planning, involving a number of government agencies and utilities, has begun for creating a comprehensive, computerized mapping system for the Bangkok metropolitan area, including roadways, property lines and public utilities. It is envisioned that the pipe and valve inventory data compiled in **MINAM** will be transferred to the Bangkok mapping system. It will be necessary to provide a means for making minor adjustments to pipe locations to resolve discrepancies between the existing distribution system record maps and the future computerized city base maps.

MINAM Capabilities

To perform the many varied data management and computational functions outlined above, the **MINAM** model was designed as a set of 7 individual programs which share the same database and which are accessed through a single master control program. The following list of these programs serves to summarize the **MINAM** capabilities.

DIGITIZE — Map locations of pipes, valves, Branch and Block boundaries, streets and important geographical features are input or revised using a digitizer. Additionally, pipe and valve data can be input by pointing at map locations with the digitizer.

READFILE — Files of pipe, valve and leak repair data are read and stored in the database. Pipe and valve data files with user-defined formats are easily created using a standard text editor. Leak repair data files can be created from standard report forms using a special program run on any IBM-compatible personal computer.

PLOT — Distribution system maps are produced on a printer or pen plotter. The user selects the area and scale of the map, the components to be shown (by data attributes if desired) and the data to be displayed.

DATATRIEVE — This is a Digital Equipment Corporation (DEC) fourth generation database query and report generator language for customizing tabular output from the pipe/valve database.

MODELFILE — Creates hydraulic link and node data files used for hydraulic modeling from the pipe/valve inventory database.

SYSOPS A hydraulic modeling program used to compute steady state flows and heads throughout a distribution system (or any portion thereof) given various system configurations, pump station and valve operating modes, and demand and leakage conditions. **SYSOPS** uses the loop-oriented iterative solution procedure first proposed and implemented by Epp and Fowler. Special algorithms have been developed for representing pump stations, valves and pressure reducing stations. **SYSOPS** includes graphical input and output capabilities. It has been documented by Camp Dresser & McKee.

UTILITIES This is a collection of special purpose routines for making database revisions.

The model capabilities listed above are achieved by integrating the following sophisticated computational features in a single package.

Database management
Graphical input from a digitizer
Specially developed tabular input routines
Graphical output to a color monitor, printer and pen plotter
Hydraulic modeling

The integration of powerful database management and computer graphics functions in the system allows for rapid input and processing of the great quantities of data associated with a major urban water distribution system, as well as attractive pictorial presentation of model outputs. Operation of the model is in an interactive, menu-driven mode, so that it will be easy to learn and use.

The **MINAM** program consists of approximately 20,000 lines of original **PASCAL** code. This code utilizes a number of purchased software packages to perform special functions, including:-

Rdb - A relational database management package supplied by DEC.

DATATRIEVE - A DEC software product associated with Rdb used for interactive data queries and report generation.

Graphic Kernal System (GKS) - A set of routines for producing graphical output on a printer or color graphics terminal screen.

HCBS - A set of routines for producing graphical output on a pen plotter.

MINAM Database

Associated with **MINAM** is a graphics database of all map elements, and tabular databases for pipes, valves and leak repair reports.

The graphics database includes locations, based on a universal coordinate system, of pipe segments, valves, Branch and Block boundaries, street centerlines and important geographic features. Map label locations for these elements are also included. Pipes and valves are organized by Branch and Block, while streets and geographic features are organized according to an existing record map grid system.

Pipe and valve data attributes currently saved for a test implementation of **MINAM** are shown in Tables 2 and 3. For many of the attributes, easily recognized two character codes are saved, e.g. TM for trunk main or AC for asbestos cement. Revisions in the set of attributes saved, as well as the valid two-character codes, can be easily accomplished as desired. For example, it is planned to add a simple maintenance record to the valve database.

The leak repair database is linked with the pipe/valve database via Branch, Block and Pipe ID numbers.

Special Features

The following are some of the special features which we think distinguish the **MINAM** model.

- The set of attributes included in the database, as well as valid description codes, can be fairly easily revised for different localities or as needs change.

- Data can be assigned to pipes and valves from the digitizer by pointing to map locations, as well as direct keying from data forms. Digitizer data input is convenient for data recorded on source Maps which are not tabulated elsewhere.

- For tabular data input, **MINAM** will read files of any user-selected set of attributes given in any user-selected order.

- Default values for many of the pipe data attributes are provided which greatly reduces the need for explicit data input.

- Operation of **MINAM** is in a completely interactive, menu-driven mode for ease of use.

- Multi-color pipe and valve maps may be produced in size ranging from A4 to A0 on the pen plotter. The user selects the area to be shown and the output scale. High quality black and white maps may be produced at A4 size on a laser printer.

- There is considerably more flexibility in the selection of pipes and valves to be shown on a map than provided by conventional computer mapping systems. Selections are not restricted to predefined layers. Rather, pipes and valves to be shown can be selected according to a range (or set) of size, material, age or any other data attributes.

- Similarly, color or line style highlighting of pipes and valves can be selected according to any data attribute or set of attributes.

- The user may select any of the pipe and valve attributes to be shown on maps. Up to 3 or 4 attributes may be shown for each pipe and valve, depending on space limitations.

- **MINAM** links the leak repair and pipe/valve data-bases. Leak repair frequencies for different categories and locations (Branch or Block) of pipes can be computed. Repair frequencies can be shown on maps for individual pipe segments, or used as a basis for highlighting pipe segments.

- Pipe network data files for hydraulic modeling can be created from the **MINAM** database. Modeling networks can be created for specified Branches and Blocks and/or for specified classes of pipes (e.g. trunk mains).

- **MINAM** pipe segments must have constant properties, but otherwise may be as long as desired without respect to junctions with other pipes. This allows significant savings in database size and data input time. When model files are created, these segments are automatically subdivided into shorter, hydraulic links on the basis of pipe interconnections.

- A fourth generation language, **DATATRIEVE**, may be used to query the database and generate user-designed reports and tables.

Computer Hardware

The general computer system requirements for installation of **MINAM** are :-

- Ability to store and rapidly process a large database

- Ability to accept graphical input and provide graphical output

- Multiuser capability

The size of the database, which will comprise tens of thousands of pipe segments and valves along with leak repair data, requires significant mass storage (disk) capacity, 100 Mb minimum. Rapid processing of the database, along with associated graphics processing, requires significant main memory capacity as well. For acceptable response time, a 32-bit CPU with at least 4 Mb main memory are considered necessary.

For input and output of distribution system mapping data, as well as hydraulic modeling, sophisticated graphics capability is required. A digitizer and plotter are required to accept and produce A0 size drawings. For enhanced clarity, display monitors should be capable of producing multi-colored images. Additionally, it is desirable that the printer, necessary for tabular output, also has monochrome graphics capability.

The data input task requires continous computer usage for an extended period of time. Multi-user capability allows applications and data verification work to be performed simultaneously with the data input.

A summary of required hardware and software features is shown in Table 4. The Bangkok MWA computer system purchased for running **MINAM** and other applications is depicted schematically in Figure 2.

Summary

MINAM is a computerized mapping and database system designed especially for water supply distribution networks. Hydraulic modeling, leak repair analysis and other special features have been incorporated to meet the data needs of water distribution system management and upgrading. It is envisioned that the system will ultimately be linked with a comprehensive

Bangkok mapping system.

Limited implementation of **MINAM** is currently underway. Upon completion of this pilot project, we will be able to gauge the time required for full-scale implementation and the problems likely to be encountered.

TABLE 1

INVENTORY OF PIPE LENGTHS BY SIZE AND MATERIAL

IN KILOMETRES JUNE-86

CATEGORY OF MAIN	SIZE mm	MATERIAL TYPE								TOTAL LENGTH
		STEEL	PC	CI	AC	PVC	GI	PB	PE	
TRUNK	1800	0.06								0.06
	1500	10.78	1.93							12.71
	1250			0.20						0.20
	1200	28.09	3.87	0.07						32.03
	1000	14.31	5.63	15.49						35.43
	900	20.40	7.44	28.94						56.78
	800	20.94	5.64	15.09						41.67
	700	31.81	9.55	12.73						54.09
	600	45.61	21.05	32.97	8.07					107.70
	500	33.00	17.92	33.07	15.61					99.60
	400	7.29	11.84	57.13	2.68					78.94
	350			0.77						0.77
	SUM=	212.29	84.87	196.46	26.36					519.98
DISTRIBUTION	300	9.03	0.24	13.61	555.67	7.24				591.79
	250	4.15		9.59	269.97	0.99			4.79	289.49
	200	8.96		47.55	777.63	6.83			10.70	851.67
	150	6.63		7.62	1972.31	5.03	2.16		14.89	2008.64
	SUM=	28.77	0.24	83.37	3576.58	20.09	2.16		30.38	3741.59
SERVICE	100	1.04		8.77	1717.90	101.86	77.27	0.06	0.94	1907.84
	75					5.26	35.94	0.42		41.62
	60					1.04	73.27	0.52		74.83
	50					73.23	394.05	116.23		583.51
	40					5.70	386.05	7.25		398.99
	25					1.81	255.00	5.21		262.02
	20					0.69	272.79	10.60		284.08
	15					0.02	11.55	0.12		11.69
	SUM=	1.04		8.77	1717.90	189.61	1505.91	140.41	0.94	3564.58
TOTAL		242.10	85.11	288.60	5320.84	209.70	1508.07	140.41	31.32	7826.15
GRAND TOTAL = 7826.15 km										

TABLE 2

PIPE DATA ATTRIBUTES

Attribute	Data Type	Comments
Pipe Key	Integer	Includes the Branch number, Block number, and a unique pipe segment identifying number within the Block
Class	2-Char. Code	Classifies a pipe as a trunk main, distribution main or service main
Length	Real	
Diameter	Real	
Material	2-Char. Code	
Joint Type	2-Char. Code	
Location	2-Char. Code	Indicates if a pipe segment is installed beneath a road, sidewalk or median, etc.
Year Built	Integer	
Contract Number	10-Char. Code	Alphanumeric code used to identify the installation contract
C-Value	Integer	

TABLE 3

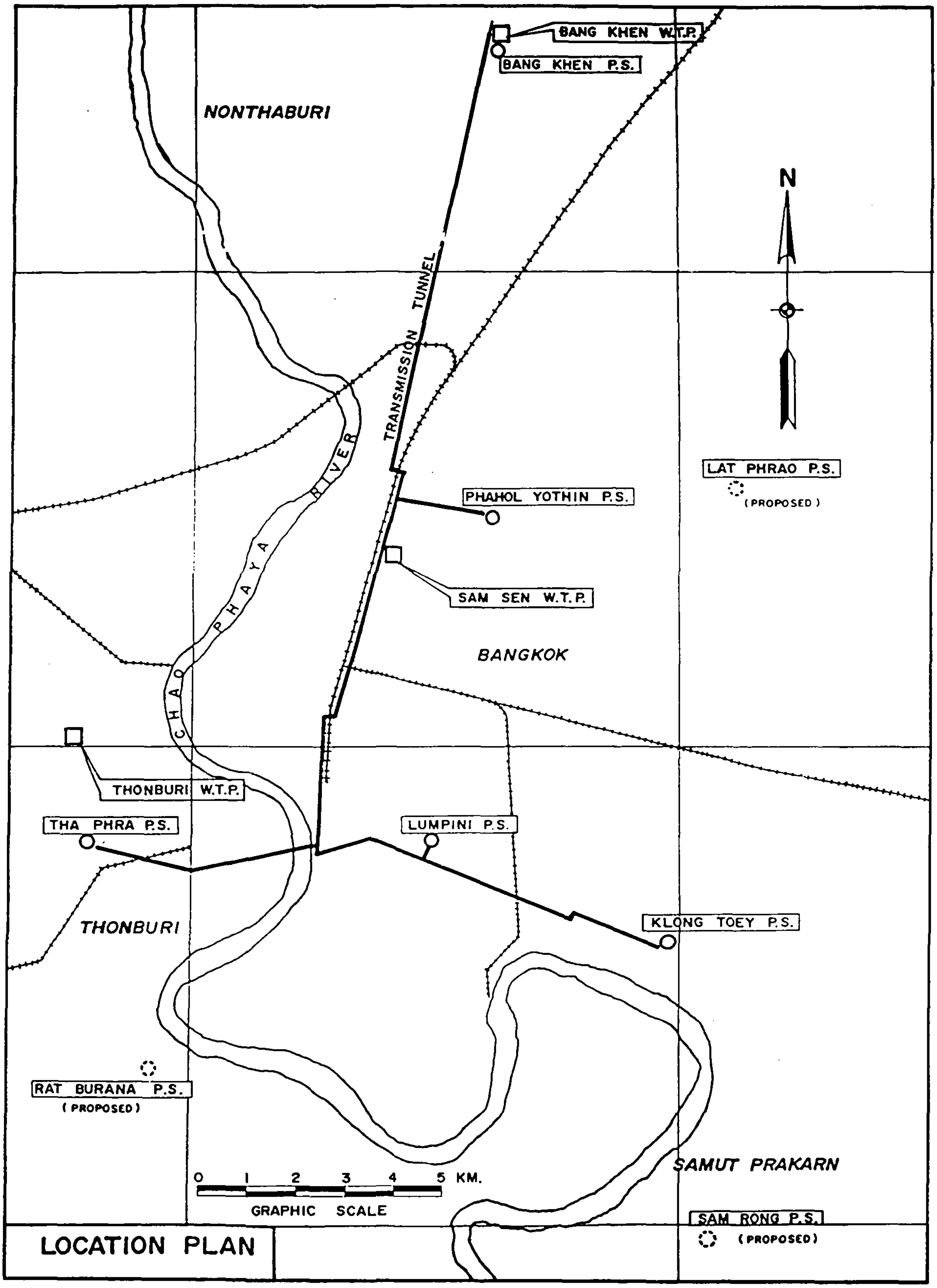
VALVE DATA ATTRIBUTES

Attribute	Data Type	Comments
Valve Key	Integer	Includes the Branch number, Block number and a unique valve identifying number within the current Block
Class	2-Char. Code	Indicates if a valve is located on a trunk main, distribution main or service main
Pipe Key	Integer	Identifies the pipe segment which the valve is a part of
Diameter	Real	
Type	2-Char. Code	Indicates if the valve is a gate valve, butterfly valve or air valve, etc.
Location	2-Char. Code	Indicates if the valve is installed beneath a road, sidewalk or median, etc.
Access	2-Char. Code	Indicates if the valve is accessed through a tube or vault
1:250 Map	Integer	Indicates the sheet number in a set of map books where the valve location is recorded in detail

TABLE 4

SUMMARY OF REQUIRED HARDWARE AND SOFTWARE FEATURES

HARDWARE	SOFTWARE
"Super" Microcomputer	Operating System
32 bit processor 4 Mb main memory Floating point co-processor	Virtual memory Multi User Network capability desirable
Hard Disk/Drive	Language Compilers
100 Mb storage	FORTRAN PASCAL
Cartridge Tape Drive	Database Management
50 Mb storage	Relational data model Use with application programs Query, report generation capabilities
Graphics Display Monitors with Keyboard	Graphics
Multi-color Medium/high resolution 120 char. width	Use with application programs Packages to drive the plotter, graphics and printer
Alphanumeric Terminals	
Use for tabular data input and output	
Printer	
Near-letter-quality Monochrome graphics desirable	
Digitizer	
A0 size	
Pen Plotter	
A0 size Multi-pen	
Voltage Stabilizer	



BANG KHEN W.T.P.
BANG KHEN P.S.
NONTHABURI
N
TRANSMISSION TUNNEL
CHAO PHAYA RIVER
LAT PHRAO P.S.
(PROPOSED)
PHAHOL YOTHIN P.S.
SAM SEN W.T.P.
BANGKOK
THONBURI W.T.P.
THA PHRA P.S.
LUMPINI P.S.
KLONG TOEY P.S.
THONBURI
RAT BURANA P.S.
(PROPOSED)
SAMUT PRAKARN
0 1 2 3 4 5 KM.
GRAPHIC SCALE
SAM RONG P.S.
(PROPOSED)
LOCATION PLAN

FIGURE 1

FIGURE 2 COMPUTER SYSTEM CONFIGURATION

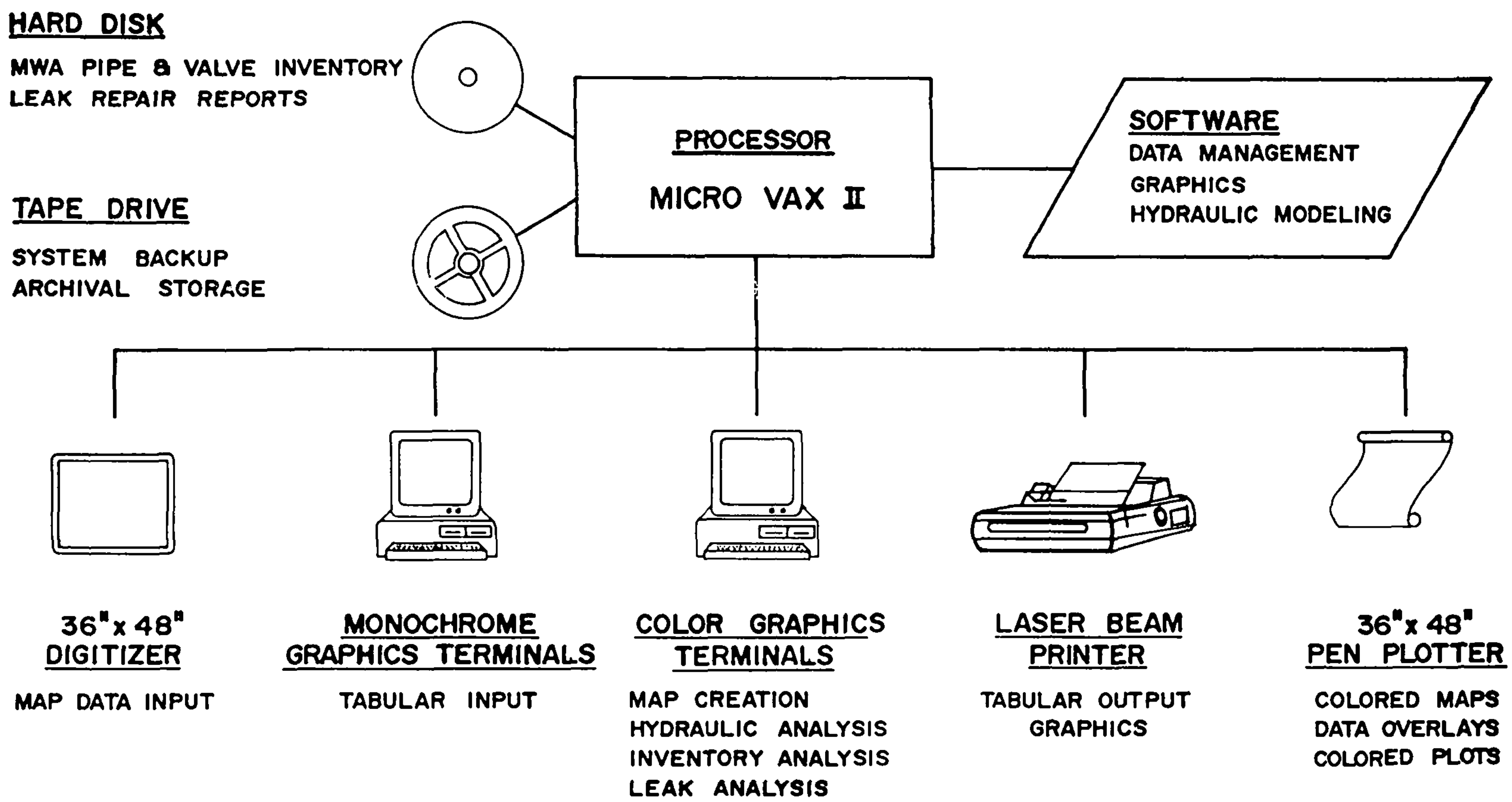


FIGURE 2

ENVIRONMENTAL ISSUES OF WATER RESOURCES DEVELOPMENT IN THE ESCAP REGION

Prepared by the Secretariat of
United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), Bangkok

INTRODUCTION

Water resources projects are often considered as playing a vital role in ensuring future economic and social development in many countries of the region, some of which have extensive experience and good traditions of sound water resources exploitation. It is estimated that at least 50 per cent more agricultural land has to be irrigated to satisfy the need for food products; the hydropower potential of about 1,000,000 MW, as yet exploited only slightly, has to be developed sufficiently to meet the region's electricity needs; safe drinking water has to be supplied to more than 1 billion people suffering from inadequate supplies of potable water in the developing countries of the region.[1/] Thus, it is quite clear that the accelerated development and extensive utilization of water resources are inevitable in the future.

With the expansion of water resources development activities in the region, more attention is being paid to the impact of these projects on the environment because all water resources projects produce, in one way or another, environmental changes, some beneficial and some not. In the past, decisions on such projects were dictated by technical and economic factors, but nowadays environmental considerations are also playing an increasing role in the process of making decisions and formulating policies on water resources development activities.

Over the past years ESCAP has given increasing attention to the problem of the integrated relationship between environment and development. This paper is intended to show the scope of the water resources development activities in the region, bringing to the attention of the participants some of the major environmental impacts of these projects and identifying ways to avoid or reduce the adverse effects.

I. ENVIRONMENTAL IMPLICATIONS OF WATER RESOURCES PROJECTS

A. Dams and reservoirs

Since the 1950s, the rate of construction of dams and associated reservoirs, designed mainly for generating electricity, supplying water for irrigation, domestic and industrial needs, and for flood control in the region, has been very impressive. In 1950, there were 1,717 dams over 15m height in service in the ESCAP region, of which 394 were located in the developing countries. In 1982, as many as 23,210 dams were listed, including 20,623 in the developing countries (see table 1).

1/ UNEP Asia-Pacific Annual Report 1983, p. 6.

Table 1. Number of dams over 15m in the ESCAP countries, by period of completion

Country or area	Number of dams			
	Until 1950	1951-1977	1978-1982	Total
Afghanistan	-	2	-	2
Australia	122	198	54	374
Bangladesh	-	1	-	1
Bhutan	-	-	-	-
Brunei Darussalam	-	1	-	1
Burma	1	1	-	2
China	8	16 492	2 095	18 595
Fiji	-	-	2	2
Hong Kong	13	24	-	37
India	202	797	86	1 085
Indonesia	14	12	7	33
Iran (Islamic Republic of)	-	17	4	21
Japan	1 173	833	136	2 142
Lao People's Democratic Republic	-	1	-	1
Malaysia	1	10	1	12
Maldives	-	-	-	-
Mongolia	-	-	-	-
Nepal	-	-	1	1
New Zealand	28	38	6	72
Pupua New Guinea	-	3	-	3
Pakistan	3	30	5	38
Philippines	1	5	3	9
Republic of Korea	116	443	69	628
Samoa	-	-	-	-
Singapore	-	2	1	3
Sri Lanka	23	41	5	69
Taiwan (a province of the People's Republic of China)	12	23	2	37
Thailand	-	22	19	41
Viet Nam	-	1	-	1
Total	1 717	18 997	2 496	23 210

Source: International Committee on Large Dams, World Register of Dams, (1984).

The environmental effects of dams and reservoirs are felt far beyond the sites of the projects because such large engineering structures change to a large extent the overall hydrological regimes of the rivers on which they are constructed. The nature, importance and magnitude of impacts will vary considerably from one reservoir to another owing to the influence of a number of variables: size, shape, and depth of reservoir; inflow and outflow rates; range of fluctuations in water level; climate and weather; geology and geomorphology; and soils in the watershed, along the reservoir shores, and in affected downstream areas; tectonic characteristics of the reservoir site; vegetative cover in the reservoir site; distance of the reservoir from the sea; riverine flora and fauna which may be affected by the impoundment; importance and value of resources and features to be flooded; and type and extent of human and animal diseases associated with the aquatic system. Some of the major impacts typical for countries of the region are described below.

1. Sedimentation

Depletion of storage capacity is the most significant upstream effect of reservoir sedimentation. The silt that accumulates behind a dam may cause considerable ecological and engineering problem and abolish the reservoir's ability to perform its intended functions, such as water supply, flood control, hydropower generation, navigation and recreation. Thus, in China, 178 reservoirs in the Huggang District of Hubei Province lose 6 million m^3 of storage capacity each year owing to silting. Many small reservoirs had to be abandoned after just two or three years of operation and some larger hydroelectric stations had to be taken partially out of operation. The survey of 33 large- and medium-sized reservoirs in the Chiang Jiang river basin revealed that 16 are already more than half filled with silt, and he average useful life will not exceed 13 years.2/

Clearly, the rate at which a reservoir silts up depends on the amount of sediments carried by the river which feeds it, and that, in turn, depends on the rate of soil erosion in the river's catchment area. The rate of soil erosion increases dramatically in areas with excessive deforestation rates since, for example, high-intensity rains can quickly wash away the soils of the tropics. Highly erodible soils, like loess, in arid and semi-arid zones with inappropriate cultivation practices and inadequate vegetation cover, are also prone to intensive soil erosion.

On the other hand, as a result of siltation in the reservoir, clear water flowing downstream causes channel degradation and bank erosion. The deposition of silt in the reservoir also results in some loss of natural nutrients downstream and thus may decrease the productivity of the flood plains downstream of the dam. Another effect of reservoir sedimentation is possible erosion of the river delta.

Since reservoir sedimentation influences all parts of a river basin and leads to several adverse effects, a detailed study of alterations in erosion and sedimentation processes has to be carried out on any proposed dam project.

2. Inundation

The creation of reservoirs often leads to the inundation of large areas of land. In many cases the flooded area contains thousands of hectares of valuable agricultural land. In India, for example, more than 40,000 ha of farmland were submerged by the Srisailam hydroelectric scheme; that land had provided a livelihood for about 100,000 local villagers. In Sri Lanka about 3,000 ha of land cultivated with various crops will have been flooded owing to the construction of the Victoria dam.3/

The flooding of a reservoir without clearing the area beforehand is a common practice. The inundated land is often covered with forest having not only commercial value but also great ecological importance, particularly in tropical and subtropical zones. Thus, in Malaysia, the Temenggor dam project has resulted in flooding of valuable forest area, threatening the survival of 100 species of mammals and 300 species of birds.4/ In India,

2/ Vaclav Smil, The Bad Earth: Rnvironmental Degradation in China (Armonk, New York, M.E. Sharpe, Inc., 1984).

3/ E. Goldsmith and N. Hildyard, The Social and Environmental Effects of Large Dams, volume one, Overview (Wadebridge Ecological Centre, Camelford, Cornwall, United Kingdom, 1984), P. 49.

4/ Ibid, p. 55.

one of the main considerations taken into account in shelving the proposed dam project in the Silent Valley was the threat to the tropical forest and its unique wildlife. Several more water resources development projects have been abandoned in the region in view of possible adverse effects on the environment. In Malaysia, for instance, the Tembeling hydropower project has been cancelled[5/] on the grounds that, if it had been implemented, 130 km^2 of tropical rain forest, which serve as the habitat for a number of rare species, would have been inundated.

Some of the most important and serious problems of dam construction are connected with evacuation and resettlement of the people whose homeland is flooded by the waters of man-made reservoirs. Approximate data on the number of persons resettled owing to creation of several selected water reservoirs in the region are given in table 2. Moreover, there are some large projects the construction of which will trigger the veritable exodus of hundreds of thousands of affected dwellers. In China, the gigantic Three Gorges multi-purpose scheme is estimated to displace 1.4 million people; in the Philippines, the construction of 40 proposed new large dams could affect more than 1.5 million.[6/]

3. Seismic effects

It is assumed that the weight of impounded water imposes new stresses on the earth's crust which, in turn, may generate seismic activity owing to the existence of layers having varying compressibility. Such seismic activities have been recorded for a number of dams and associated reservoirs in the ESCAP region. For example, major earthquakes occurred at Hsinfengkiang in China in 1962 (magnitude 6.1 on the Richter scale) and at Koyna in India in 1967 (6.5 on the Richter scale).[7/]

Table 2. Resettlement of people owing to the construction of selected dams and reservoirs in the ESCAP region

Name of project and date of completion	Country	Number of people relocated
Bhakra, 1963	India	36 000
Damodar (4 projects, 1959)	India	93 000
Gandhi Sagar	India	52 000
Lam Pao	Thailand	30 000
11 projects 1963-1971	Thailand	130 000
Nam Ngum, 1971	Lao People's Democratic Republic	3 000
Nam Pong, 1963	Thailand	25 000-30 000
Nanela, 1967	Pakistan	90 000
Pa Mong (projected)	Thailand/Lao People's	310 000-480 000
Tarbela, 1974	Pakistan	86 000
Upper Pampanga, 1973	Philippines	14 000

Source: A.K. Biswas, "Impacts of hydroelectric development on the environment", Energy Policy December 1982, p. 349.

5/ Water Power and Dam Construction (United Kingdom), vol. 35, No. 5 (May 1983), p. 5.
6/ Goldsmith and Hildyard, op. cit., pp. 15-16.
7/ Ibid., p. 107.

Other dams and reservoirs in the countries of the region suspected of triggering off minor earthquakes are Benmore in New Zealand (1966), Kurobe in Japan (1961), Talbingo in Australia (1972)[8/] and Danjiangkan in China,[9/] where more than 100 minor earthquakes have been experienced.

Dams can be designed to resist collapse during earthquakes, and sites where large dams and reservoirs are to be constructed have to be investigated thoroughly for potential earthquake hazards. The need for caution is especially great in areas that are known to be seismically active.

4. Microclimate changes

Local changes in the microclimate, favourable or not, are caused by man-made water reservoirs. The area affected depends mainly on a climatic zone, local meteorological conditions and dimensions of the reservoir, and extends, as a rule, over the territory adjacent to the water body. The major microclimatic effect is increased atmospheric moisture.[10/]

It has been observed that the microclimate becomes less continental in the vicinity of reservoirs located in temperate or semi-arid zones. In China, for example, meteorological studies carried out near the Danjiangkan reservoir have revealed a moderating effect of the reservoir on the climate. The mean summer temperature around the reservoir has decreased by about $1^{o}C$, and the average winter temperature has increased by about the same amount.[11/]

B. Irrigation

Irrigation plays a crucial role in promoting agricultural development in the ESCAP region, where 60 per cent of the world's irrigated land is found. Since the early 1960s, the total irrigated area in the region has increased by 36.7 per cent, from 94.1 million to 128.6 million ha in 1983 (table 4), and it covers 28 per cent of the arable land in the region.

The introduction of irrigation to an area leads to significant ecological changes. There is no doubt that an irrigation project has a favourable effect on the microclimate after the area is irrigated: relative humidity is increased, evaporation rates are lower, and in certain cases temperatures are also modified favourably. However, many irrigation schemes in the region have resulted in degradation of cropland and water quality, and in the spread of water-related diseases. Since the impact of irrigation on the environment tends to be cumulative, the results can best be seen in those regions where irrigation has been practised intensively for a relatively long time. But, it should also be recognized that the same practices may have a much more rapid and severe effect when introduced into the fragile and delicately balanced ecosystems of some of the developing countries of the region.

8/ Goldsmith and Hildyard, op. cit., p. 114.

9/ A Biswas, "Environment and sustainable water development" in Water for Human Consumption, Man and his Environment, 1982, p. 384.

10/ Interim Committee for Co-ordination of Investigations of the Lower Mekong Basin, Environmental Impact Assessment: Guidelines for Application to Tropical River Basin Development (1982), p. 37.

11/ Biswas, loc. cit., p. 383.

1. Waterlogging and salinization

Irrigation water is generally brought to crops through unlined canals and ditches that allow vast quantities of water to percolate. Flood irrigation methods widely practised in the region also contribute to the infiltration of water. Where drainage is inadequate, the ground-water level gradually rises, eventually entering the crop's root zone and waterlogging the soil. In arid and semi-arid zones, waterlogging may be accompanied by salinization affecting crop yields by interfering with the capacity of plants to take up moisture and oxygen.

The problem of waterlogging and salinization is particularly urgent, as the processes are continuing at a rapid pace, in China, India, the Islamic Republic of Iran and Pakistan. Thus, in the Indus Valley in Pakistan, there is one of the largest irrigation systems in the world. With the fast extension of irrigation there, started about 40 years ago, ground-water levels have risen from an average depth of 25 m up to near the soil surface.12/ In the country as a whole, more than 10 million ha out of 14.7 million under irrigation are now estimated to suffer from salinity and waterlogging. Of that land, 2 million ha are classified as severely affected by salinity, 4 million as suffering patchy salinity, and 4 million as being poorly drained. Overall, 23 per cent of the country's land is

Table 4. Cultivated land and irrigated area in the ESCAP region
(Thousands of hectares)

Country or area	Cultivated land, 1983	Irrigated area 1961-1965	Irrigated area 1969-1971	Irrigated area 1983	Cultivated land Irrigated area (Percentage)
Afghanistan	8 054	2 208	2 340	2 660	33.0
Australia	46 572	1 115	1 474	1 750	3.7
Bangladesh	9 136	501	1 054	1 848	20.2
Bhutan	98	-	-	-	-
Brunei Darussalam	7	-	-	1	14.2
Burma	10 077	681	849	1 011	10.0
China	100 894	35 200a/	42 000	45 144	44.7
Democratic People's Republic of Korea	2 290	500	500	1 060	46.3
Fiji	236	-	1	1	0.4
India	168 350	25 523	30 183	39 500	23.4
Indonesia	20 310	4 100	4 371	5 418	26.7
Iran (Islamic Republic of)	13 700	4 800	5 184	4 000	29.2
Japan	4 806	3 176	3 312	3 240	67.4
Lao People's Democratic Republic	890	13	18	118	13.2
Malaysia	4 340	333	338	334	7.7
Mongolia	1 313	-	10	38	2.9
Nepal	2 332	77	116	230	9.8
New Zealand	466	82	109	230	49.3
Papua New Guinea	374	-	-	-	-
Pakistan	20 490	11 139	12 904	14 720	71.8
Philippines	11 250	896	1 150	1 400	12.4
Republic of Korea	2 167	682	993	1 190	54.9
Samoa	122	-	-	-	-
Sri Lanka	2 186	361	436	538	24.6
Thailand	19 370	1 729	1 965	3 472	17.9
Viet Nam	7 585	992	980	1 730	22.8
Total:	457 415	94 106	109 872	128 633	28.1

12/ World Environment Handbook, p. 255.

Source: FAO Production Yearbook, various issues.
a/ ESCAP estimation.
A dash (-) indicates that the amount is negligible.

affected in varying degrees by salinization or waterlogging, that figure reaching 80 per cent in the Punjab.[13/] According to some estimates, 40,500 ha of irrigated land are degraded annually owing to waterlogging and salinization. Over the past seven years, Pakistan has spent $US 31 million on its On-Farm Water Project with the aim of reducing the seeping of water from the 63,100 km canal network and thus preventing waterlogging. In addition, nearly 200,000 tube-wells have been installed to exploit ground water and lower the water table. Yet, Pakistan planned to spend about $US 317 million during the 1985/86 financial year to continue to combat salinization and to improve its irrigation systems.[14/]

Owing to soil salinization and waterlogging, large areas of irrigated land in the region have been abandoned, thus contributing to the spread of desertification, the expansion of which is estimated at one million ha per annum in Asia.[15/]

2. Spread of water-borne diseases

In tropical and subtropical areas, the introduction of perennial irrigation schemes appears to enhance the favourable conditions for the incidence and spread of water-related diseases, such as malaria and schistosomiasis. Relatively few studies have been undertaken to compare the distribution and intensity of these diseases in areas before and after irrigation development, but those that have been carried out point to surface irrigation practices as a significant factor in the increase in the prevalance of malaria, schistosomiasis and other water-borne diseases.[16/]

3. Degradation of water quality

Degradation of both ground- and surface-water quality owing to irrigation development has become a serious problem in some areas of the region. Various pollutants, such as nitrogen compounds and pesticides, which are used widely in irrigated agriculture, may be washed out by filtrating water into ground water. Owing to the growing use of fertilizers, nitrate contamination is increasing rapidly in areas under perennial irrigation.

Salty water from irrigation systems is generally returned to the nearest river, inevitably increasing the river's salt content. For downstream agriculture, it poses the problem of irrigation with increasingly saline water. Thus, in Pakistan the waters of the lower Indus River are polluted by salty irrigation return flow from irrigation systems in the upper part of the basin.

The potential effects of irrigation and proposed remedies for their alleviation are summarized in table 5. It may be noted that there are a number of measures which can be taken to prevent the extensive environmental damage that might have been caused by irrigation. Even waterlogging and salinization are not inevitable consequences of irrigation development and can be alleviated by sound design and construction of irrigation and

13/ Goldsmith and Hildyard, op. cit., p. 140

14/ World Water (United Kingdom), October 1985, p. 13.

15/ ESCAP, "State of the environment in Asia and the Pacific" vol. two, 1985, p. 20.

16/ Draft guidelines on the environmental impacts of irrigation in arid and semi-arid regions (UNEP/WG 31/3), p. 12.

drainage systems and efficient water management, especially by reduction of seepage losses from irrigation networks and by better farm water management.

Table 5. Impacts of irrigation development

Causal activity	Possible impact	Possible remedies
Surface irrigation	1. Waterlogging 2. Soil salinization 3. Increase of diseases 4. Degradation of water quality	1. Increased irrigation efficiency 2. Construction of drainage systems 3. Disease control measures 4. Control of irrigation water quality
Sewage irrigation	1. Contamination of food crops 2. Direct contamination of humans 3. Dispersion in air 4. Contamination of grazing animals	1. Regulatory control 2. Tertiary treatment and sterilization of sewage
Use of fertilizers	1. Pollution of ground water, especially with nitrates 2. Pollution of surface flow	1. Controlled use of fertilizers 2. Increased irrigation efficiency
Use of pesticides	1. Pollution of surface flow 2. Destruction of fish	1. Limited use of pesticides 2. Co-ordination with schedule of irrigation
Irrigation with high silt load	1. Clogging of canals 2. Raising of level of fields 3. Harmful sediment deposits on fields and crops	1. Avoiding use of flow with high silt load 2. Soil conservation measures on upstream watershed
High velocity surface flow	1. Erosion of earth canals 2. Furrow erosion 3. Surface erosion	1. Proper design of canals 2. Proper design of furrows 3. Land levelling 4. Correctly built and maintained terraces
Intensive sprinkling on sloping land	1. Soil erosion	1. Correctly designed and operated system

Source: Adapted from UNEP "Draft guidelines on the environmental impacts of irrigation in arid and semi-arid regions", 1979.

C. Ground-water exploitation

Ground water is used extensively in some parts of the region for drinking water supply as this source is usually of high quality and in most cases not contaminated, and is free of mud and sediment. With the increased availability of pumping equipment, ground water is also becoming the preferred source of supply for irrigation, especially in the alluvial plains where ground water is nearer the surface. In the northern provinces of China, for example, nearly one million wells have been sunk since the middle of the 1950s. During the 1960s and 1970s, 1.6 million tube-wells were installed in India resulting in an increase in the area irrigated by ground water from 29 per cent in the early 1950s to 40 per cent in the mid-1970s.[17]

1. Depletion of ground water

Ground-water reserves are recharged by the natural infiltration of surface water. However, ground water is often pumped at rates that exceed replenishment, resulting in the depletion of the resource, the lowering of ground-water levels or decreased pressure in the aquifers. Excessive ground-water exploitation and subsequent lowering of ground-water tables appear to be increasingly common in the region. Thus, in Thailand, in the Bangkok metropolitan area, it has been estimated that in 1982 1.3 million m^3/day were pumped from public and private wells, while studies undertaken by various experts have recommended that the safe yield in the area should be around 600,000 m^3/day, taking into account reasonable aquifer recharge.[18] This extremely high rate of extraction exceeding the recommended safe yield by more than twice has caused a rapid decline in the ground-water level of about 2.5 m per annum. In the North China Plain, where irrigated crop farming is impossible without ground-water, and major cities in this zone, including Beijing, are critically dependent on ground-water pumping for basic domestic and industrial supply, ground-water overdrafts have led to rapid ground-water level drops amounting to 4.4 m a year in the Baimiao district of Tianjin Province. In Tamil Nadu State in southern India, water tables fell by 25-30 m over the 1970s owing to overpumping of ground water for irrigation.[19] Large parts of Bangladesh also suffer from overpumping and subsequent decline in the water table by as much as one metre per year. In many cases, ground water cannot be further pumped by the widely used No. 6 hand pump, designed to lift water from depths reaching 7 m and utilized throughout the country in 65,000 villages.

2. Land subsidence

The ground-water withdrawals accompanied by the decline of its level often cause land subsidence or land surface settling. Subsidence rates can range from 1 cm to 50 cm per 10 m drop in ground-water level, depending on the thickness and compressibility of the water-bearing formations. Surface sinking owing to ground-water withdrawals has been observed in several parts of the region. Impressive cases of land subsidence have been reported in China. In Shanghai city, a cumulative amount of subsidence equal to 2.63 m was recorded over the period from 1921 to 1965.[20] As a result of this phenomenon, the city suffered great damage as water overflowed the Chiang Jiang river banks flooding the depression, and industrial, commercial and social development were severely affected.[21] However, because the city is not critically dependent on ground-water supplies, extraction rates were lowered and since 1963 the aquifers have been replenished with 17 million m^3 of surface water a year, and the problem is now basically under control.[22]

3. Salt-water intrusion

In coastal areas, excessive exploitation of ground water inevitably leads to salinization of coastal fresh-water aquifers owing to intrusion of

17/ Goldsmith and Hildyard, op. cit., p. 12.

18/ World Water (United Kingdom), July 1985, p. 16.

19/ Sandra Postel, Water: Rethinking Management in an Age of Scarcity, Worldwatch Paper 62, December 1984, p. 23.

20/ Laura Carbognin, "Land subsidence: a worldwide environmental hazard", UNESCO, Nature and Resources, vol. XXI, No. 1, 1985, p. 9.

21/ ESCAP, Geology for Urban Planning: Selected Papers on the Asian and Pacific Region (ST/ESCAP/394), p. 26.

22/ Smil, op. cit., p. 94.

salt water from the sea. Salt-water intrusion threatens to contaminate the drinking water supplies of many coastal cities and towns in the region. The situation is especially severe in those areas where ground-water tables have been lowered far below sea level, and induced salt-water intrusion has caused deterioration of the water quality. Thus, the shallow aquifers, which once supplied fresh water to consumers, have become contaminated with salt water in Manila and Jakarta, where the ground-water levels have declined to as much as 150 m and 30 m below sea level respectively.23/ Intrusion of salt water is also a major problem impeding municipal water supply development in Bangkok.

Intrusion of sea water, with considerable detrimental effects on soil and vegetation, has been reported in the coastal zones of Australia, Bangladesh, China, India, Thailand, Viet Nam and the South Pacific islands, where excessive extraction of ground water is widely practised. In small islands and atolls of the Pacific, the inhabitants of which depend to a large extent on ground water for their domestic supplies, ground-water reserves and freshwater lenses floating on sea water are highly vulnerable to salt-water intrusion, owing to the low surface elevation and small size of the islands and atolls.24/

A number of measures can be taken to avoid the adverse implications of ground-water exploitation. First of all, to prevent depletion of groundwater reserves, safe yields of aquifers have to be determined and should not be exceeded. In order to decrease and stop subsidence, demand for ground water may be reduced by using alternative sources and, in some cases, ground-water extraction has to be fully stopped and replaced with other sources of water. Artificial replenishment of ground-water reserves by the infiltration of surface water can be successfully applied if the quality of water injected is satisfactory.

D. Flood control works

Floods represent a serious problem in many river basins throughout the region, particularly in the areas affected by typhoons. Flood plains occupy up to 20 per cent of the territory in several countries of the region. The percentage is much higher in Bangladesh, where about two thirds of the territory lies in the flood plains of the Ganges and Brahmaputra rivers. In the ESCAP countries, the cost of damage caused by floods was estimated at more than $US 5 billion in 1981 and has been steadily increasing in most of the countries affected by floods. In India, for example, the annual average damage cost has increased from less than $US 200 million during the first half of the 1960s to $US 1,000 million for the second half of the 1970s.25/ Meanwhile the total area subject to flooding has doubled, from 20 million ha in 1971 to 40 million ha in 1981.26/ In China, 10.6 million ha were affected by floods during 1984. The loss of agricultural products in an area of 5.3 million ha of farmland damaged by floods is estimated to have exceeded 30 per cent in comparison with the average production of normal years.27/

23/ ESCAP, Geology for Urban Planning ..., pp. 14 and 24.

24/ ESCAP, Proceedings of the Meeting on Water Resources Development in the South Pacific (Suva, March 1983), Water Resources Series No. 57 (United Nations publication, Sales No. E.84.II.F.7), p. 5.

25/ ESCAP, Water Resources Journal, June 1983 (E/ESCAP/SER.C/137), pp. 1-2.

26/ Darryl, D'Morte, Temples or Tombs (New Delhi, 1985), p. 14.

27/ ESCAP, Water Resources Journal, June 1985 (E/ESCAP/SER.C/145), p. 42.

To mitigate floods or their effects and thereby reduce the damage, engineering works, often referred to as structural measures, are traditionally and widely used in the countries prone to this natural disaster. Structural measures include construction of dams, reservoirs, levees and floodwalls, channel modifications and floodways. Dams and reservoirs are constructed upstream of the area they are intended to protect.

One of the main methods used for controlling floods is the construction of levees along the river in order to confine flood waters to the part of the flood plain where its passage causes little or no damage. The total length of the levees in 10 selected countries of the region exceeds 200,000 km (see table 6).

Levees occupy relatively small areas on flood plains, but can produce catastrophic results if they are breached or overtopped. The problems of drainage congestion can also be created behind the embankments. This impact has been observed in India, where the levees were constructed along some

Table 6. Length of flood-control levees in selected ESCAP countries (1984)

Country	Length of levees km	Country	Length of levees km
Bangladesh	4 963 a/	Malaysia	437
China	170 000	New Zealand	3 000
India	11 868 a/	Pakistan	4 150 b/
Japan	9 682	Philippines	572
Republic of Korea	17 640	Thailand	445

Source: Based on information provided to the ESCAP secretariat by the countries of the region.
a/ For 1980.
b/ For 1981.

sections of the Brahmaputra and Kosi rivers.[28/] To avoid this problem, it is recommended that drainage outlets be provided so that drainage of valleys is not impeded. The environmental impacts of levee construction might include alteration of the riverside benthic fauna and flora, which perhaps causes changes in the trophic chain, fish stocks could also be affected by the elimination of spawning grounds.

Improving flow conditions by channel modifications may enable flood water to be passed at a lower level than would have occurred naturally. In general, modification of natural stream channels by clearing, dredging and straightening is more appropriate to small streams, but may also result in minor improvements in the passage of flood flows in large watercourses. The environmental effects of flood-control channel modifications can be quite severe in some cases. Although these effects vary considerably, those observed include water quality degradation and loss of terrestrial and aquatic habitat. Probably the most considerable effects are caused by dredging activities. Dredging a waterway, of course, destroys local benthic life; and in an estuary, increasing the depth can induce penetration of salt water further upstream.

28/ R.P. Malhotra and R.L. Qazi, "Impact of environment by irrigation/multipurpose projects" in Indo-Soviet Workshop on Evaluation and Modelling of Impacts on Environment of Water Resources Projects, New Delhi, September 1985 (New Delhi, Central Board of Irrigation and Power, 1985), p. I-92.

E. Interbasin water transfer

In some countries of the region, interbasin water transfer is becoming an attractive option in redistributing the available water resources in conformity with the demand for water. Mass water transfer over long distances from a water-surplus region to a water-deficient area to promote the agricultural and industrial development of that area could be achieved by diverting the course of water or by constructing a large canal.

Australia, India, Japan, Malaysia and Pakistan have constructed some projects varying in scope to divert water from one basin to another. In addition, Japan, India, the Islamic Republic of Iran, Nepal and Thailand are seriously considering the feasibility of other such projects, and China has recently taken a decision to start diverting annually 15 km^3 of water from the Chiang Jiang River to the North China Plain. Some of these projects envisage water diversions which would occur solely within the country. Others may concern the interests of the co-basin countries.

Mass water transfer schemes undoubtedly have not only important economic effects but also significant environmental consequences, which need to be carefully analysed and assessed. The environmental impacts of a large-scale water-transfer scheme could best be evaluated in three groups separately for (a) the exporting basin, (b) the route of conveyance, and (c) the importing basin.29/ For each group it is recommended to consider the impacts on physical system, water quantity, water quality, land, atmosphere, and biological system.

The impacts to be anticipated in the exporting basins include changes in the flow, sediment load and channel configuration resulting from decreased discharge of the river. The decrease in discharge also has important implications for salinity conditions and the ecology in the estuary. These potential impacts depend mainly on the regime of diversion from the river. Concerning the impacts of conveyance on ground- and surface-water systems along the route, the routes are to be carefully selected considering the possibility of seepage from transfer canals. In areas of delivery, the possibility of increasing salinity in agricultural areas receiving the additional irrigation water is to be assessed first. In addition, throughout the transfer scheme under consideration, the effects on water quality, health and climate are to be looked into as well.

II. PROSPECTS FOR CO-OPERATION

There is a need for intensified regional co-operation in the field of environmental management in water resources development. Some countries have accumulated essential experience and knowledge in environmentally-sound development of their water resources. This experience and knowledge could be very useful for those countries starting to plan and carry out large water resources development programmes, in helping them to avoid repeating the mistakes made by the other countries in the past. Further regional co-operation should be aimed at the exchange of information and experience on identification of the potential implications of water resources development projects, application of methods and techniques for their evaluation, and legal and institutional aspects of incorporating environmental considerations into water resources development planning.

29/ Charles Greer, "The Texas Water System: Implications for Environmental Assessment in Planning for Interbasin Water Transfers", in *Long-distance Water Transfer* (Dublin, Tycooly International Publishing Limited, 1983), p. 83.

In particular, collaboration in elaboration and application of appropriate methods and procedures, adapted to local conditions, for studying and assessing the environmental implications of water-related development activities could be very fruitful, as interest in this subject has recently become widespread in the region. The assessment of environmental impacts is considered as a means of developing essential information for planning and decision-making in order to assure that a proposed development project is compatible with the environment. The developed countries of the region have created some mechanisms for predicting the impacts of new development projects on the environment. A number of the developing countries of the region have also introduced procedures for environmental impact assessment with a view to ensuring that environmental factors are taken into account in the Government's decision-making.

However, in practice, developing countries are sometimes reluctant to request preparation of environmental impact assessment because of the belief that it may cause unacceptable delays in implementation of a development project, and the cost of the assessment may be too high. In addition, it is thought that some of the existing methods requiring highly specialized expertise are too sophisticated to be carried out in developing countries, where lack of background data and qualified specialists is common. In view of this, some developing countries have tried to develop simplified methods of environmental impact assessment suitable for their conditions. Thus, India and Thailand have developed guidelines for environmental assessment of development projects, which could be adapted, with necessary modifications, by other countries of the region to the assessment of their development projects.30/

Furthermore, it is essential to promote regional co-operation in education, training and research related to environmental aspects of water resources development in order to strengthen the ability of the countries concerned to identify the potentially adverse impact of water resources development projects on the environment, effectively take them into account and minimize any eventual damage.

III. CONCLUSIONS

There is a growing awareness in the countries of the region that economic development based on intensive use of natural resources, including water resources, should take place without deterioration of the environment. It is also widely recognized that the environmental considerations should not retard the sustained rate of economic growth, since many of the negative consequences of water resources development projects can be avoided or substantially alleviated if they are clearly identified and taken into consideration at the conception stage of the project. Therefore, the elaboration of a balanced approach to water resources development and environmental protection is very important.

30/ ESCAP "State of the environment ....", p. 425.

The Development of Piped Rural Water Supply in Thailand

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Summary

The paper describes the development of piped rural water supply (RWS) in Thailand from its beginning in 1966 to the present times (1986). The Provincial Waterworks Authority (PWA) who was in charge of the development, construction and supervision of RWS since its establishment in 1979 has prepared a "Decade Plan" in 1986 for the future development and transfer of RWS into its responsibility for operation and maintenance in follow up of the International Drinking Water Supply and Sanitation Decade (IDWSSD) and sector policy of the Government which is presented in the paper.

PWA's decade planning for RWS was based on a survey in 1984/85 of 674 RWS serving 1.652 communities with a total population of 2.88 million which are presently managed by provincial authorities or village committees. The main features of the "Decade Plan" are:

- Increase of Coverage in Existing Service Areas
- Development of New Service Areas
- Water Quality Improvement
- Transfer of Operational Responsibility of RWS to PWA
- Community Participation Improvement
- Rehabilitation and Repair of Existing RWS

The total investment cost for the "Decade Plan" are estimated to Baht 1,468.5 million for the period up to 1995. It assumes that during this period 3.57 million more people in rural areas of Thailand could be served with safe piped water at reasonable cost of Baht 410 corresponding to US $ 16 per person.

Financing of "Decade Plan" is proposed mainly from internal sources as revenues from water sales and community contributions. Government subsidies and soft loans of foreign donors shall only be used to achieve full cost recovery after the plan period.

The Development of Piped Rural Water Supply in Thailand

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1. History of Piped Rural Water Supply in Thailand

The development of piped rural water supply (RWS) in Thailand started early in 1966 when the Royal Thai Government (RTG) and USOM/US-AID executed the Community Potable Water (CPW) project and the Sanitary Engineering Division (SED) of the Department of Health (DOH) in 1967 launched the National Potable Water (NPW) program assisted by WHO and UNICEF. The SED was assisted for the CPW project by the consultants Tippetts-Abbott-Mc.Carty-Stratton. The period of the latter project was covering five years with a RTG contribution of Baht 146 million (US $ 7 million) and USAID commitment of US $ 4.3 million.

In mid-1969, 101 piped RWS schemes were completed under the CPW project and 28 under the NPW project. The target of the CPW project was to complete 600 RWS schemes by 1971. The NPW program proposed to serve 5.000 rural communities with piped schemes in 1982 and 10.000 in 1994, an ambitious target which was never reached.

However, the CPW project with the help of the foreign consultants allowed to build up the SED into a capable organization for the NPW program. Project criteria and standard designs established by this project are still used by PWA's Community Water Supply Division with minor modification. The main project criteria were:

- Minimum population 500
- Maximum population 10.000
- Public taps 18 lcd)
- Private connections 80 lcd) average 50 lcd

Other important technical criteria were:

- 3 percent population growth p.a.,
- planning horizon = 15 years,
- maximum day demand = 1.5 average day demand,
- peak hour demand = 1/6 average day demand,
- 10 pumping hours per day, maximum 15 hours,
- total storage capacity = 70 percent of average day supply
- elevated tanks = 20 percent of average day supply

Standard designs were developed for 10, 20, 30 and 50 cum/h capacity waterworks, examples are shown on Phtographs No. 1 to 3.

Up to the establishment of PWA in 1979 the SED of DOH had completed 572 piped RWS schemes in the whole country under the NPW program. The rule was to finance one third or more of the construction cost from loans provided by the Department of Local Administration (DOLA) through the Provincial Government where the RWS schemes were under sanitary district (Sukapiban) responsibility and up to 25 percent from connection fees and/or direct participation of villagers

Photo No. 1

Tubewell with electric driven turbine pump, 15 cum/h

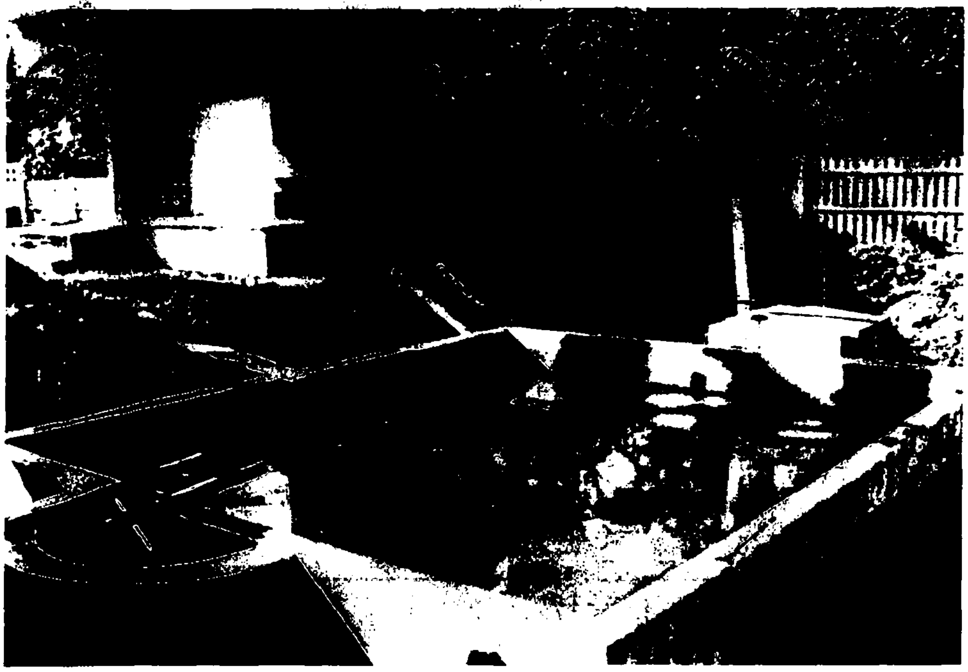


Photo No. 2

Slow sand filter

Photo No. 3

Elevated tank, 45 cum

for RWS schemes to be operated by the community. The remaining amount was contributed as a grant from RTG under the abovementioned program with only small participation of foreign donors. RTG contributions were increased annually by about 5 percent but this was fairly outweighted by increasing construction cost of RWS schemes which raised from Baht 360 (US $ 9.00) per capita in 1969 to an average of Baht 740 (US $ 32) in 1983. However, local contribution could be increased remarkably from about 20 percent in 1969 to about 40 percent in 1975/76 whereas it declined to less than 20 percent again in 1981/82.

2. PWA's Role in Piped Rural Water Supply

When PWA took over the responsibility of the SED of DOH in 1979 for the development of piped RWS schemes, most of the former SED and CPW project staff was transferred to PWA which allowed PWA to continue with development, supervision and technical assistance for RWS schemes without major interruption.

The performance of PWA's Community Water Supply Division after 1979 is summarized in Table 1.

TABLE 1 RWS SCHEMES CONSTRUCTED AND IMPROVED BY PWA, (Ref. 1)

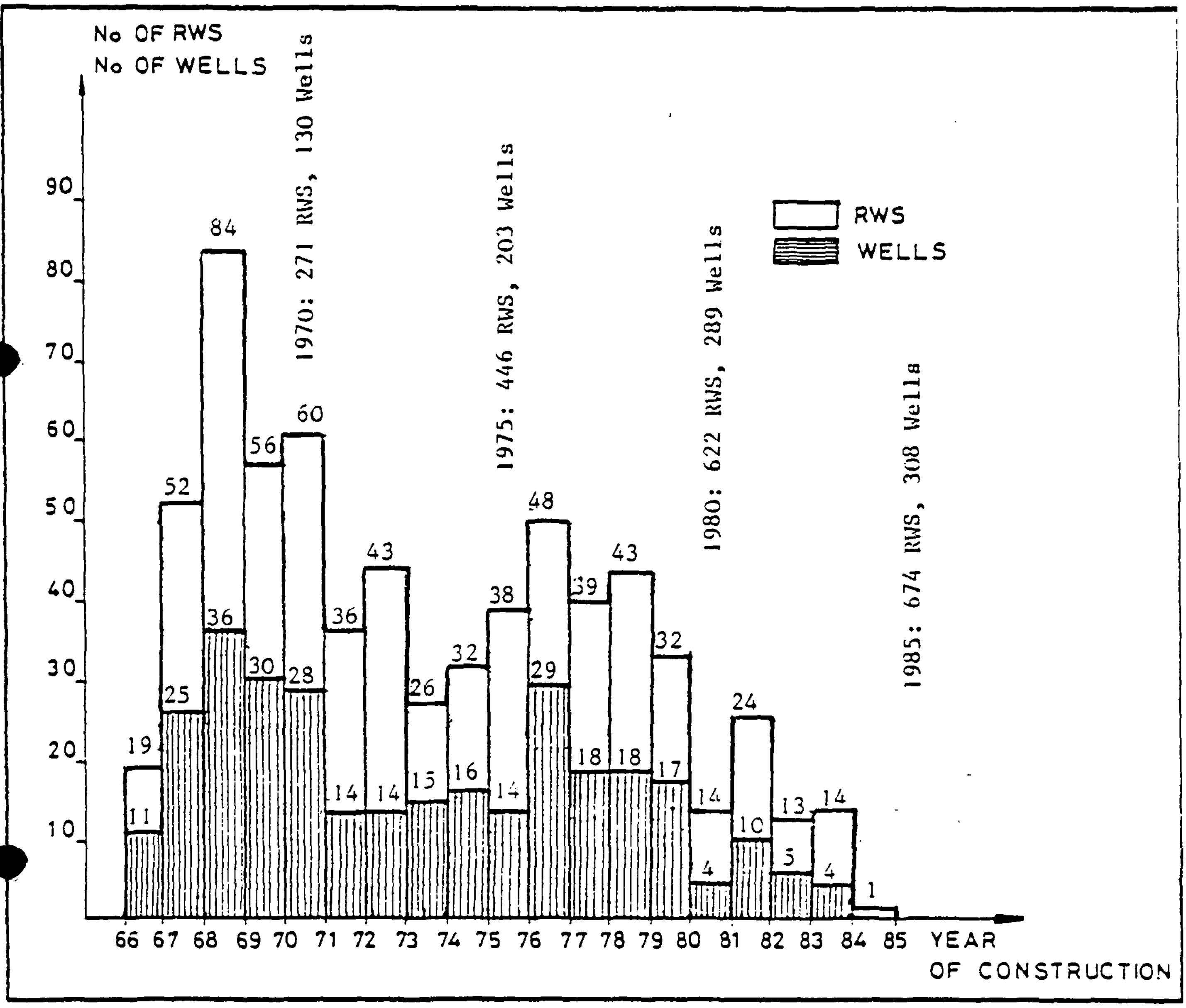
Fiscal Year	No. of RWS Schemes		RTG Budget Contribution	
	Constructed	Improved	Approved Baht	Spent Baht
1979/2522	33	11	57,260,000	44,618,076
1980/2523	12	7	46,280,421	37,712,242
1981/2524	26	6	116,620,000	91,706,274
1982/2525	12	2	52,540,882	45,497,518
1983/2526	15	18	75,340,935	64,589,883 1/
1984/2527	1	7	27,800,000	13,670,500 2/
1985/2528	(10)	(8)	57,690,000	-
Total	99	51	472,012,238	297,794,493

1/ Loan from Krung Thai Bank
2/ Loan from Krung Thai Bank requested
( ) planned figures

Table 1 illustrates the constant decrease in the number of piped RWS constructed, respectively improved under PWA from 1979 onward, whereas RTG contributions after an remarkable increase in 1981 remained more or less constant at about Baht 60 Million per fiscal year. The main reasons for this unfavourable trend are increase in construction cost and reduced contribution of communities for reasons to be explained later.

The number of RWS constructed each year, using either surface water or wells as source of supply is shown on Figure 1.

FIGURE 1 RWS CONSTRUCTED 1966 TO 1985 BY DOH AND PWA, (Ref 1)



3. Operation and Maintenance of Piped Rural Water Supplies

On December 26, 1983 the RTG re-affirmed by cabinet resolution the 1979 Provincial Waterworks Authority Act and ruled that all piped water supply schemes (urban, except Bangkok Metropolitan Area, and rural), not yet operated by PWA, are to be handed over to PWA by transfer of the respective assets and personnel. By general law, legal ownership includes the responsibility of operation and maintenance. In follow up of the cabinet resolution, the Ministry of Interior has ordered to hand over 38 urban (municipality concession) and rural (sanitary district) water supply schemes to PWA in FY 1984/85.

The cabinet resolution, using again the Thai word "prapa" for "piped waterworks" did not distinguish between urban schemes (UWS) which were still operated under concessions by the municipalities (as i.e. Korat, Puget, Lopburi) and piped RWS schemes which were either operated by sanitary districts and provincial management organizations (PMO) or rural communities (Muban). The consequences of the cabinet resolution on PWA's operation are ambigous, because taking over all UWS, which are regarded by PWA as profitable, at least cost covering, was the intention of PWA's management; whereas the ownership and operation of RWS was never anticipated or even considered. Furthermore the exact number of piped RWS existing in Thailand is not even known, because beside the 674 schemes constructed by DOH and PWA there are numerous other small-scale piped RWS in the country which were implemented by DOH and other agencies and are owned and operated by small communities, schools, monastries etc. Their number might exceed 20.000, the population served by this small-scale RWS is estimated to 2.3 million (Ref. 2).

It was therefore indispensable for PWA to establish their own policy and to define their future role in RWS development and operation.

In order to obtain more reliable information on demand, physical and operational conditions, tariff systems as well as socio-economic data of the 674 RWS a survey was executed in 1984 and 1985.

The survey of RWS schemes as well as interviews with plant operators, village committee members, sanitary district and PMO officers revealed that the quality of operation and maintenance is, to a large extent, dependent on the interest the community and the respective officers show in the management and supervision of RWS. RWS operated by monastries were found to be among the best operated and maintained.

Waterwork operators of RWS under sanitary district and PMO management frequently complained that in case of major breakdowns there is no provision in the budget for immediate repair and/or replacement of pumps, motors and other mechanical equipment. Looking into this matter in more detail, it was found that the responsible officers, with some few exceptions, were used to provide only for current operation cost of RWS in their budgets, even if the RWS under their management were making profit over operation cost for many years.

Active participation of the local communities in the construction and operation of RWS was executed on different levels and in different ways. The most efficient and direct form of community participation is through the elected Muban Committee headed by the village chief.

Another source of information were monthly operating sheets of RWS compiled by the PWA Regional Offices which contain revenues and expenditures on a monthly basis. Because of restricted time and the uncompleteness of this data, only the annual 1984 data could be evaluated for a sample of 114 RWS out of the total of 674.

A comparism of main operational indicators of RWS under provincial authorities, community management and UWS operated by PWA is presented in Table 2.

TABLE 2 COMPARISM OF OPERATIONAL INDICATORS OF RWS AND UWS (PWA) 1983 (Ref. 1)

	INDICATOR AVERAGES	Comm. RWS	Provin. RWS	Total RWS	PWA UWS
DEMAND	Population in Service Area/RWS/UWS	3,172	5,090	4,270	12,630
	Connection/RWS/UWS	194	368	285	2.022
	Inhabitants/Connection	16.4	13.8	15	10.7
	Coverage in percent	40	47	44	50
	Consumer/Connection	6.6	6.5	6.5	5.4
	cum/Connection/Year	68.0	190.5	132.3	295.7
	lcd	28	80	63	150
FINANCIAL	Revenue/RWS/UWS (1.000 Baht)	41.6	166.9	107.4	4.135
	Expenses/RWS/UWS (1.000 Baht)	39.6	145.8	95.4	3.802
	Revenue/Expenses	1.05	1.14	1.13	1.09
	Tariff (Baht/cum)	2.90	3.42	3.20	2.68
	Construction Cost/RWS/UWS (1.000 Baht)	3.842	3.391	3.601	15.286
	Construction Cost/Consumer	3.000	1.418	1.914	1.400
OPERATION	Capacity of RWS/UWS (cum/h)	13.0	29.3	24.1	189.6
	Salary/Person/Month (Baht)	967	2.635	1.970	5.172
	Persons/1000 Connections	6.2	4.9	5.5	14.8
	Production Losses (percent)	50	50	50	40

Based on an estimated total of 187.000 connections for the 674 RWS the number of employees per 1.000 connections in 1983 was 5.5 which is a very low ratio compared to PWA's 1983 ratio of 14.8 employees per 1.000 connections. Split into provincial authorities and community operated RWS the ratios are 4.9 and 6.2 respectively. The reasons for this extremely low ratio which comes close to figures in industrialized countries can be explained as follows:

- for smaller RWS of 10 to 20 cum/h capacity only one operator is permanently employed who is also in charge of meter reading. Financial management (billing, revenue collection, bookkeeping, orders for chemicals and repair) is mostly provided by sanitary district and PMO officers or members of the Muban Committees. In case of provincial officers their salary is paid from the general budget of the province or sanitary district and not separately accounted for RWS operation whereas in case of community operated RWS frequently teachers or monks are providing management services voluntarily or for a small monthly fee.
- operators and others employees of RWS are not subject to strict labour-law-regulations as PWA's staff. RWS which operate more than 8 hours per day are not forced to employ two operators.
- PWA Regional Offices provide technical supervision and advise free of charge to RWS.

Wages are also far lower than with PWA. According to Table 2 the average monthly salary in 1984 was Baht 1.970 with a remarkable lower average of Baht 967 for community operated RWS compared to Baht 2.635 for RWS under provincial management. Wages/salaries amounted to 24 percent of operating expenses in FY 1984/85 compared to 44 percent with PWA. This is explainable by the three times higher rate of employees per 1.000 connections and the 2.6 times higher average wage rates at PWA (Baht 1.970 to Baht 5.172 average monthly salary).

According to the survey there were more than 60 percent of the diesel engines, aeration towers and chlorine feeders and more than 20 percent of turbine pumps, rapid and slow sand filters requiring immediate repair or replacement. Raw and clear water pumps and motors were generally in good and fair condition (more than 80 percent) whereas 27 percent of the turbine pumps need to be repaired or replaced.

The condition of wells was difficult to assess without test pumping and inspection of the screens which requires special equipment. 14 percent showed high sand intrusion or already collapsed filter screens, on the other hand the age distribution of the 308 tube wells presented in Figure 1 shows that 71 percent of the wells are already exceeding the assumed lifetime of 10 years.

Figure 1 also indicates the general trend that, due to the unfavourable age structure of the 674 RWS (66 percent are older than 10, and 42 percent older than 15 years), cost for rehabilitation and repair will increase dramatically over the next decade.

According to the socio-economic survey the percentage of water expenses related to household income is less than 1 percent on average. Case by case there are 64 percent of the households which spend less than 1 percent of their household income for water, in 24 percent of the households surveyed the percentage of water expenses is between 1 and 2 percent. 12 percent of the households spend more than 2 percent of their income for water.

4. PWA's Decade Planning of Piped Rural Water Supply Development

In order to comply with the International Drinking Water Supply and Sanitation Decade (IDWSSD) tne RTG has set a coverage target for safe drinking water of 95 percent by the year 1990 for the whole population of Thailand. The Masterplan for Rural Water Supply and Sanitation (Ref. 2) is based on a coverage target of 95 percent water for drinking purposes and 75 percent for domestic use. However, in 1985, after half of the IDWSSD more than 50 percent of the Thai population was still using unsafe water and only 15 percent of the rural population was served by piped water systems.

Increase of Coverage in Existing Service Areas

In 1985 2.88 million people were living in the service areas of the 674 RWS of which only 1.27 million (44 percent) were connected. In its Corporate Plan for the Second Half of the Water Decade (Ref. 3) PWA has set its own coverage target to 90 percent of the population living in its service areas by 1995 and to 75 percent by 1990. Based on an assumed average growth rate of the rural population of 1.5 percent for the period up to 1990 and 1.0 percent for the period 1990 to 1995 the respective demand figures are shown in Table 3.

The figures in Table 3 were comupted assuming a slight decrease in the number of consumer per connection (6.5 in 1985 to 5.5 in 1995) and moderate increase in per capita consumption (63 lcd in 1985 to 75 lcd in 1995) which seems to be justified because of improved living standard and decreasing size of families.

TABLE 3 TARGETS FOR INCREASED COVERAGE OF THE RWS DECADE PLAN (Ref. 1)

Demand	1985			1990			1995		
	Comm. RWS	Provin. RWS	Total RWS	Comm. RWS	Provin. RWS	Total RWS	Comm. RWS	Provin. RWS	Total RWS
Population in Service Area (million)	1.04	1.84	2.88	1.12	1.98	3.10	1.18	2.08	3.26
Coverage in percent	40	47	44	75	75	75	90	90	90
Population Connected (million)	0.41	0.86	1.27	0.84	1.49	2.33	1.06	1.87	2.93
Consumer/Connection	6.6	6.5	6.5	6.0	6.0	6.0	5.5	5.5	5.5
No Connections (1000)	62	132	194	140	248	388	192	340	532
lcd	28	80	63	40	90	72	50	90	75
MCM/Year	4.19	25.11	29.30	12.26	48.95	61.21	19.35	61.43	80.78

Development of New Service Areas

The number of towns and villages in Thailand having more than 2.000 population is not exactly known. Assuming that 20 percent of the rural population are living in villages with more than 2.000 inhabitants, the total number might be about 4.000.

The existing 674 RWS are serving 1.652 rural communities - the average population is 1.740 - consequently there are about 2350 more communities to be served, 950 more RWS to be constructed.

Taking the above figure as a hypothetical assumption and comparing it with PWA's past performance and RTG budget allocations which allowed only to construct 16.5 new RWS schemes per FY on average, it would take 58 years to comply with this demand. It is therefore more realistic to base the decade planning on the actual demand for development of RWS which can be measured by the number of applications submitted to PWA by communities. In 1985 their number was 118 RWS for all 10 PWA regions. Extending this number to 200 RWS for the year 1995 might be a realistic assumption.

Water Quality Standard

Piped water supplied by PWA has to comply with national (TIS) quality standards which are more stringent than WHO's 1984 Guidelines for Drinking Water Quality. The Masterplan for RWS and Sanitation assumes water quality standards in rural areas lower than TIS without any definition. As water quality standards have direct implications on investments (wells, treatment, disinfection) and more than 60 percent of the RWS surveyed were supposed not to deliver water according to TIS standards it is doubtful wether the target of compliance with PWA-TIS water quality standards for all RWS will be achievable.At least for RWS remaining under community operation WHO's 1984 Guidelines should be accepted.

Transfer of Operational Responsibility of RWS to PWA

Based on the institutional scenario and the results of the RWS surveys it can be assumed that about 350 RWS under provincial and sanitary district administration can be taken over by PWA into full operational responsibility within a period of 10 years.Such a program would imply to take over 30 to 40 RWS per year or 3 to 4 in each of the 10 PWA Regions per year which would have tolerable impacts on PWA's operational capacity under the condition that a comprehensive rehabilitation program for about 200 RWS (57 percent of 350 RWS) could be executed and financed within a period of 10 years.

Community Participation

One important mean to achieve better cost coverage of RWS, beside increasing the tariffs, is to improve the contributions of consumers to construction cost. Under the NPW program, communities having the status of sanitary districts could obtain government loans with 4 percent interest rate and ten years repaiment period through DOLA. This program expired in 1983 which was one of the reasons why community contribution to construction cost of RWS decreased remarkable after this date. Under the assumption that RTG is willing to subsidize further PWA's RWS development, either the former loan program with DOLA must be reinstated, or PWA must be furnished with a revolving fund to provide loans to communities under similar favourable conditions.

For RWS operated by communities which are not able to obtain government loans because they have no legal status, PWA with the assistance of the German Agency for Technical Cooperation (GTZ) has already established a revolving fund for the improvement of RWS. This program is ment to encourage other foreign donors to participate, but also to demonstrate how community participation in RWS development could be improved again.

Replacement of Devaluated Assets

Compared with the average lifetime of RWS components (civil works, equipment, wells), the need for replacement is related to equipment and wells, respectively, while the civil work component has only reached a maximum age of 19 years. This means that during the next decade primarily equipment and wells would have to be considered for replacement and rehabilitation.

The total estimated amount of re-investment required (equipment and wells) in 1986 is worth about Baht 210 million. From this amount the re-investments allready carried out must be subtracted. The value of implemented re-investment, however, is not exactly known.

Financial Requirements for RWS Extension

The targets of increasing the coverage in the existing RWS service areas to 75 percent in 1990 and to 90 percent in 1995 is not feasible with individual yard connections. Assuming that 20 percent of the population to be connected will be served by coin operated or kiosktype standposts the costs for the extension of the 674 existing RWS are estimated to Baht 374.5 million for the period up to 1990 and Baht 230 million for the period 1991 to 1995. 94 percent of this costs, however, are expected to be born by the community assuming a connection fee of Baht 2.500 per yard connection.

Financial Requirements for New RWS

It was estimated that 200 new RWS could be constructed between 1986 and 1995 of which 50 percent will be handed over to rural communities (Muban) and another 100 would be operated by PWA. The costs for the construction of 200 new RWS at 1985 prices are estimated to Baht 582.6 million for the period up to 1995.

TABLE 4 SUMMARY OF COST ESTIMATED FOR THE RWS-DECADE PLAN (1985 PRICES) (Ref. 1)

Item	1986-1990			1991-1995			Total 1995		
	Comm. RWS	Provin. PWA RWS	Total RWS	Comm. RWS	Provin. PWA RWS	Total RWS	Comm. RWS	Provin. PWA RWS	Total RWS
Population Connected (million)	0.53	0.73	1.26	0.44	0.60	1.04	1.38	2.19	3.57
Yard Connections (1000)	71	98	169	64	87	151	197	317	514
Standposts (for 250 conn. each)	425	585	1.010	354	482	836	779	1.067	1.846
Cost of Rehabilitation (million Baht)	116.0	116.5	232.5	21.2	27.7	48.9	137.2	144.2	281.4
Cost of Extension (million Baht)	151.4	223.1	374.5	84.6	145.4	230.0	236.0	368.5	604.5
Subtotal Rehabilitation plus Extension (million Baht)	267.4	339.6	607.0	105.8	173.1	278.9	373.2	512.7	885.9
Cost of New RWS (million Baht)	105.9	135.9	241.8	155.4	185.4	340.8	261.3	321.3	582.6
Total (million Baht)	373.3	475.5	848.8	261.2	358.5	619.7	634.5	834.0	1.468.5

Summary of Financial Requirements for the RWS-Decade Plan

The total amount of investments required for the RWS-Decade Plan are summarized in Table 4. It assumes that up to 1995 3.57 million more people in rural areas of Thailand will have access to piped water supply which will increase the total rural population served with piped water to 8.8 million.

The specific investment cost for repair and extension of RWS are about one third of cost for new construction. This is due to the fact that for new constructed RWS only 120 yard connections per RWS were assumed at the beginning of their operation which will increase to 600 per RWS over a ten years period. The specific investment cost per capita and per connection are decreasing over the decade period reaching average figures of Baht 3.200 per yard connection corresponding to Baht 460 per capita for community operated RWS, and Baht 2.631 per yard connection corresponding to Baht 380 per capita for PWA operated RWS. The lower figures for PWA operated RWS are due to the better economics of scale of larger RWS (30 cum/h). Investment cost per capita for supply by coin operated standpost are about one third of cost for supply by yard connection.

However, average investment cost per person supplied by yard connections of Baht 410 corresponding to US $ 16 for the whole RWS-Decade Plan are low compared with figures in other developing countries and even the highest figure of Baht 1.660 corresponding to US $ 64 per connected person for new constructed RWS schemes is by far lower than the World Bank's 1984 estimate of US $ 150 (Ref. 4). Also coin operated standposts require less investment per capita (Baht 140 = US $ 5.40) than handpumps (US $ 25) if they are used to supply the dispersed population in fringe-areas of larger villages and towns.

Proposals for the Financing of the RWS-Decade Plan

There are basically four different sources to be used for financing the investments required for the implementation of the RWS-Decade Plan:

- revenues from water sales (surplus over operation and replacement cost)
- community (consumer's) contribution (prepaid connection fees, voluntary labour, contributions in kind)
- RTG subsidies (soft loans through DOLA for communities or Krung Thai Bank (PWA)
- subsidies of foreign donors and development agencies (grants, soft loans, revolving funds)

the latter two sources should only be considered as means to achieve full cost coverage at the end of the RWS-Decade Plan. In Table 5 an Investment Program is proposed for the RWS-Decade Plan, assuming the availability of the sources mentioned above and moderate inflation rates between 2.5 and 3.5 percent.

TABLE INVESTMENT PROGRAM FOR THE RWS-DECADE PLAN 1986-1995 (MILLION BAHT)

Item	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Inflation Rate	2.5	2.6	3.4	3.5	3.5	3.4	3.4	3.4	3.4	3.4
Rehabilitation & Extension Comm. RWS 1985 Prices	53.5	53.5	53.5	53.5	53.5	21.2	21.2	21.2	21.2	21.2
Current Cost	54.8	56.2	58.1	60.1	62.2	25.5	26.4	27.3	28.2	29.2
Comm. Contribution 35 percent	19.2	19.7	20.3	21.0	21.8	8.9	9.2	9.6	9.9	10.2
RWS Revolving Fund	35.6	36.5	37.8	39.1	40.4	16.6	17.2	17.7	18.3	19.0
Rehabilitation & Extension PWA RWS 1985 Prices [1)]	67.9	67.9	67.9	67.9	67.9	34.6	34.6	34.6	34.6	34.6
Current Cost	69.6	71.4	73.8	76.4	79.1	35.8	37.0	38.2	39.5	40.9
Comm. Contribution 35 percent	24.4	25.0	25.8	26.7	27.7	12.5	13.0	13.4	13.8	14.3
RTG Loan PWA 25 percent	17.4	17.9	18.5	19.1	19.8	9.0	9.3	9.6	9.9	10.2
I + II Loan ext. 40 percent	27.8	28.5	29.5	30.6	31.6	14.3	14.7	15.2	15.8	16.4
100 New RWS, Comm. 1985 Prices	21.2	21.2	21.2	21.2	21.2	31.1	31.1	31.1	31.1	31.1
Current Cost	21.7	22.3	23.1	23.9	24.7	37.5	38.7	40.1	41.4	42.8
Comm. Contribution 40 percent	8.7	8.9	9.2	9.6	9.9	15.0	15.5	16.0	16.6	17.1
RTG Loan PWA or DOLA	13.0	13.4	13.9	14.3	14.8	22.5	23.2	24.1	24.8	25.7
100 New RWS, PWA 1985 Prices	27.2	27.2	27.2	27.2	27.2	37.1	37.1	37.1	37.1	37.1
Current Cost	27.9	28.6	29.6	30.6	31.7	44.6	46.2	47.8	49.4	51.1
Comm. Contribution 40 percent	11.2	11.4	11.8	12.2	12.7	17.8	18.5	19.1	19.8	20.4
RTG Loan PWA	16.7	17.2	17.8	18.4	19.0	26.8	27.7	28.7	29.6	30.7
Total Community Contribution	63.5	65.0	67.1	69.5	72.1	54.2	56.2	58.1	60.1	62.0
Total RTG Loan	47.1	48.5	50.2	51.8	53.6	58.3	60.2	62.4	64.3	66.6
Total Revolving Fund	35.6	36.5	37.8	39.1	40.4	16.6	17.2	17.7	18.3	19.0
I + II Loan ext.	27.8	28.5	29.5	30.6	31.6	14.3	14.7	15.2	15.8	16.4
Total Investment	174.0	178.5	184.6	191.0	197.7	143.4	148.3	153.4	158.5	164.0

1) 48 million Baht for PWA's operating equipment 1986-1990 not included.

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THE NEED FOR THE PRACTICAL APPLICATION OF WATER CONSERVATION AND REUSE STRATEGIES IN THE INDUSTRIAL SECTOR OF THAILAND --- A CONSULTANT'S VIEW

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Introduction

Industrial development in Thailand has so far centred around the city of Bangkok and neighbouring provinces of Samutprakarn, Samutsakorn and Pathumtani though there are attempts to rectify this by encouraging investment in other parts of the country. In the Bangkok Metropolitan area industrial development is not concentrated in any one district but is scattered, though industrial zones and estates are now being established.

This paper will essentially focus on the industrial water needs and problems in the Bangkok area. In other parts of the country the increasing recurrence of drought and the resultant reduction in stream flows plus the increasing difficulty of finding suitable water sources for large scale industrial development is a source of concern.

Water resources in the Bangkok area and surrounding provinces are being depleted and contaminated at alarming rates. Groundwater reserves in the Bangkok area are highly vulnerable to excessive exploitation and quality deterioration associated with rapid industrial development and the associated population growth. The high rate of population increase coupled with rapid expansion and diversification of industries without accompanying effluent pollution control schemes, has led to serious deterioration of the environmental quality. Although there is a growing awareness of the need to protect the environment by pollution abatement and water conservation in the industries, not enough is being done.

Several undesirable consequences of this are the depletion of aquifers, salt-water encroachment, land subsidence (with resulting damage to infrastructure) and interference with prior water rights of others. In some part of the municipal area, there has been no development of surface resources and all the water is obtained from the ground. The total groundwater extraction by both public supply and private wells in the Bangkok area was estimated to be about 0.6 million cu.m./day in 1976, 1 million cu.m./day in 1979 and currently in excess of 1.5 million cu.m./day. 1/

Rain water replenishment of groundwater in limited to less than 3% of annual rainfall (1,300 mm) due to a thick layer of impervious clay immediately underlying the Bangkok area which prevents direct percolation. Other reasons for depletion are the combined effects of reduced recharge due to an increased amount of paved area and pond eutrophication. Thus, although Bangkok possesses abundant ground water resources, the situation will become critical unless strategies to conserve and reuse water without contaminating the groundwater resources are employed.

We have to move from a "throwaway" economy to a "recycling" economy. Industrial wastewater reuse and water conservation should be employed as tools for pollution control and abatement, a dual strategy of water conservation and water resource recovery. There is a need for information if intelligent decisions concerning water reuse management and the subsequent wastewater management are to be made with respect to existing laws and regulations and the need to design and construct systems that are cost-effective.

The question is how to motivate traditionally profligate consumers to change habits. The principal import of this paper is to show how the long term advantages of encouraging increased wastewater reuse and groundwater conservation may be achieved. Industries have to understand that limited water supplies for new processing plants and the need for large quantities of processing water are major issues and that water conservation and reuse are vital parts of the water use system. To do this we must develop cost effective water use systems which lead to efficient conservation of water, and which require minimal technical expertise.

Industrial Water Use --- Trends and Needs

Industries in Thailand have traditionally paid little heed to water conservation. In Thailand, as in many other countries of the region, industry makes the largest withdrawal of water, be it for the generation of steam, for cooling, washing, processing, steeping or other purposes. Examples are the chemical, pulp and paper, and food industries which are all heavy users of water. Table I shows some water consumption figures from a cross-section of industries served by the consultants.

It is of course not only the water intake that matters, but also the capacity of industry to contaminate the water it uses, before returning it to the streamflow. Together with rising water rates and treatment requirements the stringent enforcement of water quality standards will encourage industrial efforts to reduce water pollution discharges. These measures have compelled industrial users to heed the wisdom of using water for several different applications in descending order of cleanliness before calling it waste. Far-sighted industrial management should consider water use plans which results in zero discharge, or as close to this goal as is possible. This type of conservation produces the dual benefits of less wastewater to be treated and a reduction in overall consumption.

Table I. Industrial Water Consumption

Location	Type of industry	Average Water use (cu.m./d)	Water source
Bangplee District, Samutprakarn Province	Poultry processing	2,500	D.W.
Bangkhen District, Bangkok	Integrated circuit components	350	D.W.
Klongtoey District Bangkok	Detergents, toiletries, etc.	280	D.W.+ MWWA
Bangkhen District, Bangkok	Dairy products	329	D.W.+ MWWA
Bangna District, Bangkok	Poultry processing	1,600	D.W.
Bangpoo Industrial Estate Bangkok	Fish processing	370	D.W.
Samutsakorn Province	Squid processing	1,500	D.W.
Sumrong District, Bangkok	Integrated circuit components	310	D.W.+ MWWA
Sampran District, Nakornpathom	Fruit processing	940	D.W.

* D.W. - Private Deep Well
* MWWA - Metropolitan Water Works Authority

Other regulations enacted by the authorities to curb groundwater extraction have played a vital role in this shift. These include laws which prevent users from replacing old wells with new ones if municipal water has been extended to their locations. As consumers are forced to pay more, water has become too valuable a commodity to supply once and dump. At the same time the municipality has incurred increasing costs with the extension of distribution systems to locations farther from central treatment facilities and as treatment costs (including costs of excessive sludge disposal) have increased.

The price of water for industries and residential areas levied by the Metropolitan Water Works Authority is shown in Table II. In contrast users of groundwater from private wells pay only 1 baht per cu.m. This is a major reason why many refuse to use the MWWA service.

Table II. Water Rates, Bangkok, Nontaburi and Samutprakarn, 1987

Category 1: Residential		Category 2: Commercial, industrial	
Water consumption (cu.m.)	Rate (Baht/cu.m.)	Water consumption (cu.m.)	Rate (Baht/cu.m.)
0 - 30 (not less than 20 baht)	4.00	0 - 10	minimum 50.00
31 - 40	4.25	11 - 20	6.20
41 - 50	4.50	21 - 30	6.45
51 - 60	4.75	31 - 40	6.70
61 - 70	5.00	41 - 50	6.95
71 - 80	5.25	51 - 60	7.20
81 - 90	6.15	61 - 80	7.45
91 - 100	6.40	81 - 100	7.70
101 - 120	6.65	101 - 120	7.95
121 - 160	6.90	121 - 160	8.20
161 - 200	7.15	161 - 200	8.45
over 201	7.65	over 201	8.70

These prices cover the city of Bangkok and the surrounding provinces of Nontaburi and Samutprakarn where the MWWA supplies about 1.5 million cu.m./day. Of this approximately 200,000 cu.m./day (7%) is still drawn from 50 deep wells.2/ The MWWA plans to extend its service to the industrial districts of Paknam and Prapradaeng where groundwater depletion is a serious problem.

Many industrial water users have poor housekeeping practices. Often the first line of defence against waste, the metering of all water use is not employed. Thus the major water use requirements are not known and data provided is questionable given that empirical relations are used to calculate water requirements in various processes. Data on overall consumption is recorded but when data on groundwater usage is analysed caution must be exercised, as tampering with meters is common.

The incentives for greater conservation of water and re-use in the future are, however, considerable. Such incentives will stem from increasing pressures on limited supplies, integration of reclamation schemes into comprehensive water resources planning, and the changes which will occur in the economic values placed upon alternative uses of water. Additionally many reclamation projects, not now technologically widespread, should become attractive as new technology becomes available and is more widely adapted to local needs.

1/,2/: Data provided by Bangkok Metropolitan Water Works Authority

The use of reclaimed wastewater by industry will doubtlessly increase, especially where and when industrial development begins to occur in areas where water is in short supply and/or is of unsatisfactory quality. So as decenteralization take place we will see this trend occur or at least forced upon industries. In the future, the cost of water as an industrial raw material, for whatever purposes it may be employed, will increasingly be determined by availability and quality, which in turn will determine whether conservation and re-use are economically attractive.

The burden of initiating these changes lies with the engineers and scientists, with the assistance of the planners and decision makers. Rational water management in the industrial sector of Thailand needs a cooperative, multi disciplinary effort. Engineers, hydrologists, agronomists, ecologists, economists and sociologist have to act in conjunction with civil servants, corporate executives and politicians. Their objective must be to increase efficiency by re-use, re-cycling and conservation (reducing waste).

We are already witnessing signs of competition for water to be used in the production of energy, as against its use in the production of food-agriculture and food processing industries - (witness the debate on Nam Choan dam in Kanchanaburi). The creation of additional dams, takes farm land out of production and eliminates prime forest reserves. Reuse of industrial wastewater with the resultant availability of additional unpolluted surface water due to the direct benefits of reuse and conservation can help alleviate some of these problems, permitting the nation to increase its industrial base without taking farmland and forest reserves to create new water supply sources.

Strategies for re-use and conservation

Conservation and re-use are almost synonymous when applied to water in industry. Use of unneeded water (i.e. no conservation) is a double cost, first of the input water, and then in the wastewater system (i.e. no reuse). However, before proceeding further we should define these terms.

Reuse is the productive utilization of appropriately treated wastewater while recycling is a special case of reuse which uses water over and over again for the same identical application from which it came. Multiple reuse is another approach to water conservation which also helps reduce cost of water treatment due to lower volumes discharged, and therefore, reduces capital and operating costs for wastewater treatment facilities. It is a method of reuse which implies its use ~~more~~ than once, but each time for a different purpose, for example, the countercurrent use of water for successively dirtier applications, until it is no longer needed. This is in contrast to once-through use of water. The term reclamation is one employed when used water is restored to a usefull condition. From a water resource management point it will be the restoration of water finally rejected by one user to a condition suitable for another use by arrangement.

Water reuse in Thailand is increasing, there is no doubt about it. There are however no figures on reuse ratios for major industries in Thailand. However, much higher reuse is potentially possible under appropriate conditions. It is hoped that the trend will continue to be motivated by the pressures of limited water supply, poor water supply quality, and, more recently, environmental considerations. The later should accelerate the trend in the near future.

In general there are there major industrial water use functions with different water quality requirements. These are:-

- Process use – contacts products and raw materials in the manufacturing process.

- Cooling – for process operations and power production.

- Steam production – for process use and power production.

As practised today even cooling water and condensed re-coverable steam are not reused sufficiently in Thailand. Reusing steam condensates for direct boiler feed and new steam production, practiced for years, was motivated by engineering factors related to boiler operations and construction. Process wastewaters are seldom reused or recycled. Waste water can be used, directly or indirectly, as feed waters for boiler feed make-up. Similarly process wastewaters can be utilised as cooling waters and for cooling water makeup. Accordingly, a plan for a wastewater recycle system in Thailand is not a pipe drain and is within the realm of engineering reality.

In view of current and prospective environmental standards, each industrial plant should ask itself which way is best to proceed to comply with regulatory demands. In considering the alternatives, there are really only two: no discharge, or discharge complying with current and future requirements of the regulatory agency. Where conditions may initially dictate treatment for discharges, the resulting effluent might be suitable for reuse within an industrial plant-either as cooling water and/or boiler feed makeup. So why throw it away?

To reduce wastewater discharge by reuse or recycle, the water used must be continually purged of waste materials which accumulates (build in conc) with usage. It is this accumulation which affects water quality and limits the extent of water reuse achievable. The concentrations of salinity, hardness, alkalinity, organic matter and suspended solids must be controlled in such a system by their selective removal at appropriate locations and in appropriate amounts. In this manner water quality may be controlled to meet reuse or recycle requirements.

The simplest way to design a wastewater reuse system is to measure the variable volumes and pollutant concentrations of wastewater at the end of the pipe, determine the treatment that will upgrade the wastewater for the major use needs, establish the surge capacities, and design the system. In addition an economic evaluation of reuse versus disposal should be done. The danger is that if one proceeds with an end-of-pipe design, a latter survey may show that the design has wasted most of the cost in unnecessary structures and operating costs.

The effectiveness of a reuse system --- to reduce the concentration of contaminants in a given source of water or to produce water with certain required characteristics --- is a function of the operation of the overall water system, not just of the treatment portion of the system itself.

When an industry wants to evaluate reuse and conservation strategies it must explore some of the circumstances under which reuse can be cheaper then disposal. This will provide clear cut benefits in economic terms to motivate changes. The circumstances which can be enumerated are:-

- Disposal involves losing some process material having a reclaim value

- The value of new water is unusually high or is expected to steadily rise

- Quality requirements for effluents set by regulatory agencies are stricter then requirements for use

- Pollution damage claims are excessive

- Quality requirements for effluent are higher than raw water quality commonly available.

However, we the scientists, engineers and consultants need to present information which will be helpfull in the ordinary, everyday cases in which there is no special boost due to high water cost, threat of pollution claims, strict effluent requirements, or loss of reclaimable material. The information should be presented to aid industry to compare the two schemes for handling water, the conventional scheme: purchase water at normal rates, treat and condition it, use it, treat waste prior to disposal, and dispose by some method, and the reuse scheme: purchase only nominal makeup water, and treat waste for reuse.

Consideration of water reuse should evaluate the advantages of complete water reuse. If water reuse and pollutants reuse or disposal are considered as different systems, the cost may be much greater. When all factors are considered, complete water reuse, or zero discharge, may be an economic asset instead of an economic liability for industry. Reuse of the pollutant fraction should be an integral part of all water reuse planning.

There are two possible ways of re-using waste waters in industries:

- The so-called open-cycle system, where the water is used at several successive points in order of the degree of purity required at each point; and

- The closed-cycle system, where after use the water undergoes suitable treatment in the light of the specific requirements and is recycled through the plant. In this case any new take-up of supply water serves only to make good inevitable losses and to compensate for waste water and slurries that may be drawn off because they cannot be processed or re-used.

Special prior attention should be given to conservation before industries embark on looking at reuse, recycle and reclamation. In principle conservation is preferable to recycle and reclamation as an overall strategy in water use management. Water conservation in industry in Thailand must be encouraged and can be achieved by a variety of methods the appropriatness of which have to be tested.

Structural Methods: Water saving devices and metering which are physical devices that can reduce waste demand. The most obvious method.

Economic Methods: Metering, coupled with pricing stategies which significantly reduce the demand for water.
Socio Political Methods: These include those that require building code modifications and regulations or ordinances designed to reduce water demand.
Operational methods: Water use restrictions can be adopted but are not really practicable for industrial users.

Apart from conservation and reuse schemes, aquifer recharge schemes should also be more thoroughly investigated to combat the various negative impacts of excessive groundwater abstraction. It is possible to site, construct and manage these using reclaimed water, in such a way that a high degree of quality improvements of the reclaimed water can be achieved between recharge and extracton points. Use of reclaimed water for aquifer recharge may well prove benefical as a means of conserving water resources, of improving the quality of the aquifer water or for long term rehabilitation and storage of treated wastewaters.

We need to determine situations in which aquifer recharge with reclaimed water may be feasible. This will undoubtedly depend on many interrelated factors. As pilot studies will be needed, these are long term options. However the extent of engineering design and construction required are usually low and hence the implementation period is short once feasibility and pilot studies are satisfactorilly completed.

Some Case Studies and Examples

The following case studies and examples drawn from the consultant's experience of working within the industrial sector will aim to show how waste water reuse and conservation technologies/strategies are currently being used or where there are opportunities for application.

Pineapple Canning Industry

Thailand ranks as the second major country producing canned pineapple. There are seven major manufacturers and they require large quantities of high quality water; for each ton of raw fruit about 2.5 tons of clean water are required.

Less than 10% of the water usage is currently used for cooling. Up through 1977 all plants in Thailand used once-through cooling systems. Water requirements were 5 tons of clean water per ton of raw fruits, but shortages and increasing costs of raw water supplies finally shifted the balance in favour of closed or partially closed systems. Closed systems required only 5 to 10 percent makings water supply for the cooling towers, and hence the water requirements of the industry dropped by almost 50 percent in 1978.

The schematic process diagram shown in Fig. 1, together with water use and wastewater generated is for a local factory producing 12,000 cases of pineapple products per day (565 tons raw material processed). The main areas are namely (1) fruits receiving area (raw material washing) (2) fruit preparation area (3) processing area (filling, can closing, cooker/cooler) (4) and the juice extraction plant. Wastewater flows are essentially the same as water supplied during processing, except a considerable amount of wastewater is generated from plant washdown which occurs at the end of each working day.

Various opportunities to conserve and reuse water present themselves in the scheme of operations. Raw material washing water can often be recirculated thereby producing minimum wastewater flows. During plant washdown, tremendous amounts of water are used which affect the hydraulic loading to the waste treatment system. This amount of water can be reduced. Workers generally use water houses to wash down solids on the floor to the drains. Two ways of reducing this would be to use trigger nozzles on hoses in conjunction with high pressure, low volume

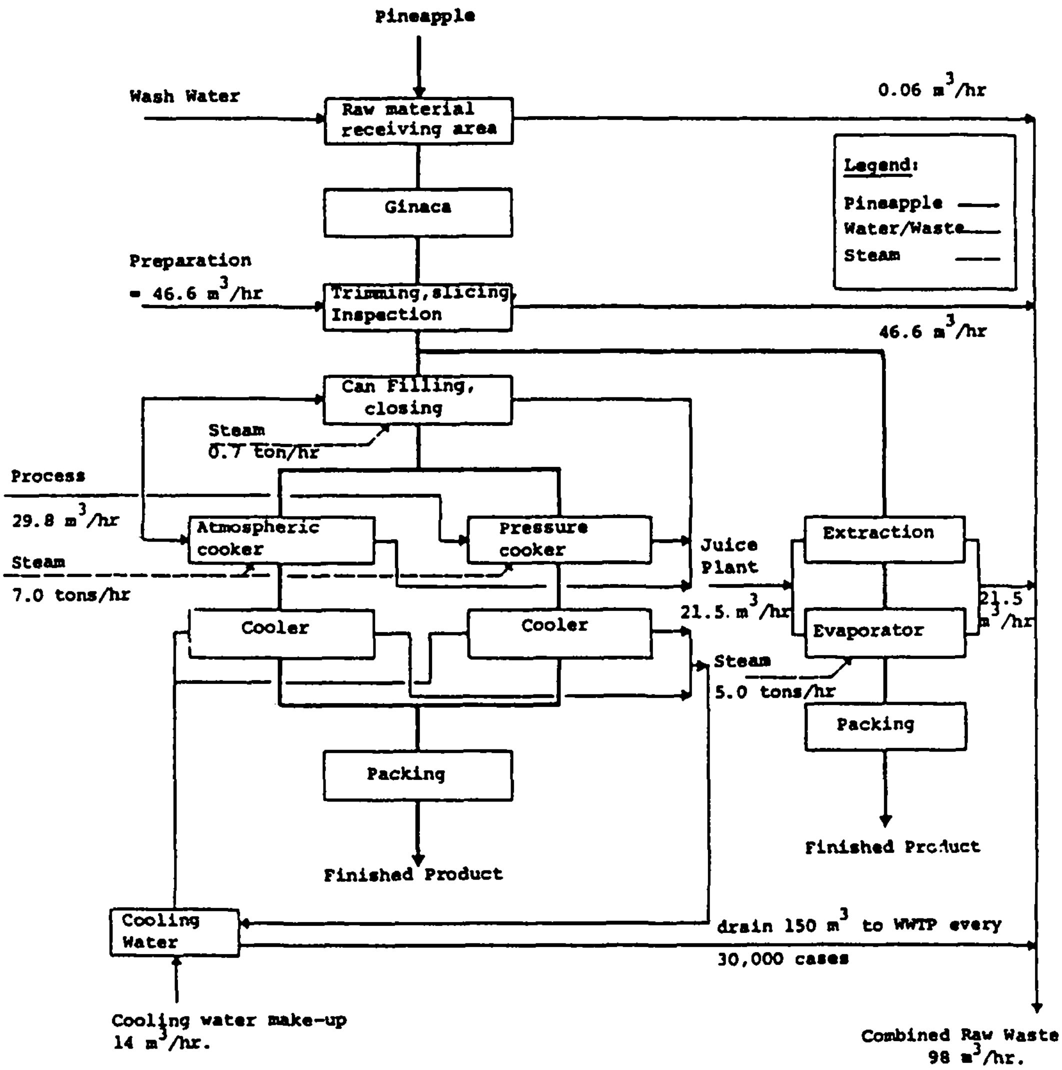

Fig. 1: Schematic process diagram, water usage and wastewater generation (565 tpd raw material)

clean up systems or better still to avoid the use of water by manual sweeping to remove solids to the drain. This would result in considerable amount of water being saved, estimated at 100 cu.m./day (almost 0.2 cu.m./ton).

In an industry such as this where almost 20% of the total weight of the raw fruit is wasted the use of less water increases the concentration of solids in water and thereby the potential for recovery or by-product utilization (e.g. for animal feed) is enhanced. Where evaporators are used to produce concentrated juice, reverse osmosis techniques can be employed to replace these, using crossflow membrane systems. Even with the increased efficiency of multiple-effect evaporators, evaporation is an energy intensive process which needs a lot of water (940 BTU per pound of water removed), though recirculation systems can be used for reducing water consumption and wastewater volume.

Other areas where reuse of treated processing wastewater has not been widely employed in Thailand but which have been proven technically feasible are-:

- Equipment cleaning
- Product cleaning and conveying
- Boiler feed to produce steam for: cleaning, exhausting, cooking
- Direct contact container cooling

The overall objective would be to supplement the water supply of the factory by reclaiming processing wastewater so limitations on groundwater withdrawal from the cannery would not limit their pineapple processing capabilities. In such a program there would be the need for an evaluation of the waste treatment effluent and disinfection for reclaimation and reuse in the cannery. It will require also consideration of the effect of this water-saving procedure on the quality of the final product, on general sanitation of the plant, and especially, consideration of the effect on the sanitary condition of the unit operation in which the water is to reused. The cost of waste water reclamation for reuse will include the additional operating costs and the amortised first cost of the facilities on an annual basis.

Poultry Processing

The poultry processing industry is a major growth industry in Thailand with almost all the big companies expanding their operations. The processing plant has a basic flow stream from slaughtering, scalding, defeathering, washing, evisceration, chilling to final packing. Feathers, blood, dirt and viscera are the waste products generated. Large volumes of waters are consumed both in washing and cleaning the poultry during processing and also in carrying away large amounts of waste to screening and ultimate disposal.

With expansion in processing capacity (e.g. from 40,000 birds/day to 100,000 birds/day) many of these processors who abstract groundwater are beginning to encounter problems which will inevitably have widespread implications on their operations. At one factory process water is presently drawn from a deep well which already has problems coping with demand during peak production (i.e. recharge < abstraction). There is the prospect that the cost of this groundwater will increase significantly in the coming years as the authorities seek to impose higher levies. The other consideration is that the factory is located in a green belt area where stringent environmental regulations require treated effluent to have a BOD of 20 mg/l and suspended solids of 20 mg/l before discharge to a waterway. The present treatment facility will not be able to cope with the increased load.

Here is a case where the interrelated aspects of water conservation, reuse and water pollution control can be applied. The consultants proposed a study to quantify waste flows and wasteloads with specific reference to water usage in the process. Currently no accurate figures are kept on water usage (i.e. no meters) in different process zones and regulations do not require the owner to measure waste flows. The objective of such a study would be to establish data on litres/bird processed and Kg BOD/day which would then make it possible to project water requirements, wastewater flows and BOD generated when the planned increase in output goes on stream.

The consultants also proposed that all operations be investigated to assess water saving potential and to determine the source of greatest water usage. Water usage classification was also recommended to relate process water quality to each process. The study included evaluation of in-house practices to reduce the throughput to the waste water treatment plant.

Finally it was proposed that it will be essential to review the reuse potential of various streams within the processing area and also the renovation and reuse potential of the final waste. Treatment technologies available for such renovation will have to be examined and presented as feasible options to meet the needs of the factory. Moreover, the implications of reuse on the quality of the product too will have to be studied and the potential for contamination thoroughly examined.

The rationale for such an approach is the reduction of water use in the processing operation and waste reaching the final effluent. It is in the interest of the client to reduce not only the quantity of water it uses (conservation) but also to reduce the load of pollutants it discharges. The problems of insufficient water will be overcome if reuse is made economically viable. Since the product is one used for human consumption the reuse option will have to be evaluated from both an investment and quality control standpoint. In an industry such as this the role of the consultants is critical in convincing the owner that the reduction of flow need not be completely at odds with the trend of industry towards modernization and improved processing using flowaway systems.

Television Component Manufacturers

This is a factory about to be established in the new Lamchabang Industrial Estate which is situated outside Bangkok near the tourist resort of Pattaya. This example is chosen to highlight an approach proposed by the consultants to take into consideration not only pollution control but also the reduction of water intake from a suface reservoir serving the area. The reservoirs in the area are prone to quality fluctuations especially turbidity. Moreover the waste products include several heavy metals.

To reduce water usage, thereby fostering conservation of national water resources and to limit discharge of heavy metals the scheme outlined in Fig. 2 was proposed. As shown the daily intake of water is about 3000 cu.m./day. The water undergoes primary treatment on site and is then further treated for potable and process use.

All avenues for reuse were explored and incorporated into the overall integrated water supply and wastewater treatment system. Detailed study of the characteristics of each waste stream revealed the potential to take advantage of dilution and reverse osmosis to remove certain heavy metals and thereby recycle almost one third of the intake. This is a substancial saving in water intake which also reduces operating costs of the water treatment plant and ensures that heavy metal pollution is controlled.

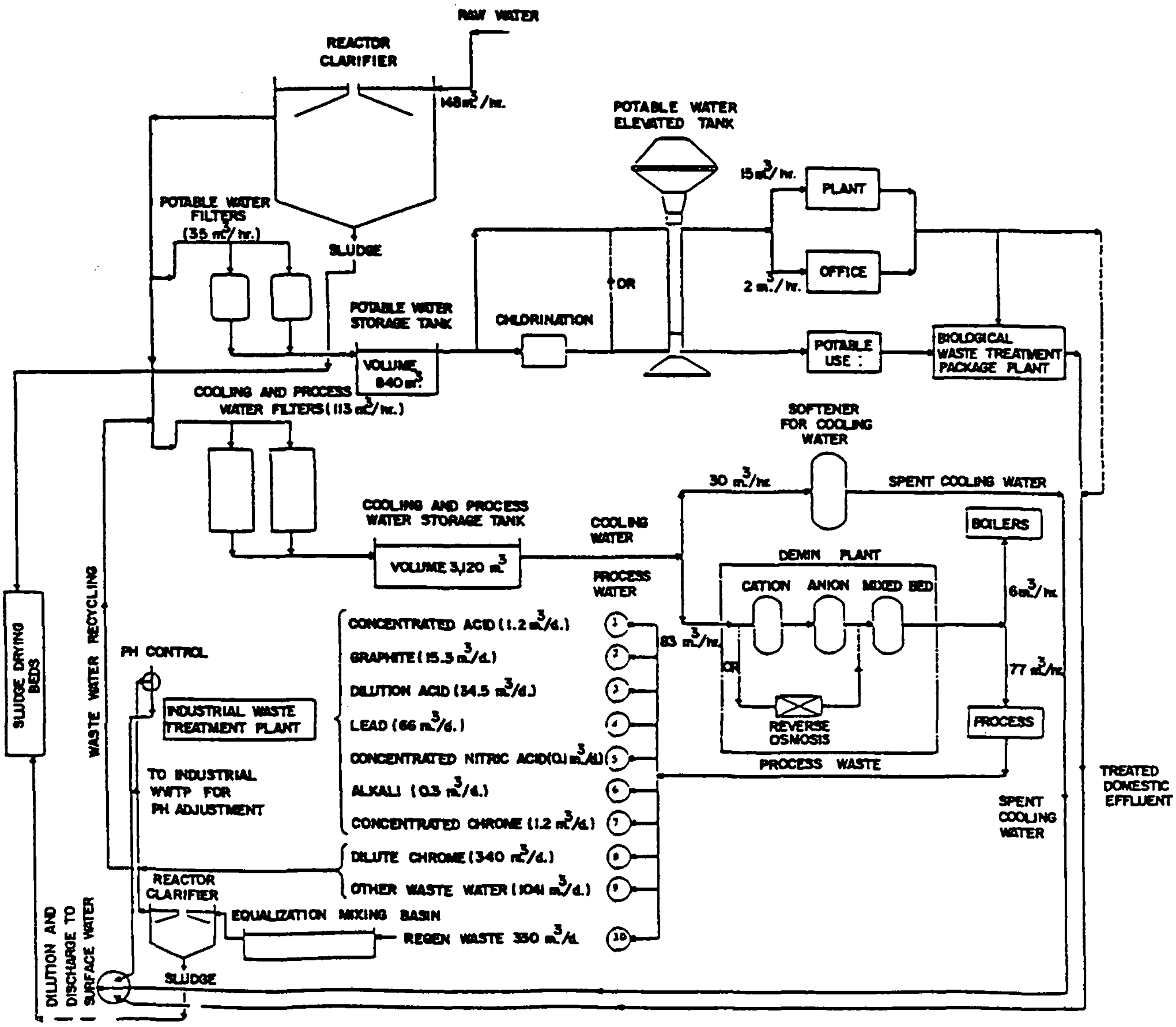

FIG. 2 : SCHEMATIC. DIAGRAM OF SYSTEM FOR INTEGRATED WATER AND WASTEWATER TREATMENT INCLUDING REUSE

This approach has been one which employes an end-of-pipe design. In addition there are numerous ways in which water consumption can be reduced by an evaluation of the production process. An obvious one would be the evaluation of the rinsing systems used. Considerable savings in water use can be achieved by using counter current rinse systems in two or three stages.

Obstacles to Implementation

Having shown that numerous opportunities exist to employ strategies for water conservation and reuse it is imperative to also present the obstacles to the implementation of these strategies. These will be presented so that they may be tested by subjecting them to the strain of criticism.

The first is the lack of research and development (R & D) which has the objective of assimilating imported processes into local conditions so that they take root and spread. We are talking of innovation to adapt proven technologies rather than just an absorption. We need R & D which understands that successful transfer of technology is a very complex socio-economic process with many facets beyond the mere introduction of packaged processes and know-how. Furthermore, experience with total reuse-recycle systems in industrial complexes is rare, which indicates R & D efforts are needed in this area.

Basic technology for technically and economically feasible closed-cycles is generally accepted as available. More often then not it is practiced in piece-meal fashion in specific applications. The time has arrived in Thailand (and other countries of the region) to consider putting the pieces together to develop totally engineered systems suitable for typical local industrial plant needs, and to research water quality parameters which are the controlling factors in water reuse and the affected economies. We have to find out how this can be done.

The next issue is one of economy. For industry economic considerations are of overwhelming importance and are the crux of the problem more than just evidence that conservation, reuse and pollution control are amenable to rational solutions. Studies directly related to the needs of industry (funded by industry?) should look at all factors which can influence costs. This sort of economic analysis should be more directly available and presented in a useful form together with sets of plans and specifications for systems employing reuse and conservation. In the final analysis there is no substitute for a good up-to-date engineering estimate based on local conditions. This approach should increase understanding of what each industry faces as potential water pollution costs. At the same time alternatives of by-product recovery VS disposal or treatment (for reuse) can be approximated more easily.

Just as important is the conscientization of the general public and industrial management to the needs of water demand regulation - i.e. water is not a free resource. This should go hand in hand with an integral set of laws, incentives, fiscal and other penalties (or tax reliefs), standards, and last but not least, adequate tariffs. Certainly in Bangkok and surrounding provinces we should begin to look at a tariff system for the consumption of water, commensurate with the amount of water withdrawn (used), the purpose for which it is used, the purpose for which it is used, and the degree of contamination it causes. If a progressive pricing system is socially and politically acceptable, and which means it can be enforced among the large amount of water consuming industries, it may become a major cause of water conservation, reuse and purification.

On the subject of attitudes there is also a lot to be done. The word "wastewater" has negative psychological implications linked with "filth" and "dirtiness" no matter how well it has been treated. The sanitary/environmental engineering profession needs to actively convince industrial managers, that properly treated effluent can be reused or recycled. In order to overcome this rejection or at least reluctance, toward direct water reuse, intensive education of the industrial sector (seminars) plus enthusiastic professional campaigns are necessary.

Managers in industry have to be encouraged into accepting that decisions should not be made just on balancing costs and benefits that can be quantified. A value must be placed on intangibles. The elements applicable to such a cost/benefit analysis are-:

Costs

- Buying input freshwater for use
- Preparing the water for use
- Preparing the wastewater for reuse
- Preparing the watsewater for disposal
- Disposing of treatment concentrates
- Modifying plant processes
- Making inplant structural changes
- Training plant personnel in use of new systems
- Preparing reports for control agencies

Benefits

- Reducing purchase of freshwater
- Eliminating reports for control agencies
- Saving in costs of treating for reuse instead of disposal
- Improving housekeeping
- Improving public relations
- Improving plant personnel morale
- Establishing independance

One point in the cost/benefit analysis that needs attention is the training of personnel to handle new systems. This is a task that looks at vocational training and engineering education as taught in this country. No matter how well one designs and builds a water reuse system, its success depends on good operation and maintenance. Instructions should be written so that they are easily understood, assuming the operator already has sound training in the basics. Training courses to instill in operators the importance of sound operation and maintenance is essential to assure good results.

Summary

This paper has not covered the field exhaustively, but an attempt has been made to present the long term advantages of water economy schemes aimed at conservation and re-use in Thailand. Conservation is a problem that concerns the nation as a whole and as a logical extension so is the use of water.

Here in Thailand we not only use more we do not recover enough. At the same time we treat less or at times do not even do that. At both ends of the spectrum the damage is telling. The future supply and demand as well as quality of water for the industrial sector will be influenced by the trends and initiatives taken now to combat overuse and pollution. To succeed the goals should reflect the desires of an informed industrial sector and public. The scientific community has a responsibility to inform them about the negative impact of current practices and the benefits cum consequences of trying to achieve these goals. Water management ought to become an integral part of waste management especially as water is used for the disposal of waste products, which upsets the environmental balance. Wastewater management should at the same time be put into a broader perspective which considers the long term constraints of the biosphere we all share.

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THE SRI LANKAN DEVELOPMENT EXPERIENCE IN WATER SUPPLY AND SANITATION

A CASE STUDY BY

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INTRODUCTION

The challenge to provide safe drinking water and sanitary disposal of wastes throughout the developing world is of staggering proportions. Of the three billion people living in the developing world in 1980, approximately two billion were without adequate service. World Bank estimates of the investments required to clear the backlog of unserved people (excluding China and providing standards of service equivalent to most Bank-assisted projects) exceed $500 billion; and while the United Nations established a ten year timetable to eliminate the backlog when it inaugurated the International Drinking Water Supply and Sanitation Decade, even the most optomistic observers now conclude that this goal is well beyond reasonable expectations.

The sheer magnitude of the construction program contemplated in upgrading water supply and sanitation services worldwide is overwhelming; yet, the problem does not end there. Almost all developing nations are suffering the ill effects of inadequate maintenance of equipment and facilities; and few, if any, have achieved self sufficiency in the management and financing of water supply and sanitation systems. These and related problems are causing near universal underutilization and deterioration of existing facilities. Equally distressing, they require the diversion of scarce resources to shore-up failing facilities.

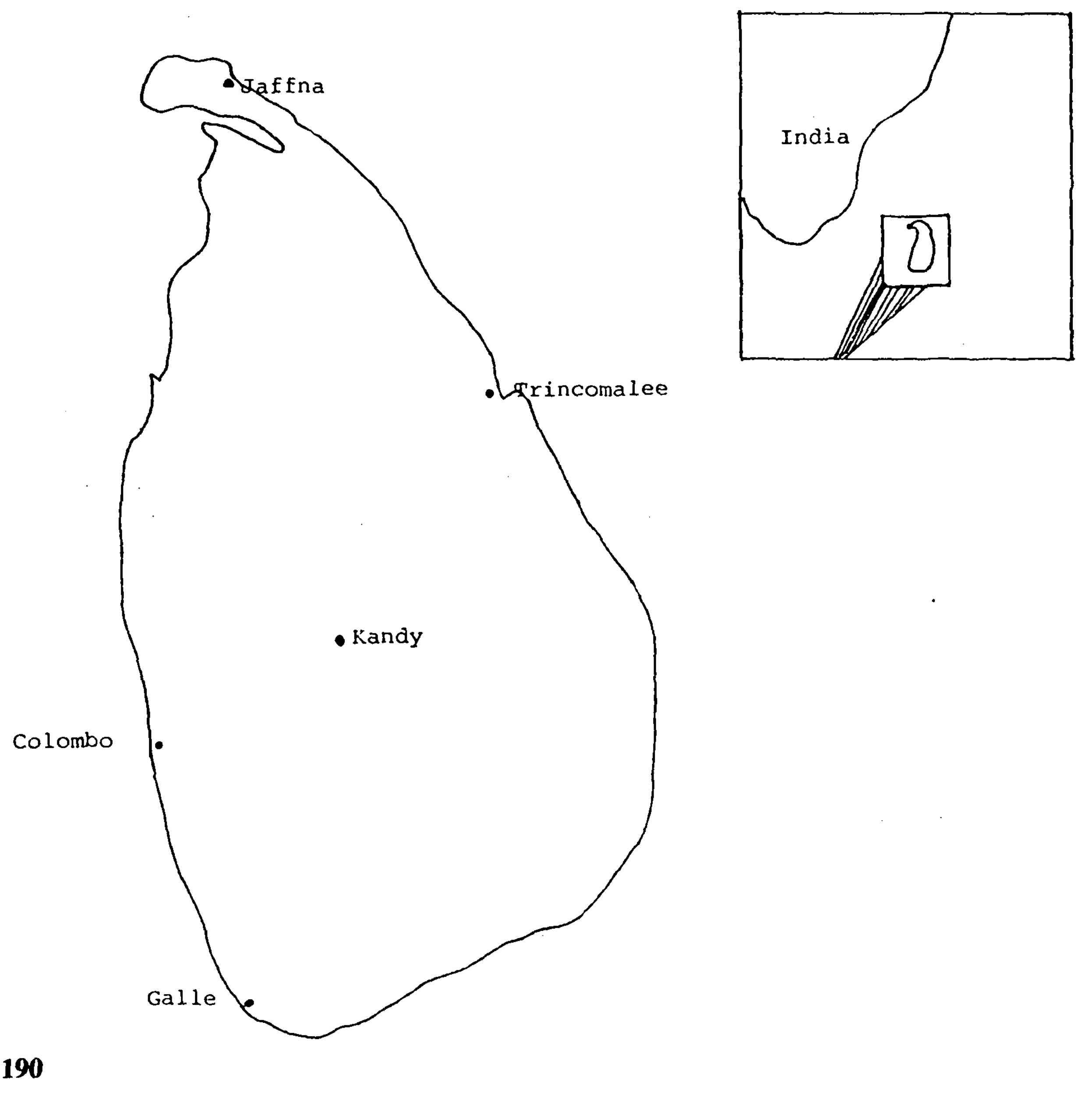
Sri Lanka, an island nation of approximately 15,000,000 population (Map included as Exhibit 1), represents a microcosm of this global water supply and sanitation development scenario -- the country's needs and expectations far outstrip available resources and the development initiatives undertaken (and the results achieved) have paralleled those experienced by other developing countries. This paper seeks to examine the Sri Lankan experience; and based on that analysis, to offer suggestions on how to improve development programs worldwide.

The central conclusion emerging from the Sri Lankan exprience is that development is something much more than project or series of projects. It is, instead, a process. More specifically, it is an evolutionary process of managed changed which enhances the abundance and quality of life and yields lasting benefits. It is most effective when undertaken in accordance with a long-term, comprehensive improvement strategy -- taking into account policy reforms and management improvements as well as infrastructure development proposals.

The case study which follows focuses on the major development programs undertaken by the National Water Supply and Drainage Board (NWSDB), the principal implementation agency for water supply and sanitation improvements. The study opens with a background statement highlighting two large scale projects funded primarily by the World Bank and an institutional development project sponsored by the USAID. Also included in this section is a summary of recent development programs undertaken by the NWSDB -- with funding support from the Asian Development Bank and the

EXHIBIT I

S R I L A N K A



World Bank. This is followed by an appraisal of Sri Lanka's overall development experience in water supply and sanitation. The appraisal sets forth a candid assessment of the good and the bad of the Sri Lankan development experience and includes a summary of lessons learned. It affords others the opportunity to share fully in Sri Lanka's learning experience and to adopt those development concepts and strategies which may have application potential elsewhere.

OVERVIEW OF THE SRI LANKAN EXPERIENCE

Sri Lanka launched an ambitious, islandwide water supply and sanitation improvement program in the mid-1970s with the creation of the National Water Supply and Drainage Board (NWSDB) and the adoption of The Sri Lanka Decade Plan. The goals of the program were indeed lofty -- to provide 100% urban water supply coverage by 1990 and to achieve 100% rural water supply and urban sanitation coverage by 1995. The organizational environment created to undertake the challenge is depicted in Exhibits II and III.

The Government immediately increased its investments in water supply and sanitation sharply (more than 200%) in quest of these goals and has since maintained a steadfast commitment to succeed. This resolve has been matched (and, in fact, multiplied severalfold financially) by ever-increasing support and assistance from the international donor community. The World Bank has financed the largest and most comprehensive projects undertaken to date, while extensive bi-lateral assistance has been provided to construct, expand or otherwise improve scores of smaller schemes. Bi-lateral assistance (USAID) has also been instrumental in opening up a new dimension -- namely, institutional development -- to Sri Lanka's water supply and sanitation development program.

This case study concentrates on the World Bank and USAID sponsored improvement programs. The World Bank Projects are important because of their size and scope and because they are illustrative of Sri Lanka's traditional water supply and sanitation development approach/experience. The USAID Project is important because it represents a unique, innovative approach to development. It is, in short, a comprehensive organization and management improvement program that seeks to transform the NWSDB into a mature, self-sufficient organization. It includes civil works, but it focuses on direly needed improvements in management and training. The study also includes a summary of recent water supply and sanitation development initiatives. These are important because they signal directions for the future in Sri Lanka.

World Bank Projects

First Project

The overall development of water supply and sewerage facilities in Greater Colombo and environs through the year 2000 was the subject of a Master Plan and Feasibility Study undertaken in 1972 by consulting engineers under contract to the World Health Organization. As a part of that study, the consultants prepared preliminary studies for high priority facilities required during

EXHIBIT II

GOVERNMENT ORGANIZATION
SRI LANKA
WATER SUPPLY & SANITATION SECTOR

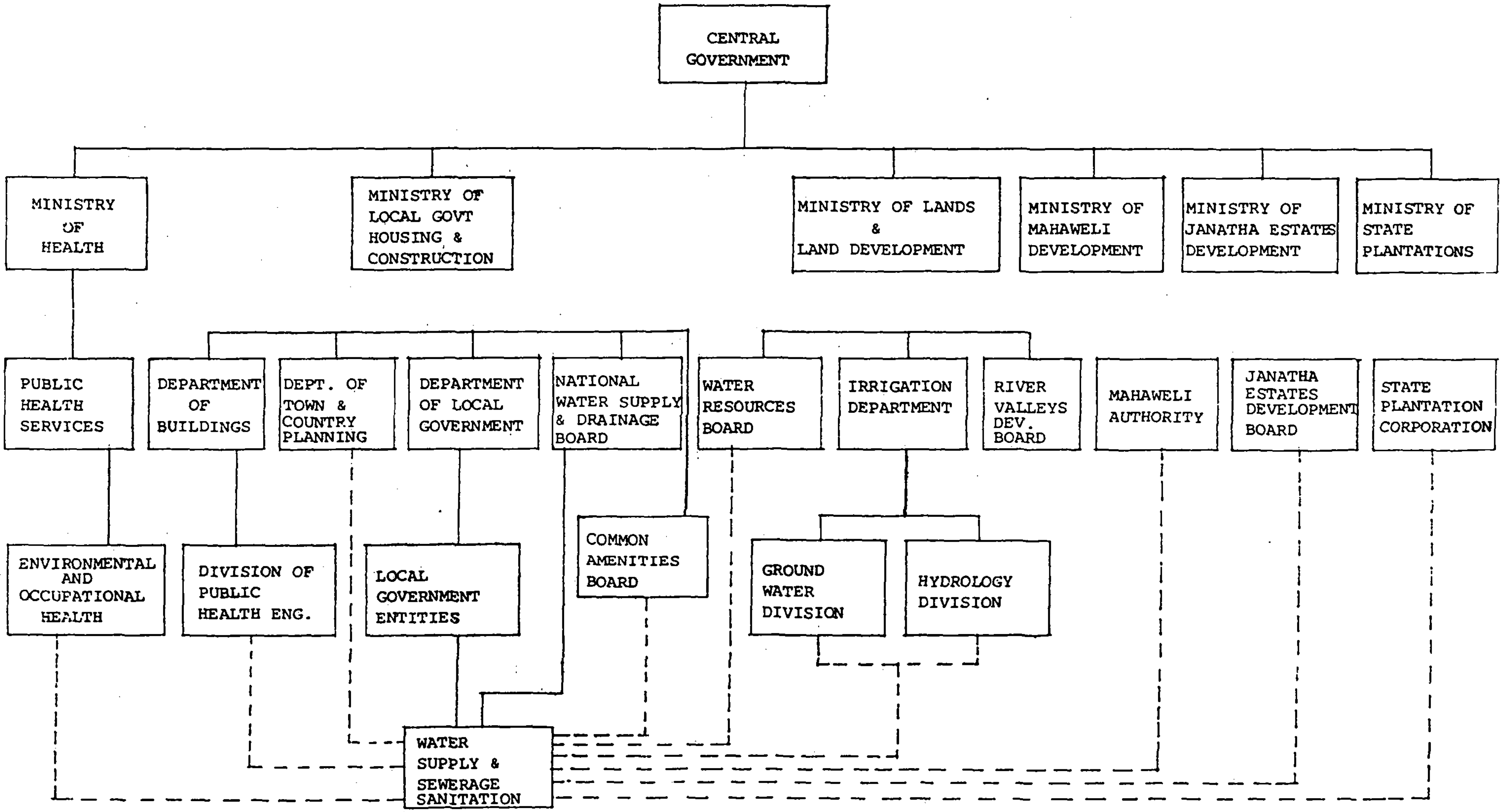
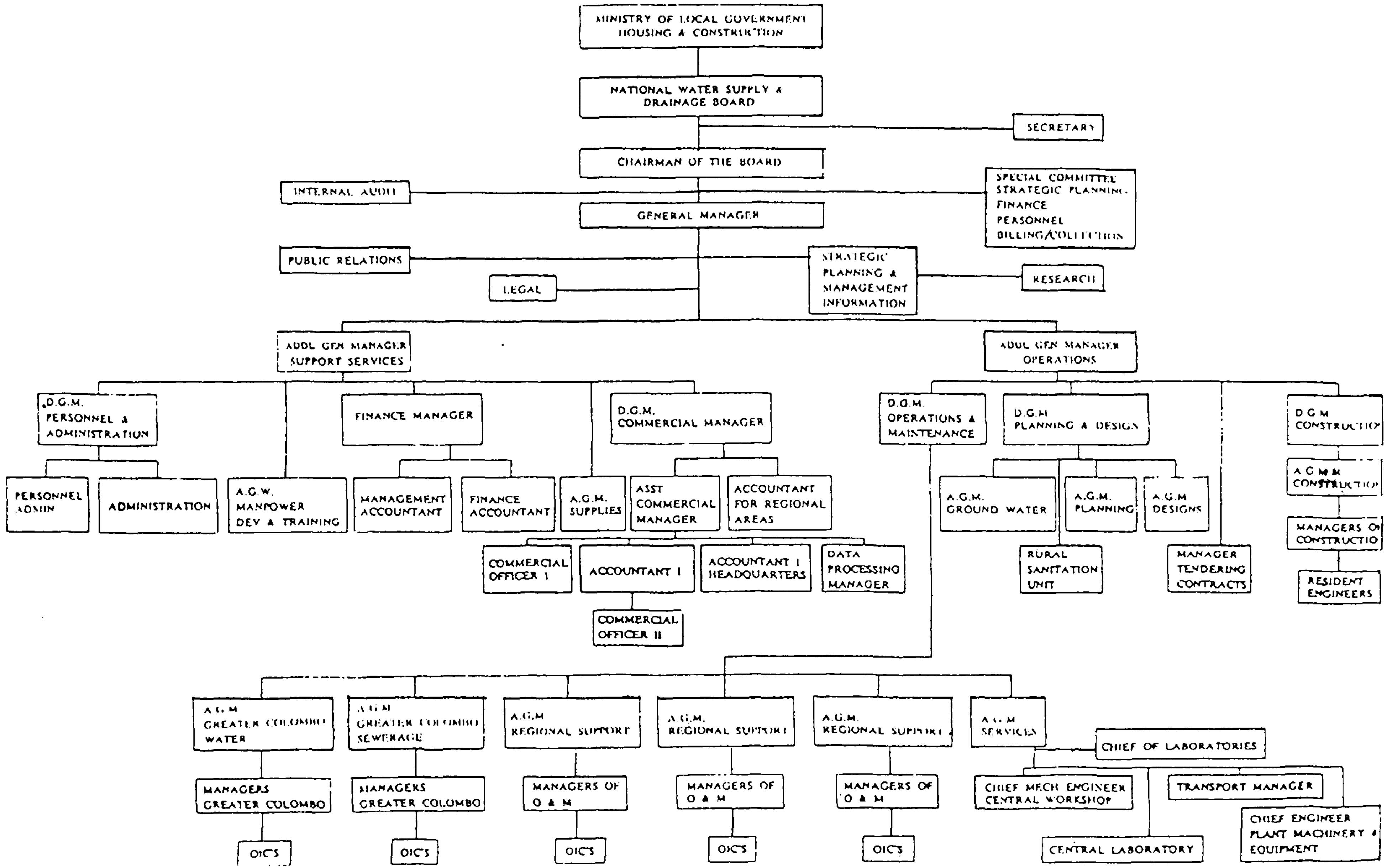


EXHIBIT III

NATIONAL WATER SUPPLY & DRAINAGE BOARD
ORGANIZATION CHART



the first five years of the Master Plan period. Bi-lateral assistance was secured to finance a portion of the requisite improvements. However, this was insufficient to complete the system. Consequently, the Government of Sri Lanka requested World Bank assistance to complete the most crucial components of the proposed improvement program.

IDA Credit 709-CE, commonly referred to as the First Project, represented the first World Bank participation in water supply and sanitation in Sri Lanka. Project objectives were: (1) to upgrade and expand water services in Greater Colombo, (2) to strengthen the institutional capabilities of the executing agency, (3) to undertake an areawide metering program, and (4) to prepare water supply and sewerage component designs for future implementation. The physical components of the project were designed to yield new or improved service to over 1.5 million people. Many of these people were among the heretofore unserved urban poor.

The project experienced significant delays and cost overruns from the very onset. Included among the most prominent factors and events contributing to these adversities were the following:

1. Change in governments -- Soon after the initial negotiations for the project were completed Sri Lanka experienced a change in governments. This required a complete review of the project.

2. Price escalation -- Original cost estimates were prepared in 1977. Spiraling energy costs, combined with rapid inflation, rendered these estimates obsolete and created a staggering funding shortfall (nearly 100%). Additional financing was required to launch the project.

3. Contract cancellations -- International competition was sought in the contracts letting process. However, the number and size of contracts were such that responses were few. Most contracts were awarded to in-country contractors who unfortunately did not have adequate resources (financial or otherwise) to execute the works. Accordingly, many contracts had to be cancelled and rebid.

4. Civil disturbances -- Work was seriously constrained as a result of civil disturbances in July, 1983.

5. Brain drain -- The implementing agency (National Water Supply and Drainage Board) suffered from continuous turnover and shortages of key management and professional staff. This problem was made more serious by the above referenced civil disturbances.

Despite these problems and delays the project was ultimately completed and, on balance, was successful. Twenty-one civil works contracts were eventually entered into and successfully completed. The NWSDB gained valuable experience in construction management and benefitted from increased exposure to modern utility management policies, practices and procedures. Finally, and most importantly, service delivery was expanded and improved appreciably, yielding direct benefits to over 1.5 million people.

The project was, however, decidedly unsuccessful in improving the management and operational capabilities of the executing agency'. Progress in these areas was confined to limited training (primarily on-the-job training); the introduction of more advanced commercial concepts in utility management; and rudimentary enhancements to established accounting and financial management systems. The project also fell considerably short of its most ambitious financial goal -- to achieve rapidly escalating rates of return of 5% in 1978, 6% in 1979-81, and 7% in 1982. In this regard, problems were experienced on both sides of the ledger. On the revenue side, experienced revealed that it was simply too ambitious to introduce dramatic changes in the commercial operations of the implementing agency and to expect rapid results. On the expense side, rapidly increasing energy prices exacted a heavy toll from the NWSDB. The NWSDB eventually fell in default of loan covenants prescribing required rates of return and had to undertake a concentrated Financial Recovery Plan to improve its financial performance.

Second Project

During the execution of the First Project it became abundantly clear that as a result of rapid development of the urban area of Greater Colombo it would be necessary to undertake as parts of the Second Project not only the sewerage system improvements studied in the First Project, but also certain of the water facilities contemplated in Stage II of the original Master Plan. Accordingly, the ultimate project design included both water and sanitation components. Water improvements included a new river intake and pumping station increasing extraction capabilities by 28 million gallons per day (and with expansion capacity to 70 million gallons per day) and improvements to the treatment and storage facilities, together with an additional pumping station and a new transmission main. Sewerage facilities consisted of two ocean outfalls; the modification and improvement of nine sewer pumping stations; the construction of eight-two kilometers of mains and six pumping stations; and extensive rehabilitation of existing mains. The sewerage system service area was expanded to include three satellite cities and the project included provision for financial incentives to encourage lower income property owners to secure connections.

The Second Project was approved and became effective in 1980. Delays were experienced in project start-up and these setbacks were compounded by the civil disturbances in July, 1983. Critical staffing deficiencies also distracted from the orderly prosecution of the project and intermittant problems were experienced with unsatisfactory contractor performance, unforeseen design and construction requirements and cost overruns.

The Second Project was recently completed; and although data have not yet been fully compiled and analyzed, it is apparant that overall results will parallel those recorded in the First Project. Civil works have been completed in full; services have been expanded and upgraded significantly; and some progress has been made in improving the organization, management and operations of the executing agency. The one area in which performance varied greatly (and, fortunately, in a most encouraging way) from earlier experience was in financial management. Billing and collection performance was improved significantly (e.g. 60% increase in monthly receipts); customer service was decentralized, with accompanying improvements in customer contact and satisfaction; accounting and financial reporting were streamlined; and increased automation was introduced. Most of these gains were made as a direct result of the Financial Recovery Plan initiated during the course of the First Project. More recently this effort has been reinforced by the USAID/NWSDB institutional development project and the employment of a team of professional managers/consultants in the Finance and Commercial Departments of tne NWSDB.

Sector Study

During the course of the Second Project the World Bank undertook a Water Supply and Sanitation Sector Study. The study, which involved intermittant consultancies by four experts and included two follow-up sessions with Government of Sri Lanka Officials, was completed and the final report issued in June, 1984. The study provided a timely and substantive assessment of overall progress to date and outlined a strategy to guide future development assistance.

The principal findings, conclusions and recommendations of the study are summarized as follows:

1. Rehabilitation -- Future development assistance should be concentrated on rehabilitation. Needs were described as quite extensive and of such urgency as to threaten public health.

2. Preventive maintenance -- The companion need to strengthen operations and maintenance was also cited as critical and time-urgent.

3. Distribution networks -- Sharp disparities in production capabilities and distribution facilities were noted, giving rise to a third recommendation to expand distribution networks. Balance in production and distribution was emphasized not only for improved plant operations but also for revenue generation.

4. Intergovernmental coordination -- Interagency cooperation and coordination in water supply and sanitation were judged deficient; hence, a recommendation was included urging immediate exploration of practical and permanent solutions to enhance interagency coordination.

5. Fiscal responsibility -- The study revealed a deteriorating financial situation at the National Water Supply and Drainage Board which was characterized as 'a matter of major concern'. This led to forceful recommendation to pursue billing and collection aggressively.

6. Investment planning -- The report concluded with a recommendation to review the sector's investment program and to formulate a macro-investment plan to guide future development programs.

The Government of Sri Lanka responded admirably to the findings, conclusions and recommendations set forth in the report. For example, the NWSDB, as mentioned earlier, immediately undertook an intensive, high priority financial recovery program; and, as indicated above, ultimately recorded significant gains in billing and collection performance and made noteworthy improvements in accounting and financial reporting. The NWSDB also commissioned a consultant study to prepare a macro-investment plan; and after review and approval of the plan, the agency convened an international donors conference to apprise everyone of its long-range plans and to enlist their cooperation and support. Finally, the NWSDB initiated a long-term, comprehensive institutional development program to improve its organization, management and operations.

Institutional Development

The USAID/NWSDB Institutional Development Project introduced above, and discussed briefly earlier in this case study, is an all-encompassing management improvement program. Its ultimate goal is to make the NWDSB a self reliant, competent organization.

Pursuant to this overall goal, the original project design cited a twofold objective: (1) to develop and improve the institutional capabilities of the National Water Supply and Drainage Board to plan, design, rehabilitate/construct, operate and maintain water and sanitation systems throughout Sri Lanka; and (2) to develop and improve health education, rural sanitation services and community participation in water supply and sanitation. The project design went on to delineate scores of expected improvements and outputs in six major areas of management improvement (e.g. management, commercial, human resources development, capital facilities management, operations and maintenance and special services) and in health education, sanitation and community participation.

The program was originally budgeted at $US 19.6 and included over 500 person months of technical assistance. Project implementation was begun in earnest in April, 1985. Since then the overall concept and approach of the project have remained constant, but priorities and implementation strategies have been subjected to periodic review and revision. Results to date have been mixed at best; at worst, they have fallen woefully short of original expectations.

The project has been beset with problems since start-up. Both the NWDSB and the consultant experienced problems with staff mobilization; and in the case of the consultant, these early difficulties were exacerbated by excessive turn-over in resident staff, including, for example, replacement of both the team leader and the deputy team leader within the first few months of the project. These, and related problems, reached crisis proportions approximately four months into the project when it became apparant that the NWSDB and its consultant could not meet certain 'conditions precedent to disbursement'. High level intervention on the part of both the Government of Sri Lanka and the USAID was required to ameliorate the crisis (e.g. potential cancellation of the project).

Unfortunately, settlement of this early crisis did not resolve underlying difficulties with the project. Instead, problems grew worse; and according to some accounts, resistance to change (the natural phenomenon which can be anticipated in any institutional development program) was being replaced by overt opposition to the project. The USAID commissioned a study to examine these and related problems. The survey report confirmed feelings about deficiencies in the project; cited multiple factors contributing to those shortcomings; and offered several worthwhile suggestions for improving project execution. In the process, the study arrested a rapidly deteriorating situation and marked a turning point in the project.

Since the issuance of the USAID Project Evaluation Report, the Government of Sri Lanka, the consultant and the USAID all have taken important decisions and actions designed to improve the management and execution of the project. Problems persist and progress remains slow and uncertain. Nevertheless, progress is being made and project implementation is showing gradual signs of improvement. Moreover, some complementary programs recently undertaken by the NWSDB in consultation with the Asian Development Bank and the World Bank hold promise of reinforcing (and, hopefully, accelerating) the USAID project. Those recent initiatives are discussed in the ensuing paragraphs.

Recent Development Initiatives

The NWSDB has taken some decisive steps during recent months to overcome its longstanding deficiencies in financial performance and to address rapidly emerging, increasingly serious problems in operations and maintenance. The new initiatives have been taken collaboration with the Asian Development Bank and the World Bank, and with significant, long-term financial support and assistance from those institutions.

World Bank Projects

The World Bank program (Third Water Supply and Sanitation Project and a companion Municipal Management Improvement Project) represents a continuation of the Sri Lanka/World Bank partnership forged some ten years ago to foster development in water supply and sanitation. The program includes extensive capital improvements. However, its most distinguishing characteristics are: (1) a broader, more enlightened approach to development in the water supply and sanitation sector; and (2) a renewed commitment to institutional development, with particular emphasis on improving NWSDB accounting and financial management policies, practices and procedures.

The long-term health and well-being of the NWSDB are inextricably linked to the growth and development of municipal governments islandwide. Municipal governments are at present the NWSDB's largest customers and they are targeted to assume responsibility for retail water and sewer operations in the near future. This interdependency has long been recognized, but not directly supported by development programs. The Government of Sri Lanka and the World Bank addressed this issue forthrightly in the formulation of their most recent development program; and in the process, developed a more comprehensive, far reaching improvement strategy, including among other things several specific steps to enhance the financial health of the NWSDB. Both projects are, for example, committed to improving billing and collection for water and sewer services. They also share mutually supportive strategies to increase consumer connections, to reduce wastage, to strengthen operations and maintenance, and to eliminate municipal arrears to the NWSDB. This latter objective is particularly important to the financial health of the NWSDB since 22% of the current debt owed the NWSDB is attributable to local governments.

Concurrent with the adoption of this expanded water supply and sanitation development strategy, the Government of Sri Lanka, working in close harmony with the World Bank, took a number of important policy decisions and management actions designed to strengthen the institutional capacity of the NWSDB. At the national government level the Cabinet reaffirmed the Government's commitment to systems rehabilitation and improved operations and maintenance, and agreed to provide the NWSDB with revenue grants when the agency was required to construct or to assume responsibility for water or sewer schemes which had been determined in advance to be commercially non-viable. At the implementing agency level, the World Bank at the request of the NWSDB agreed to fund five management and professional positions (Sri Lankan professionals serving in a dual capacity as consultants and line managers and/or senior level professional staff) in the Finance and Commercial Departments of the organization and to support increased training. The Bank also agree to fund an accelerated meter rectification and customer connection program, and to support two technical assistance efforts (one designed to strengthen internal audit and one required to complete a fixed assets inventory). It is too early to assess fully the impact of these recent decisions and actions. However, preliminary results suggest that the employment of the five management and professional staff represents the most positive step taken to date in improving the financial health of the NWSDB -- and perhaps the most important step taken to date in achieving institutional development. The policy decisions are designed to yield long-range benefits; hence, their impact will have to be measured at a later date. Nevertheless, it is reasonable to assume that they will have profound effect, and that they will contribute significantly to achieving institutional reform. Similarly, the expanded development strategy (addressing the NWSDB and local governments simultaneously) is designed to produce long-term, sustainable gains. Both the Government of Sri Lanka and the World Bank are most encouraged by preliminary results. However, these accomplishments must stand the test of time before a meaningful evaluation can be performed.

ADB Water Supply Project

The NWSDB/ADB Water Supply Project is the most recent major development program undertaken by the NWSDB. The project is still in the early stages of mobilization and, therefore, cannot be assessed in terms of development experience or impact. It is, however, important to review the scope and content of the project for they provide valuable insight into the current problems and needs of the NWSDB; and, therefore, serve as a useful barometer to measure previous development experience.

The primary objective of the project, as described in official project documents, is 'to provide an adequate, safe and reliable water supply service to 800,000 people'. In keeping with this overall objective, the project aspires: (1) to improve water accountability and to enhance revenues; (2) to rehabilitate 30-40 water supply schemes; (3) to improve operations and maintenance; (4) to attain financial viability; and (5) to facilitate the transfer of water distribution systems from the NWSDB to concerned local authorities.

This statement of work is quite revealing. It reaffirms, in general, the major findings and conclusions of the World Bank Sector Survey Mission (e.g. operations and maintenance are deficient, the NWSDB needs to increase revenues and to improve its financial management, rehabilitation requires high priority attention, etcetera); it establishes the fact that the NWSDB has not achieved institutional maturity; and it confirms an emerging awareness that development is a long-term, intricate process.

Going beyond the basic statement of work, project documents call for improved systems and procedures, increased attention to training and staff development, expanded health education, greater fiscal responsibility, improved interagency coordination and cooperation, and a host of related improvements. Again, the task list serves not just to reveal shortcomings at the NWSDB, but also to demonstrate that lasting solutions to the water supply and sanitation problems of Sri Lanka lie not in civil works alone, but in development in its broadest and most comprehensive sense.

EVALUATION OF RESULTS ACHIEVED

Perhaps the most difficult challenge in evaluating Sri Lanka's overall development experience in water supply and sanitation is to determine what constitutes success. One approach would be to assess results in relation to goals defined in the Sri Lanka Decade Plan. However, objective analysis of the Decade Plan suggests that it was not a well-conceived document. Its goals, like those of the United Nations International Drinking Water Supply and Sanitation Decade Plan from which it was derived, were indeed wholesome. Unfortunately, they were, at the same time, overly simplified and unduly optimistic. Coverage objectives were, for example, so straightforward and ambitious that they may have at times actually distracted from true development (e.g. lasting improvements) by encouraging accelerated construction programs without requiring commensurate attention to proper planning and ongoing management and operation of newly acquired facilities. Another approach which could be taken in measuring the success of various development programs would be to appraise results in light of project specific goals and objectives. This approach has merit, but it is narrow in scope. Moreover, it presumes that project goals were indeed well thoughtout. Again, Sri Lanka's experience suggests that project designs are not always thoroughly researched. Hence, a project can be completely successful in terms of project specific goals (i.e. contruction of X miles of mains, in Y period of time, at z cost) and yet be a detriment to development as a result of having, for example, introduced inappropriate technology, created financial hardship or caused other undesirable effects/results. Still another approach which could be taken in evaluating development would be to assess performance in terms of benefits derived or clientele served. This is an attractive alternative, but it is difficult to achieve. It requires a level of sophistication in data collection and analysis that is not always readily available. Furthermore, it is a dynamic process and relys heavily on subjective judgements. Finally, Sri Lanka's overall water supply and sanitation development experience could be examined on the basis of contributions made toward the attainment of national goals and objectives. This approach offers the advantage of broad, long-range perspective, but it, too, is very difficult to achieve. Quantifying national goals and objectives is in itself a very difficult task. To correlate and evaluate effectively development in water supply and sanitation in relation to those goals would be eminently more difficult. Nevertheless, failure to do so, at least in general terms, would result in a serious omission -- for what good is development in any sector if it does not contribute to the attainment of national goals.

Difficulties in deciding on the approach to be taken in evaluating development are compounded by the need to consider varying perspectives and priorities. The completion of a water treatment plant is, for example, viewed quite differently by an engineer and an economist -- and their differences are multiplied exponentially when the opinions of public health specialists, administrators, financial analysts, etcetera are taken into account. Evaluation is further complicated by the need to be sensitive to a host of external influences (i.e. prevailing traditions and value systems, political considerations, absorptive capacity, etcetera).

In short, evaluation is an exceedingly difficult, complex task. In this regard, it parallels the process (e.g. development) it seeks to examine and attests to the premise that development is something much more than a mere project or series of projects.

Decade of Progress in Perspective

It would be an interesting, worthwhile exercise to examine each and every water supply and sanitation development project in light of all of the above outlined criteria. However, the purpose of this paper is to make a summary appraisal of the overall development experience and to identify concepts, techniques and lessons learned which may have application potential elsewhere. Consequently, Sri Lanka's water supply and sanitation development experience will be examined in the context of a continuum of improvements, with attention focused on determining the aggregate effect of that overall experience and the reasons why some projects (or project components) succeeded while others failed.

Major Accomplishments

Sri Lanka's overall development experience in water supply and sanitation has been quite positive. Systematic progress has been made toward the attainment of most project specific goals and objectives; and these accomplishments, in sum, have contributed significantly to the fullfillment of national goals and objectives. Most importantly, the people have been well served. Millions of heretofore unserved citizens now have ready access to potable water and sanitation facilities and standards have been improved markedly.

Census data collected shortly after the adoption of the Decade Plan indicated coverage by piped water systems to be less than 50% of the urban population and 5% of the rural population. Today more than 75% of urban dwellers enjoy access to piped water and coverage in rural areas has been increased threefold (to 15%) -- and construction continues at a rapid pace. Access to sanitary facilities also shows significant signs of improvement. Whereas only a small percentage of the population had access to some type of latrine facility less than ten years ago, current data indicate that over 70% of the population have access to sanitary facilities. Even in rural areas coverage has been increased to approximately one-third of the population.

Construction statistics associated with this expansion provide convincing evidence of improvements. The NWSDB has managed a construction program averaging $US 40 million per year; and although delays and cost overruns have been commonplace, all projects have ultimately been completed. The NWSDB, when created less than a decade ago, assumed responsibility for 96 water schemes; today the agency operates over 200 schemes and fixed assets have been increased by a factor of 250. Similar progress has been recorded in the construction of improved sanitation facilities; and the overall magnitude of the construction program has been accompanied by increasing size, complexity and sophistication of individual projects undertaken. The NWSDB has, for example, undertaken or managed the construction of large impoundment facilities and conveyance systems, complex intake and treatment works, large scale sewerage collection and disposal facilities (including two ocean outfalls and numerous pumping stations) and numerous other demanding construction projects.

These physical improvements (and the concomitant expansion and improvement in service delivery systems) have been accompanied by significant socio-economic advancements and some progress has been made toward strengthening the organization, management and operations of the NWSDB. Health statistics, particularly those related to cholera and other diseases linked to inadequate water supply and sanitation, have reflected steady improvement. Economic development has been stimulated, and the broader, more all-encompassing objectives of various national development programs have been well served.

Finally, the Government has made noteworthy progress in improving its strategic planning for water supply and sanitation and it has demonstrated an ever-increasing awareness of the need for (and the capacity to facilitate) interagency coordination and cooperation. As a result the Government's goals and priorities are more clearly defined (and better understood). Its capacity to formulate more enlightened policy has been strengthened. And its ability to prepare and execute more effective development plans has been enhanced. These improvements should, in time, obviate (or at least minimize) perennial problems associated with financial performance and the operation and maintenance of facilities and equipment.

Present Situation

Nothwithstanding the numerous, very encouraging signs of progress cited above, the Government of Sri Lanka has not achieved optimal efficiency and effectiveness in the design and execution of its water supply and sanitation development programs. On the contrary, the Government (and more specifically, the NWSDB) still faces a formidable challenge in improving its capacity to formulate well conceived development plans and in accomplishing timely and efficient execution of those plans. Even more disquieting is the fact that the NWSDB has still not made sufficient progress toward achieving institutional maturity and current efforts are not yeilding satisfactory results. The agency is still incapable of operating and maintaining existing facilities efficiently and effectively; it is inordinately dependent upon consultants; its financial position is desperate; and it has not demonstrated the capacity to attract and retain competent staff.

A partial listing of some of the most urgent problems and needs confronting the NWSDB will attest to the magnitude and complexity of the challenge at hand.

1. Operations and Maintenance -- A recent consultant study (August, '86) reconfirmed findings of earlier studies (e.g. plant and equipment are in a constant state of deterioration and O&M activities are typically assigned very low priorities) and offered an action plan to improve O&M. One scheme studied in depth was less than two years old at the time of the study and was conservatively estimated to be at least 40% overstaffed; yet, it was in a serious state of disarray and becoming worse each day. Regretfully, the study recommendations have not been yet implemented.

2. Rehabilitation -- As indicated earlier, the scope and content of the ADB project provide prima facia evidence of the sub-standard condition of some 30-40 schemes islandwide. The Government, too, has acknowledged this problem/need; and, by Cabinet decision, has established rehabilitation as its number one priority in the water supply and sanitation sector.

3. Commercial Viability -- The NWSDB has made significant progress in its quest to attain commercial viability. Nevertheless, its level of achievement remains well short of commitments made both to the Government of Sri Lanka and to the international donor community. Progress to date is most commendable, but the challenge is great.

4. Institutional Development -- The organization and management of the NWSDB are seriously deficient. As indicated above, the organization has been reinforced by extensive use of consultants; yet, it is still unable to discharge even its most basic duties and responsibilities satisfactorily. To achieve proficient management is, of course, exceedingly difficult; and in fairness to the NWSDB, it must be reiterated that some progress has been made. Nonetheless, the challenge to improve administrative management will remain the loftiest (and very possibly the most elusive) of goals in the years ahead. Moreover, the challenge is not confined to the NWSDB. The Government, as mentioned earlier, has launched a very ambitious decentralization program which calls for the transfer of water supply and sanitation O&M responsibilities to local authorities. Hence, these entities, too, will require extensive institutional strengthening.

Lessons Learned

The Sri Lankan development experience in water supply and sanitation has been most informative. It has given rise to many lessons learned and it has enhanced the Government's capacity to plan, organize and direct future programs more efficiently and effectively.

Central Conclusion

The most important lesson learned from the Sri Lankan development experience is that development -- genuine development -- is something much more complex than a project or a series of projects. It is, instead, a process. More specifically, it is a process of managed change. It is evolutionary in character; it requires multiple inputs; and it very often involves policy reforms and management improvements as well as infrastructure development proposals. When properly done, development enhances the abundance and quality of life and yields lasting benefits.

Infrastructure development is, of course, the most attractive component of the development process. Bricks and mortar are easily understood, measured and financed. And those involved in the development process typically receive their greatest accolades when new facilities are commissioned. Yet, development is often best served when a decision is taken not to build a certain facility -- or to alter its design or construction priority. The Sri Lankan experience illustrates this finding quite vividly. The Government in its zeal to achieve the coverage objectives set forth in the Decade Plan has constructed numerous schemes which are not commercially viable. This places a heavy financial burden not only upon the implementing agency but also upon the Government. Moreover, it inevitably distracts from proper operation and maintenance because scarce resorces are diverted to fund deficits. In other cases hasty decisions taken to pursue new construction goals have led to wasteful resouce allocation, inappropriate technology, proliferation of equipment and supplies and a host of related problems. In short, Sri Lanka would be better off today if it had on many occasions shown the wisdom and fortitude to say no -- even when donor agencies offered 100% funding for new construction projects.

In addition to encouraging broader perspective, the Sri Lankan experience (process) suggests the need for more long-range planning and commitment. And in this regard, recent decisions and actions taken by the Government of Sri Lanka speak well of the foresight and courage now being exercised in their planning and decision-making processes. For example, all development projects are now subjected to a very deliberate review and evaluation process; and in the case of water supply schemes, commercial viability must be demonstrated before projects are approved or a conscious, up-front decision must be taken to fund projected shortfalls from the national treasury. The Government (and more recently, the international donor community) has also acknowledged formally the vital linkage between local government reform and improvements in the water supply and sanitation sector; and it has initiated a comprehensive, long-term management improvement program designed to address simultaneously the companion needs of both sectors.

Sri Lanka no longer views individual projects/initiatives as separate and distinct undertakings. Instead, they are viewed as vital components of a larger, more important development process -- and they are subordinate to that process.

Success Criteria

The Sri Lankan development experience also suggests that there are several rather straightforward, yet exceedingly important guiding principles -- or success criteria -- which should be kept uppermost in mind when formulating and executing a development program. These criteria, as summarized below, flow logically from the premise that development is a process. Collectively, they constitute a sound project design and implementation strategy, if not a formula for success.

1. All development proposals should take cognizance of established policy and prevailing traditions and value systems; specific projects should be fully integrated with country's macro-investment strategy/plan.

2. Individual development projects, like the country's overall development program, should be comprehensive in scope. They should address (individually or in concert with other development projects) the full range of needs of a development sector or institution; and when civil works are involved, they should ensure capacity to manage, operate and maintain those facilities after commissioning.

3. Project designs should be sufficiently visionary and flexible to encourage initiative and creative; at the same time goal setting should be tempered by reason and accountability should be assiduously preserved.

4. Project execution should be monitored closely, with specific provision made for periodic review and evaluation of results achieved (ideally, by independent authority) and reprogramming.

5. Success should be measured on the basis of predetermined, project specific standards of excellence as well as progress made toward the attainment of national goals.

Planning has been characterized as the essential prerequisite to effective management. The Sri Lankan development experience confirms this axiom; therefore, the Sri Lankan success formula places significant emphasis upon planning. Success criteria 1-3 are devoted almost exclusively to planning, and criteria 4 and 5 depend greatly upon competent planning. The Sri Lankan success formula goes on to prescribe some of the characteristics of (or minimum requirements for) a successful planning process. Planning must be tailored to needs, requirements and expectations of the host government. It should be forward-thinking, but not utopian. It should be comprehensive, but not unduly burdensome. And it should facilitate development, rather than supercede development.

Planning is important, but program/project implementation is preeminent. And the Sri Lankan experience suggests that intensive management is the key to success in program/project implementation. Rigorous management is crucial because delays (or worse, failures) retard overall development and cause increases, very often sharp increases, in unit costs. Severe delays can even cause losses in funding support -- either through missed financing opportunities or lapsed credits/loans. The need for intensive management is compounded by the fact that developing nations are generally heavily dependent upon foreign technical assistance, and the long-term interests of the country and those of the source(s) of technical assistance are not always synonymous.

The Sri Lankan success formula presumes two factors to be of paramount importance to the management process and, thus, to effective project management/implementation. First, understanding and agreement must be reached as to what constitutes success and how it will be measured. Second, the measurement process must be undertaken systematically. Determining what constitutes success and how it should be measured seems straightforward; and, in fact, when civil works are the principal component of a development initiative such determinations are generally accomplished quite readily. However, when policy reforms and/or management improvements are involved the process becomes much more difficult. The NWSDB/USAID institutional development project offers a grievous example of this dilemma. After nearly two years of project implementation, the program still suffers from a pervasive lack of understanding and agreement as to what its purpose(s) and priorities are and how progress/success should be measured. Sytematic review and evaluation of results achieved and reprogramming, too, seems straightforward. Yet, the Government of Sri Lanka has not always achieved satisfactory results in monitoring its water supply and sanitation projects. Instead, the Government has often been confronted with staggering revelations or crises which could have been avoided if a competent review and evaluation and reprogramming system had been in place. What is required is an orderly, unbiased system that will contribute to informed decion-taking. This need is best served by a comprehensive reporting system, supplemented by regularly scheduled project monitoring sessions and occasional outside intervention. The important consideration is to go beyond the 'good news', and to address forthrightly the full range of problems, needs and opportunities which inevitably emerge during project implementation.

Other Findings and Conclusions

In addition to the major findings and conclusions set forth above, the Sri Lankan development experience has revealed numerous 'dos and don'ts', early warning signals and project implementation techniques which are noteworthy of mention. Several of the most important of these are presented in the following random list.

1. Appropriate technology -- The importance of appropriate technology is frequently cited as being extremely

important to optimum development. The Sri Lankan experience has reconfirmed this maxim; therefore, it deserves repeating. Development professionals should be evermindful of the need to adopt appropriate technology. Included among the decision criteria to be considered are: (a) all-in costs, (b) capacity to operate and maintain proposed technologies, and (c) availability of replacement parts.

2. Project mobilization -- Development is greatly facilitated by timely, effective mobilization. Costs can be reduced sharply; and when consultants are involved, their work can be expedited and made more effective by well planned, properly executed project mobilization.

3. Consultant selection/management -- Two findings emerge from the Sri Lankan experience with regard to consultant selection/management: (1) the challenge is of paramount importance, and (2) present capabilities/techniques are inadequate. Developing nations are heavily dependent on consultants; yet, they are ill-equipped to perform these all important fuctions. This is a subject which deserves further research; and perhaps some form on intervention (i.e. training, guidelines or technical assistance) from the professional community to assist developing nations.

4. Coordination/cooperation -- Platitudes abound about the need for and value of interagency coordination and cooperation. The Sri Lankan experience bears witness to this premise. More importantly, it has yielded some valuable insights into how to achieve improved coordination/cooperation. First and foremost, the host country must establish a well conceived, clearly articulated strategic plan -- and promulgate 'the rules of the game'. The international donor community must then tailor its support programs to the dictates of the plan -- or seek amendments to the plan if such is deemed necessary or desirable. The two (host country and donor community) must then work diligently to ensure thorough understanding of and commitment to the strategy/plan and to enforce compliance. As a part of the enforcement effort the project review and evaluation and reprogramming process referred to earlier should include interagency coordination/cooperation as one of its benchmarks for measuring success.

5. Standardization -- Included among 'the rules of the game' which should be promulgated is a requirement to encourage standardization of equipment, materials and supplies. The advantages of standardization are well known and broadly accepted. Nevertheless, Sri Lanka, like most developing countries, has experienced difficulties in achieving standardization; and the resultant costs -- unnecessary costs for expanded inventories, down-time, etcetera -- have been exhorbitant.

6. Local participation -- Extensive local participation, not only by counterparts but also by local consultants and construction personnel should be viewed as an integral part of the development process. Indeed, for institutional development projects (and certain technical assistance and training projects) the 'litmus test' should be the speed and effectiveness with which consultants transfer skills and 'work themselves out of a job'.

7. Project organization -- Development initiatives should, to the extent feasible, be integrated with all other programs and activities. Donor agencies often recommend a separate 'project cell' or 'project implementation team'. However, such specialization is wasteful and it is contrary to good management practice. Even when such organizations expedite implementation of project objectives they distract from overall development -- for they inevitably constrain institutional development.

8. Perspective -- Closely allied to the concept of development being a process is the need to maintain perspective. Development professionals should aim high, but they must be realistic. Equally important, they must blend persistence with patience. Development does not occur; it evolves.

Summary

The Sri Lankan development experience in water supply and sanitation has been characterized as a decade of progress -- a decade of progress which has fostered growth and development and made life safer and much more pleasant for millions of heretofore unserved or underserved citizens.

Those involved in the development process point with justifiable pride to their many successes. At the same time, they readily acknowledge that there have been peaks and valleys in their performance, and that there have been occasional failures. They emphasize further that they have remained openminded throughout the process: and that this receptivity to change, coupled with an unswerving commitment to succeed, has enabled them to transform many set-backs into learning experiences. This, in turn, it has enabled them to raise steadily their level of overall achievement. It has also demonstrated convincingly that development is not just a project, but a long-ranged, all-encompassing process of managed change.

APPROPRIATE TECHNOLOGY FOR WATER SYSTEMS
From the Point of View of a Consulting Engineer

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INTRODUCTION

Appropriate technology can be defined as the technology appropriate for the conditions of the user. The process of transferring appropriate technology by the party that lacks it implies that its need is acknowledged. However, the technologies to be transferred and the methods of transferring them are something that the consultant should decide on.

The words "appropriate technology" or "transfer of technology" are phrases often seen in the Terms of Reference for Consultancy contracts. Although so many definitions abound on the subject, technology transfer, which is the step after deciding on what is the appropriate technology to be transferred, is simply putting something which is known into use or to a new application. This is through bringing new ideas, knowledge, experience, know-how, processes and products to the party that needs it. For such transfer to be effective, the appropriate technology, ideas and information must be moved in a conscious, well-planned manner. The movement of appropriate technology to the user is best done by a "linker". In engineering, the role of the linker is best played by the consulting engineer because his business is being faced with problems where solutions (new processes) must be found. Also, the consulting engineer, in transferring appropriate technology, can create an ideal and productive environment that can approximate the real world.

II. APPROPRIATE TECHNOLOGY FOR WATER SUPPLY SYSTEMS

Appropriate technology must be properly introduced to cope with conditions in projects varying from a small scale rural water supply to a huge scale metropolitan water supply system. Because of this wide range in scale, it is difficult to define what may truly be an technology although many efforts have been made by many to present measures that could apply suitably for each project's condition. For example, one measure which is suitable for one country may not be feasible for others. This matter is sometimes neglected by engineers who do not understand the country's economic, social and physical situations. As a result, constructed facilities are not as useful as expected by the designer; worse, it may not function.

Difficulties may also be due to the fact that a project undergoes several steps which start from identification, followed by master planning, feasibility study, detailed design, construction, and management and operation. To complete these steps would usually require a long time so that an original concept for implementing a project sometimes needs to be revised to suit the circumstances of the project. Therefore, technology which is originally proposed to be most appropriate may not be so, since with the lapse of time, the social and economic situations of that country have changed. Of course, at each step of a project, review and revisions are made to adjust the direction of implementation and find a most efficient and economical system.

Despite the difficulty to specify what is appropriate, the conceptual considerations are to seek for appropriate schemes in planning and designing water supply systems. There are two major factors to be considered : institutional and technical aspects. Institutional aspect may be discussed during this conference by other speakers; in this subject, I would like to present the technical aspect from the standpoint of a consulting engineer.

III. TECHNICAL ASPECTS

There are three major strategies to be considered when a water supply project is initiated and planned:

A. Grade of supplying method

As a basic concept of water supply, the first consideration is to determine to what extent water is to be supplied. This concept identifies a physical target of the water supply system for some grades of supplying water such as:

1. Manually transporting water from source point
2. Provision of shallow wells at each household (Point Source)
3. Provision of communal faucets for groups of household with or without pipe line from water sources
4. Provision of pipeline to each household

Selection among these grades can be made according to the population density, water resources, topography etc. The first three grades are usually for rural water supply, while the urban water supply always requires the fourth grade, which is the provision of supply to each household. Since the appropriate selection of the rural water supply grade will be made from three grades, each community's conditions should be studied. A classification of the communities by population, area, family, and social and economic situation, helps the planner determine the suitable water supply grade for each target. This work requires great perseverance but must be done to establish a good foundation of the project implementation.

Planning an urban water supply is easier in this regard since a planner can concentrate his efforts on the parameters necessary to determine the water demand, system constituent and their implementation scheme. But the urban water supply system will have water supply facilities which would be larger and more costly in construction, and operation and maintenance as compared to the rural water supply system.

From the above, it can be gleaned that a planner for rural water supply should have greater management and economic/financial background while a planner for urban water supply needs to have more engineering experience.

B. Grade of quality supplied water

The quality of water must meet the standards for drinking purposes. This is not always true in rural areas where experienced operators or proper treatment systems are not available. Urban water supply is however required to meet drinking water quality standards Planners and designers should always make efforts to achieve the goal of providing safe and sufficient water supply. However, various actual conditions show up as obstacle: high content of iron or manganese, salt water intrusion (for a case of groundwater), growth of algae, pollution caused by man or by agriculture (for a case of surface water) etc. To cope with these obstacles, designers may propose some counter measures such as a treatment system, or other alternatives for water intake method.

However, under urgent conditions, some communities are in dire need of water, even with lower quality, for drinking purpose. This is likely to happen in a rural water supply project. In such a case, it is best to educate the people to use a simple filter consisting of fine sand or charcoal and to boil water before drinking. If planners or designers insist that the water should always meet the set standards, the question would be who should shoulder the financial burden for treatment facilities or for higher cost for developing better water resources. In other words, water works engineering must be able to respond to actual conditions.

C. Grade of system performance

The selection of system components and its operational concept are more important in urban water supply than in rural water supply because of the complexity of the facilities and the large number of beneficiaries relying on one system.

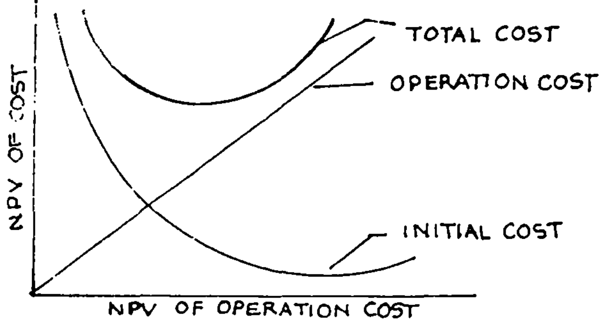
There are two extremes when considering system components and operational aspects: the completely automatic operation, and the traditional manual operation. In designing a system, these two methods are combined in the total system and in smaller components in the system. A designer should determine what is suitable for the project from a broad range of alternatives.

A designer is sometimes attracted to introduce the automatic operation by reason that a machine would work well instead of less experienced operators. A client may even insists on the most sophisticated systems. However, we should not forget to consider the availability of spare parts, the maintenance of the system as well as its cost. Even small parts of electric circuits are not easily available in some rural areas. Consequently, an automatic instrumentation system can not help but be converted to a manual operation system some years after construction. On the other hand, some automatic systems would work very efficiently in terms of cost reduction in operation in some large cities like Bangkok where sufficient maintenance services are available.

Selection of the system components should be made at every stage in the design and for every part in the system which vary from a small matter such as type of pump to a rather bigger issue like a transmission system or a total control system. Decision should be made after sufficient discussion between the client and the designer, especially about:

- how the system should be managed and operated,
- if spare parts or chemicals are easily available
- what the status of power supply or telecommunication is,
- how easy the repair work can be made, and
- what measures could be made for preventing accidents (or environmental protection).

Aside from these technical concepts, people's demand for water supply should be carefully considered. For example, in Japan, the water supply system is designed with a big safety factor so that the water interruption could be avoided as much as possible. Therefore, the system requires high investment in its initial cost by providing considerably high quality materials and advanced equipment. Reduction in its initial cost would be possible by employing cheaper materials or equipment on the condition that such system may need more frequent repair than systems which need higher initial cost. This relation is in principle presented in the figure below.



The determination of the system should be made step by step; concepts of the design and systems function should be explained to the client until he understands them and gets satisfied with them. Without understanding of the client, the system would never work. Both parties might not be able to reach an understanding; not only because of the lack of knowledge for the advanced technology in the clients side, but also due to the absence in the designer's side of the recognition for the local conditions of the people's tradition.

Of the above three strategies, the first is considered during the Master Planning while the other two are considered during the design stage of a project. If these items have been considered sufficiently, the output of the study or design would be satisfactory.

IV. APPROPRIATE TECHNOLOGY IN ACTION

A. Water level detection in an elevated tank of a rural water supply

In this case, water is taken from a deep well by pumping. This is then stored in an elevated tank. The pump should be put on when water in the tank reaches to the lowest level and should be put off when it reaches the highest level. Detection of the fluctuation of water in the tank is necessary to enable pump operation. Electric water level indicator and relaying circuit are the most reliable for this purpose. However, in rural villages, it is difficult to purchase even small electrical parts, hence, we proposed that the on-off operation of the pump may be manually done by a resident living closest to the pump. He would put on the pump in the morning and put it off when water starts to flow out. This system is rather primitive but may be the most practical in a rural condition.

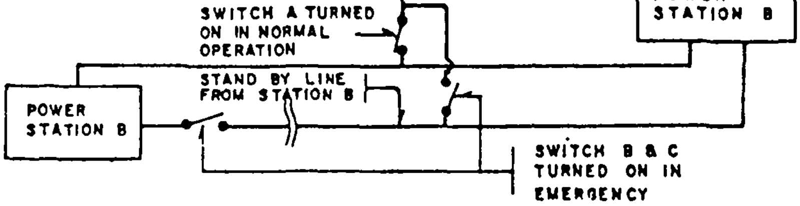
B. Use of a reciprocating pump instead of a submersible pump for deep wells

This is also a case of a rural water supply project. The use of a reciprocating pump is one of the recommendations by the World Bank for rural water supply development. A submersible pump is efficient and cheaper in initial cost; however, in rural areas, maintenance and repair works are not properly done (in some cases, no such work is expected to be made). A reciprocating pump is easier to handle and to repair for the rural people because of its structure.

Although it is difficult to predict the cost required for the maintenance and repair for each type of pump, the possibility of any malfunction of the pump should be seriously considered. It usually takes time to repair or replace a non-functioning pump.

C. Emergency power supply for treatment plants or pumping stations.

The provision of an emergency power supply is necessary to back up the system. The most appropriate is a two-source power supply. This measure is to secure the two power supply source from two independent power stations. An engine generator is also an alternative for an emergency power source when a two-source power is not available. However, it has been observed that engine generators in some treatment plants have not been used due to the absence of proper maintenance work. As a result, water production will stops when power supply stops. Considering this situation, we proposed one alternative in which a single power line is used for power supply and, in the event of a supply interruption, operators of the electric company would switch supply to the standby line fed from the other power station. (See figure below).



This is a modification of the two-source power supply. An advantage of this measure is the cheap construction cost while the disadvantage is that it takes some time (one hour in this case) to switch on the standby line. This system can be accepted if the water supply interruption during the switching is acceptable to the served people.

D. Pipe Joint and Pipe Materials

There are many types of materials and joints for water supply pipes, the prices of which vary according to the structures. In general, the more expensive ones may be more reliable in preventing leaks at the joint. In Japan, for example, a dressor type coupling is now rarely used for pipes to be laid underground because of its higher leaking probability compared to the other types such as victauris type of joint. This because the water supply interruption caused by a repair work of the pipeline is hardly accepted in Japan; consequently, the initial cost is rather high. A dressor type coupling is very cheap so that the total cost for the initial and repair work is still cheaper than the initial cost of the other type of joints. Therefore, this type will be used if initial costs need to really be minimal.

Pipe material is greatly related to leaking probability. Cast iron pipe is popularly used for smaller size distribution pipe. On the other hand, asbestos cement and plastic pipes are also used despite of their structural weakness because of their cheapest cost. However, loaking is a big problem which brings about a large amount of un-accounted for water and consequently a loss in profit. Detection and repair works for leakage in pipeline require a lot of manpower and high cost. Although leaks do occur, suitable selection of pipe material can greatly help minimize this problem.

V. CONCLUSION

Shown above are limited examples for technical measures which are usually discussed in the detailed design. Aside from these, there are many publications to show the suitable technics for developing countries. However, as well as the technical knowledge, the most important is that we, consultants, have to remind ourselves that the decision should be made with sufficient consideration on the design concepts an situation surrounding each project. In other words, the designers must consider these factors before proposin an advanced system which is obviously superior but is not always suitable to be introduced as an appropriate technology.

THE WATER SUPPLY OF MACAU
AN EXAMPLE OF THE REHABILITATION
OF A PRIVATELY MANAGED WATER COMPANY

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1. Introduction

Macau, located at the mouth of the Pearl River, 60 kilometers away from and facing Hong Kong, has the status of "Chinese territory under Portuguese administration". Territorial sovereignty is retained by the People's Republic of China, but the Portuguese republic holds the executive power through an appointed governor, who in turn shares the legislative power with an assembly composed of elected or appointed delegates. However the recent Sino-Portuguese agreement foresees the handing back of power to the PRC in December 1999. The economic regime is very liberal and the currency -the Pataca -can be freely converted. The above mentioned agreement states that this status quo will not be altered for at least 50 years starting 1999 , according to the "one country two systems" principle. Macau has privileged relations with continental China, providing an opening to the outside world. Macau is known around the world for activities such as tourism and leisure, and especially for the casinos. In recent years, Macau has undergone an economic boom, showing one of the highest growth rates in the area and a record export level, thanks to continous government and administration action, local contractors' dynamism, and the participation of Chinese industrial, commercial and banking institutions. The economic activities are mostly centered around light industries (textile, toys, artificial flowers) with a tendency towards diversification and construction. Important substructure plans -international airport, deep water harbour, and so on - should, if they take place, give a new and decisive boost to Macau's development.

The territory of Macau comprises Macau city, a 5 square km peninsula, and two islands, Taipa and Coloane, with a total area of 11 km2.
The two islands are connected to the continent by a bridge and a dyke.

The estimated total population is 400,000 but it is difficult to give an exact figure due to heavy clandestine immigration. The main concentration is on the peninsula, which is at present overpopulated . This explains why urban and economic development is being aimed at the islands whose population should grow quite rapidly in the near future.

The population comprises 95% locals or chinese immigrants. It also includes Macanese (Portuguese who have been living in Macau for generations and Sino-Portuguese mñtis), about 5000 Portuguese (mostly government workers and their families) and a few hundred foreigners.

2) Short History of Macau Water Supply.

The history of drinking water supply in Macau goes back to 1907. The estimated population then was 66,000. The first project, finally abandoned, was to use underground sources in the peninsula harnessed and stored in a 200,000 M3 reservoir able to deliver 30 l. of drinking water per person per day . The water was filtered but not sterilised.

In 1919, a second project, based on a combined use of underground and stream water stored in two reservoirs, was proposed and finally approved. However its implementation took 10 years and it was only in 1929 that the population of Macau finally had satisfactory access to drinking water supplies.

It is most interesting to note that ,even before 1929, businessmen and industrials had become interested in the lease of Macau's water supply monopoly

A frenchman, Mr Charles Ricou, took the first official step towards this end by lodging his proposal in 1915.This gentleman proved to be of a persevering nature as he went on to lodge three further proposals in 1917,1919 and 1920 without ever achieving his goal.

Several petitioners failed in their attempts until the 12th of March 1928. On this date, the first exclusive lease contract to a private company was signed. This was a fifty year contract and the concessionary company " Water Works Company " agreed to undertake the extension of the production and supply system, which became necessary with the increase in demand. A few technical and financial setbacks led to a revision of the contract in 1932 and a reorganisation and restructuring of the company's capital, which was re-named "Compania das aguas de Macau" and few years later "Sociedade de Abastecimento de Aguas de Macau" (S.A.A.M)
For the first time it was planned to use the Western River -a branch of the Pearl River-as a source of drinking water. But, given the salinity level of the river during the hot season, the use of the water had to be combined with the construction of major storage reservoirs and the setting up of a dual network for drinking and non-drinking water.

1958 is a very important year in Macau's water supply history. At the time, the concessionary company found itself facing a shortfall in ressources aggravated by an unbearable increase in the water salinity level caused by the construction, upstream, of a dam by the PRC. The S.A.A.M therefore signed the first contract for water supplies with officials of the neighbouring Chinese provinces. Ever since, Macau's water has been supplied in totality by the PRC through three conveyances gradually set up over the years. Interestingly enough, even when tension was high between Portugal and China, and especially during the Cultural Revolution, this umbilical cord was never threatened.

It is said that history never repeats itself, but in 82-84, the company was back in the situation it was in during the thirties, on a different scale. Under-capitalised and facing huge financial difficulties, the company was no longer able to meet the needs of the times. The need for technological and financial input was becoming essential to allow the system, neglected for many years, to be modernised and run profitably and for the important investments required by the territory's fast development to be made.

Two important dates have marked the recent history of the company:

1982 The New World group took over the financial and technical management, greatly improving both.

1985 The company was put under the majority control of Sino-French Water Development Ltd. A joint venture was set up with equal shares for Lyonnaise des Eaux and the New World group , the capital was increased and a new concession contract was signed until 2010. It is from this period -and more notably from 1985- that the impressive recovery of the company can be dated.

3) Short description of the S.A.A.M and its Facilities

3.1.1 The totality of untreated water used for supply purposes in Macau comes from the Zhuhai region of the Peoples' Republic of China with the exception of:

- The Porto Exterior reservoir in Macau, with a 2.157.800 m3 capacity, used only in case of emergency, and itself supplied by a conveyance from the PRC

- The Sai Pa Wan, Hac Sa and Kau-O reservoirs in Coloane with a total capacity of 1.200.000 m3 and supplied by stream waters. These reservoirs are seldom used.

(FIGURE)

3.1.2) On a quantitative standpoint, the resources at Macau's disposal seem plenty enough, given the demand at peak periods.The main problem is quality. During the dry season with the combined effect of the low water and strong tides, the salinity level exceeds accepted norms (it can reach 2.000 ppm). Under these conditions, the operations department has to carefully control "in real time" the use of different resources including the Porto Exterior reservoir.

3.1.3) When it comes to the production means, the S.A.A.M has essentially the Ilha Verde plant. The Coloane plant, handed over by the government during the transfer of the islands service and with a capacity of 10.000 m3/day, is only used when needed.

The Ilha Verde plant , an old construction ,was remodelled and renovated many times. The concept is conventional, with a treatment chain including a mixing tower for water coming in from different sources, and where the injection of reagents also takes place (aluminium polychloride at an average dosage of 35g/m3 and lime) , an array of seven decanters with silt beds (a total of 278 m2) , 18 rapid filters (total 352 m2) and a chlorination plant with a capacity of 19,6 kg/h.

The Ilha Verde installations also include the main pumping station (central pumping station) comprising 11 pumps with a capacity varying from 53 to 180 l/s, with 4 of them able to pump 100 meters away and 7 - 75 m (total power installed 1984 KW.)

3.1.4) When needed, the S.A.A.M also has the possibility, in theory, to import some of the water treated by the Xiamen plant in the PRC as a transitory solution.

3.2) The Distribution Network.

As of 31st December 1986, Macau's distribution network (Tai Pa and Coloane excluded) consisted of:

(Graph)

As for materials used, these are:

- for old pipes, galvanised steel for dia. <100 , grey cast iron for dia. >100

- for pipes laid since 1982, galvanised steel for dia. <100 and asbestos concrete for dia. >100

Given certain problems encountered with asbestos concrete pipes, the use of ductile cast iron has been decided upon for diameters over 100 mm.

3.3) Consumption

The total number of customers as at 31st December 1986, is 65,684 with a consumption of 22.723.682 m3 , an average of 155 l/inh/day broken down as follows

(Graph)

3.4) <u>Customer and Invoicing Services</u>

All consumption is measured by meters. Reading and invoicing is done monthly. Charges are levied at a flat rate per M3 (at present 2.74 Ptcas. or US$ 0.34) subject to a minimum consumption of 5 M3 / customer / month. A small monthly amount is also charged for the rental and maintenance of the meters and new customers are charged a connection fee according to official quotation. In 1986 the company had a turnover of 66.9 M Ptcas. (US$ 8.30 M) of which 1.5 % was paid to the Macau government as concession tax (in addition of course to the normal company profit tax).

3.5) <u>Organisation and Personnel</u>

The company at present employs 256 staff including 11 executives, 31 supervisory staff and 214 other workers per the following diagram

(DIAGRAM)

4) Before June 1982, water supply situation in Macau was a chaos, filters were working above designed capacity at the expense of water quality, water pumps were running day and night at the same rate without knowing why water pressure remained low in the distribution system and in many areas water was not available until later at night. Situation within the management was no better.

In order to improve the water supply situation, identification of problems was necessary. Water supply in zones was the first action taken which revealed inadequate water supply due to poor distribution network, serious water losses through leakage and wrong combination of water pumps. Following is a rough description of the work taken to improve this situation and their results.

a) Zoning

Water pressures were taken at selected points for consideration of zoning. This is a tedious task and often requires working at nights. Based on the data so obtained, the city is divided into four supply zones. We are now able to maintain adequate pressure at all areas, be that high above sea level or distant from pumping station. This work includes enlargement of pumping main, and installation of cut-line valves.

b) Waste Detection

Leakage in distribution system accounted for a high percentage in our unrecorded supply. In order to conduct a systematic test, formation of waste detection areas were necessary. This work includes laying of watermain and installation of additional sectional and boundary valves. We have divided our distribution system into 26 areas which are completed and available for testing.

However, we have intensively carried out the test in a more expensive way by sounding at night since February 1983. We have covered practically all areas 5 times by January 1984 and are repeating the test. Hundreds of leaks were detected and repaired. In fact, our unrecorded consumptions, including meter inaccuracies, theft of water, leakage losses, fire fighting and burst mains etc., has dropped from 44% in 1982 to between 25% and 28% in 1984. Our estimated water losses through leakage is less than 13% now.

Losses control do not depend on system test in distribution network alone, accuracy of measuring instruments in treatment plant, accuracy of water meters, abuse in fire fighting installations are among other factors which we are on constant watch.

c) Power Supply

Water pumps in central pumping station have three separate power connections between them. They were connected on parallel so as to maintain normal operation of all water pumps in case of power failure and to improve safety standard.

d) Cost Control

With the improvement in pumping main, distribution network, zoning operation at lower pressure level of all water pumps, power consumption was reduced. When compared with the power consumption in 1982 in terms of water supplied, there is a 25% decrease in power cost. Power consumption is now 0.31 kilowatts per M3 of water and that in 1982 was 0.45 kilowatt.

Backwash water was discharged to sea as waste. We are recycling them in open circuit and saving approximately 2,000 m3 of water per day.

Chemicals - the use of Polyaluminium Chloride in place of Aluminium sulphate as coagulant helped to save 80% of expenses in coagulant.

e) Consumer Services

Existing Consumer Services Department was restructured and its main duties is now to deal matters arising from water supply within a private property. A Registry headed by a manager, receives and processes applications for metered water supply, complaints of shortage of water supply and high and low water consumptions, arranges inspection of new and existing inside services to comply with Standard Requirements, liases with other government offices for private fire service installation and road opening for provision of water connections. The manager is also responsible for water meter readings and programmed water meter replacements.

Strict reinforcement of disconnection of water supply for non-payment of water accounts reduces losses in bank interests and same action for non-compliance of the company's requirements to rectify defects in inside services reduces bad water complaints and eliminates reverse flow through water meters.

All these actions were especially a matter of proper management. But it was not enough. To comply with the EEC standard requirements and to fulfil the very rapidly increasing water needs - our sales have been grown to 22,7 Mm3 in 1986 from 12.5 in 1981 - it was necessary to develop the existing facilities and to build new ones. It is the reason why we have embarked on a large Ptcas 150M (around US$20 M) investment program which is now about half completed. The main purposes of this program which has been established after a long term master plan prepared by the French consulting firm SAFEGE are:

- To secure on a long term basis the raw water resources imported from Mainland China, using the Modaomun Project. Modaomun channel is one of the eight outlet of the Pearl River delta to the sea. The yearly flow of river water is 88,390 million m3 and the yearly tidal inflow is 15,980 million m3, yielding an average ratio of 5.5 over the years. It is a "strong river flow, weak tidal flow" type of estuary. As the stream flow is large, pollution is light and self-purification power is strong. The duration of salt water intrusion is short. During the wet season, except in the case of strong easterly wind, it is practically unaffected by the salt wedge. During dry season, because of reduction in stream flow, the salt wedge will penetrate further upstream, resulting in higher chloride concentrations. Generally speaking, it is possible to extract fresh water with chloride concentrations less than the standard of 200 mg/l as Cl-, between the ebbing tide and the flooding tide. In very dry years, a period of continuous salt water intrusion can occur during the months of January/February. Because of this, it is considered not advisable to rely entirely on extraction by direct pumping. Thus in order to regulate the salinity the Modaomun Scheme includes the construction of three large reservoirs at Xidihang, Yinhang and Lapa for a total capacity of 4.2 million m3.

The distance between Maodaomun intake and our treatment plant is 16 kilometers. Maximum water supply is estimated to 420,000 M m3/day. Water flows from West River through a water gate which is 12 meters in width, into a storage reservoir and then is raised by pumping to a conduit at 30.0m above sea level. Water continues to flow through 7 tunnels of a total length of 6,380 meters, 2,750 meters of conduit, one overhead aqueduct of 556 meters and 2,160 meters of twin precast concrete pipe line of 1,000 mm diameter.

The estimated cost of this water scheme is RM$24 million (US$6.5 M), the funding of which we have participated by an interest free loan of US$2,5 M. Work for this project has been commenced on 11/1/1986 and will be completed by the end of February 1988.

- To improve the water distribution system.

  A complete remodeling of the distribution network is now in progress, based on a comprehensive and advanced mathematical model recently developed by SAFEGE. A total of Ptcas 27 M (US$3.5 M) has already been spent in replacement, enlargement and extension of the existing network for a total length of 44 km. The pumping facilities are to be completely renewed using a remote controlled system regulated by the level of a balance reservoir and performing the following automatized functions.

  - Calculation of the water consumption for the passed hour.

  - Calculation of the right pumps combination to apply according to the reservoir forecast level curve, to the maximum electrical consumption of the passed hour.

  - Starting and stopping of pumps to get the right combination.

  - Automatic replacement of a breakdown pump by a similar one.

  - Circular permutation of pumps at every state change.

  - Hydraulic and electric fault analysis.

- To improve the water quality and extend the existing treatment facilities.

In 1982, high turbid water was the cause of a lot of complaints and the normal capacity of our installations - old and obsolete - was no more than 30,000 m3/day. We are now able to deliver 90,000 m3/day of treated water unit, at an average turbidity of less than 0.2 NTU. Main improvements consist in:

- Sedimentation: All 6 existing coagulation tanks were reconstructed and converted into settler type and a seventh one of 25,000 m3/day capacity was added. An antomatic sludge extraction system has also been installed.

- An automatic dosing system for the reagents, PAC, polymer, lime activated carbon and chlorine has been installed, the quantity of reagent being controlled in real time by the inlet water flow, as well as automatic testing of main parameters - PH and turbidity of raw, clarified and filtered water and residual chlorine of treated water.

- Filtration: A new filtration battery using rapid sand gravity filters with automatic washing system has been carried out. The main characteristic of this battery are:

  Number of filters: 7. Total filtration area 343 m2.
  Normal capacity: 90,000 m3/day.
  Normal filtration rate: 11.3 m/h.

  All these works which are now fully in operation have been completed in record time (one year between signing of the contract and commissioning of the filtration battery and dosing system) without never interrupting the working of the existing plant.

5) Current and Future Projects

At this point in time a large part of the 5 year investment plan, which was outlined earlier, has already been put into action and some of the installations concerned are in service. Our current most immediate projects concern

- The bringing into service of a new unit to treat 40,000 M3 per day.

- The continuation of the network total renovation programme.

- The construction of a 30,000 M3 service reservoir.

- The construction of new facilities - offices, shops, workshops and a new laboratory with a complete range of equipment necessary for the complex task of checking compliance with the European quality standards (generally stricter than those of the W.H.O.) which were imposed on us as part of the franchise agreement.

- The completion of the programme to replace old meters.

- Last but not least, if not in financial terms then surely in terms of its effect on the increase in productivity and on the reliability of water supplies, the setting up of a fully automatic, computerised management system for all the conveyance, treatment, pumping and distribution operations as well as for follow - up on equipment performance.

  All these projects will be completed by the end of 1988 giving the people of Macau a water supply that is up to international standards, as much for the quality of the water supplied as for the guarantee of supply and optimisation of costs. In the longer term the rate of increase in demand and the foreseen development of Macau will oblige us to continue our investment in production and distribution at a sustained rate. To do this the necessary ressources will be found without undue price readjustment, a factor which we must account for when controlling our running costs.

6) Conclusion

In conclusion I would like to say a few words about our partners in this operation and also about what, in my opinion, has made it a success until now.

- New World is one of the major financial and property groups in Hong Kong where it owns an hotel chain, commercial centres, a large public works company and other various concerns. It is presently in the process of creating in Hong Kong one of the world's largest conference and exhibition centres. Its interests have diversified into the Peoples' Republic of China and, more recently, into North America. Its capitalisation on the Hong Kong stock exchange is HK$13.5 Billions. Under the leadership of its founder and

  principal shareholder Dr.Cheng Yu Tung, the New World Group has been able to adopt a longer term outlook on affairs, unlike some of its neighbours in the marketplace, which

  has naturally led it to take an interest in public utilities.

I. The Lyonnaise des Eaux Group
Water, Waste and Energy Services for Community Needs Worldwide

The Lyonnaise des Eaux is an international group specialized in the installation and management of water, waste and energy systems. Headquartered in Paris, the Group employs 36,000 worldwide: Europe, North and South America, the Middle East, Africa, Southeast Asia, the Far East and the Pacific region. Revenues total HK$19 billion of which 25% generated from international operations.

Although Lyonnaise has operations worldwide, its services are local in character. The general corporate mission is to provide communities with essential services to meet those long-range needs of municipalities and industries which create a better environment in which to live and work.

The three core sectors of Group services are:

- Water: In more than a century of operations, Lyonnaise has built up extensive experience in network management, and Degrémont, the Group's treatment engineering subsidiary, has built 40,000 water treatment plants in some 80 countries.

  The Group offers a full range of operations and management skills in source development, drinking water supply and wastewater treatment. Lyonnaise engineers and managers cooperate with local authorities and technicians to provide efficient and economical solutions to specific needs, whether it be the upgrading of the metering system, or a 30-year renovation project for an existing distribution network.

- Waste management: Municipal authorities more and more often call upon private sector companies to ensure the efficient collection, transport, recycling and disposal of waste. The Lyonnaise Group is European leader in waste management with broad experience covering all aspects of the field: collection of household and industrial wastes, transport and disposal systems.

- Energy: Cutting energy costs has become a necessary priority for most municipalities and industries, and for building and housing complexes. The Lyonnaise Group has developed a number of technologies and systems that increase efficiency and reduce energy expenses. Group companies build and operate cogeneration plants producing electricity or steam, multifuel power plants, and heating networks operating from geothermal wells.

  From 1980 to 1986, Group research expenditures increased five-fold to US$20 million. The Lyonnaise Research Center works with a network of 14 regional laboratories, several French and foreign research teams and each year arrives a number of specialists from different countries for research residencies.

  Two new laboratories were founded in 1986. One is devoted to membrane technology in ultra and micro-filtration water treatment, the other for artificial intelligence and expert systems applied to Group activities.

The Group is a participant in several international research programs, including the Japanese "Aquarenaissance" and the "Biofocus" programs for the development of new compact high-tech treatment processes.

International Growth

A major part of Group growth arises from two generalized tendencies observable in many countries of today's world:

- Problems concerning environmental deterioration are clearly increasing, notably where water is concerned. Water supplies have been affected by the intensive use of fertilizers, pesticides and other chemical products in the accelerated development of agriculture and industry.

- There is a generally increasing understanding among local authorities of the advantages to be gained from entrusting private companies with the management of basic public services. This awareness is not the result of ideological considerations but springs from economic necessity: local authorities have many critical and complex problems to face - unemployment, education, citizen security, transportation, housing - yet their financial and technical resources are limited. In addition, taxpayers are becoming increasingly sensitive to fiscal pressure. Many communities have found they can lighten day-to-day involvement in basic service problems by turning to private sector specialists who can offer solutions that are both sound and economical. Municipalities have learned that they can depend on the long-term commitment of these companies. This is the case in Macau as well as in Paris.

In offering services of such localized character, it was essential to establish regional offices and work in association with local partners, for example through joint ventures, such as in Malaysia, Thailand, Great Britain, Japan . . . .

In each of the above public service areas, Lyonnaise Group companies develop specific configurations to fit the individual case concerning matters such as regulatory requirements, local workforce potential, financial resources.

Technology Development

The Lyonnaise Group works in sectors demanding a tradition of professionalism. Most contracts are long term, from 10 to 30 years, success in fulfilling responsabilities requires a sustained level in technical quality. This in turn implies continually upgraded programs in research and personnel training.

Lyonnaise has operations throughout Europe, Asia and North America. As examples:

- Europe: In Spain, the Agbar Group (equity held at 40% by Lyonnaise) distributes water to 5 million consumers, and recently acquired Cespa, the third largest company in Spain specialized in household waste collection. There are Group affiliates in the U.K., West Germany, and many other European countries.

- Asia: Lyonnaise affiliate, the Macau Water Company, distributes drinking water to 400,000 people. In Japan, a joint venture was set up with Dainippon Ink and Chemicals, the new company, DIC-Degrémont, specializes in designing and installing water treatment plants built to Japanese market requirements.

- North America: Lyonnaise operates in the US market through General Waterworks Corporation which distributes water in 14 states. Group affiliate Aqua-Chem is the leading manufacturer of medium-size industrial and commercial desalination systems and leader in producing middle-range boiler plants. The Group is also present in Canada where it has been awarded its first contracts for treatment plants and for water distribution. Lyonnaise operations in the US and Canadian markets together represent revenues of some HK$1.8 billion.

International operations account for 25% of Groupe total revenues.

The Group Embarks On A New Phase of Development

Lyonnaise is ready to respond to the needs of its partners, the local communities, and to the demand for new services that is emerging. The most apparent of these concern three fields which will take on increasing importance in the society of tomorrow: communications, leisure services, and health care.

Initial operations in these domains are already well underway in France. The approach is pragmatic with well-defined steps taken to develop answers to the demands of tomorrow. Group specialists are supported by professional partners identified and chosen as being forward-looking and creative.

In these three domains - leisure, health and communications - Lyonnaise is establishing itself as a specialist in the "logistics of services", complex services organized and operated for local communities, and which most often require heavy investments.

Group strength in financial engineering, the development and management of services at the local level, dedication to adaptability and quality - all these place the Group in a good position to undertake these activities. These fields show strong growth potential and have a direct relationship with the end user: they are spoken of in terms of occupancy rates, attendance figures and viewer ratings.

Operating on site, specializing in urban services, and being more and more in direct contact with the consumer has given new dimensions to the Group's vision of its future.

In this there is no deviation from traditional occupations, but rather a true enrichment. Organized through networks of partners and clients, Group operations lead to the development of new activities which are based on these relationships and complementary to traditional professions.

From this year on, financial commitments, though measured, will be far from negligible. Detailed studies indicate that potential earnings from the various projects envisaged should be satisfactory.

II. Lyonnaise des Eaux in Asia and the Pacific
An Overview of Events and Achievements

The Group Lyonnaise des Eaux, ever since its origins, has been steadfast in its international role and its interest in the countries of Asia and the Pacific. It has supplied electricity to Noumea in New Caledonia since 1929 and Port-Vila in Vanuatu since 1939. Degrémont, the Group's subsidiary specializing in wastewater treatment, has had operations in Southeast Asia since the sixties, principally in Indonesia.

Today, the Group is confirming those continued interests while updating objectives.

New Objectives

Asia and the Pacific are two priority zones of development for the Group which offers these regions an extended range of services: water treatment and distribution, distribution of electricity, waste collection and treatment, multiservice building maintenance. . . . The Group thus responds to the needs of countries with dense populations which are destined to grow rapidly over the coming decades. They will increasingly require the kind of services offered by Lyonnaise.

A Priority Area

Today, the Asia and Pacific region makes up 12% of Group international revenues. Lyonnaise counts on increasing its operations so as to be a part of the development of the countries where it works. To do this the Group applies a policy of associating itself with local partners and a major part of revenues from operations of jointly owned companies is reinvested locally.

Lastly, the Group has a well-established network of delegates and permanent representatives (Singapore, Tokyo, Hong Kong . . .)

Milestones

China

- Degremont has booked its first orders in the PRC: water treatment at the Daya Bay nuclear power facility near Canton, and supply of feed-water for the thermal-electric power plant at Yang-Yu near Chongqing in the province of Szechwan.

- Infilco Degrémont: American affiliate of the Group and specialist in water treatment, recently signed a contract for services at a pilot station oil well for a sum of US$700,000-

  The Group continues to pursue opportunities in the Chinese market for wastewater treatment. In these efforts it is supported by the Group delegate in Hong Kong and by Degrémont's office in Beijing. Negociations are underway with municipalities, certain of which might be finalized in the current year.

- Cleaver Brooks, an American affiliate manufacturing boilers, totalled more than US$1 million in sales to China in 1986.

India

- 1986: Creation of Degrémont India, with headquarters in Dehli. The company has since been awarded its first contracts with Mohan Meakin, one of India's largest brewery/distilleries.

Japan

- 1984: after operating since the sixties through Degremont's activities in water treatment, the Group established permanent bases in Japan. Lyonnaise des Eaux and Degremont formed an association with Dainippon Ink and Chemicals (DIC), a group specializing in fine chemicals, dyes and biochemical products.

  The Lyonnaise group bought 50% of a DIC water treatment subsidiary. Under the name DIC-Degrémont, the joint venture company benefits from Degrémont technologies in the production of drinking water and ultra-pure industrial waters as well as in the domain of wastewater treatment.

- 1985: MITI authorized the participation of DIC-Degrémont in the "Aquarenaissance' research program for the development of compact automated plants for the treatment of urban and industrial wastewater. It is the first time that MITI accepted a partially foreign-owned company into a Japanese national research program.

  DIC-Degrémont is also taking part in "Biofocus", a research project on biotechnologies under the auspices of the Ministry of Construction.

- 1986: DIC-Degrémont put Group technical skills to work, first contract signed for treatment of brewery effluents.

- 1987: DIC-Degrémont signed a $14 million contract for water treatment in Mexico - a Japanese funded project.

  One of Japan's largest public works firms, the Shimizu group, will soon become a shareholder in DIC-Degremont.

Malaysia

- Since 1985 the Group has a prominent firm as partner, the Ipoh Garden Berhad group, with cooperative projects in two sectors:

  Wastewater treatment - an agreement was signed associating Degrémont and an affiliate of Ipoh Garden, UM Engineering and Construction SDN Berhad, Malaysia's largest civil engineering company.

  Energy - with the creation of a joint venture company in this sector, Cofreth Malaysia. The new enterprise recently signed its first three contracts for the technical operation and maintenance of two office buildings and a shopping center in Kuala Lumpur.

  In addition Sita, the Group specialist in waste management, acquired 45% of the equity of the Malaysian Conwaste company which operates in domestic and industrial waste collection.

Singapore

- Since 1983 the Group has a permanent delegate based in Singapore.

- Cofreth, Group specialist in energy, has created an affiliate for the technical operation and maintenance of buildings and building complexes, Illarisa Services.

The company recently won the contract for the technical systems management of Singapore's largest commercial complex, Parkway Parade, which includes 309 shops, a 17-story office block and a 3,000-lot parking garage. The contract specifies maintenance and operation of various types of facilities - Heating, Ventilation and Air-Conditioning (HVAC) systems, power distribution, sanitary facilities, emergency generators, etc.

- Sita is in the process of acquiring shares in Singapore companies working in the fields of waste collection and building cleaning and upkeep.

  These new operations are being carried out within the framework of the privatization of certain public services, and in particular those controlled by the Housing Development Board.

Thailand

- 1985: in Bangkok, Lyonnaise, in association with Ithalthai, one of Thailand's largest diversified groups (construction, public works, hotels) created Aquathai, a company applying Lyonnaise technologies in water treatment and network operation.

  Lyonnaise signed an agreement for technical cooperation and training with the Bangkok Metropolitan Water Works Authority. Program content will target specific need areas of greater Bangkok.

The Pacific

Between 1983 and 1985, in the region where it has worked for more than half a century, the Group fortified its positions. Activities in energy production and distribution were strengthened, contracts renewed, and new services offered (waste management, alternative energy sources . . .)

Affiliates established have been placed under autonomous local management: Electricité et Eau de Calédonie in New Caledonia, Unelco-Vanuatu in Vanuatu. These companies took over the distribution of power and the supply of drinking water while adding new services. They also apply a policy of reinvesting locally, an affirmation of the Group's determination to play a role in the development of those regions where it works. The Group now has solid bases for operations in its three core sectors of water, waste and energy.

New Caledonia

- 1985: the franchise for power distribution in Noumea was extended 10 years (till 1997). Electricité et Eau de Calédonie and its affiliates supply electric power (170 million kW/h per year), and drinking water (3 million m3) to their 35,000 subscribers. Other services include electrical works and network maintenance, sales of electrical supplies, advancement of new energies, data processing services.

- 1985: creation of the company Polynésienne des Eaux at Papeete in Tahiti. It will offer the entire range of Group services in two sectors, drinking water supply/wastewater treatment, and waste management. It booked its first orders shortly after it went into business.

  The Group acquired a 35% interest in the capital of Electricité de Tahiti, the company holding the franchise for power production and distribution covering most of Tahiti including Papeete, and the islands of Bora-Bora and Maupiti. It serves 23,000 subscribers.

- 1987: Group equity in Electricite de Tahiti was increased to 94.6%.

Vanuatu

- 1983: The Group was confirmed as franchise-holder for electric power distribution to the capital Port-Vila and the Island of Santo, with a contract until 1991.

- 1986: That contract was extended for 15 years.

Wallis and Futuna

- 1986: the operation and maintenance contract for water distribution, held by Electricité et Eau de Wallis et Futuna, was renewed for 15 years. The contract for electric power distribution was extended till the year 2006.

A Few Recent References

South Korea

- The Group will supply drinking water to the Pusan urban area (2,450,000 pop.).

India

- The Group has been present in India since 1959. Its latest contract is for supplying feed-waters to thermal power plants in the states of Gujarat and Andhra Pradesh.

Indonesia

- Drinking water supply for Ujung Pandang in Sulawesi (formerly Celebes) for 435,000 inhabitants, by the Group.

- The Group supplies drinking water to a total of 100 cities and towns in all areas of the country.

Saipan

The Group has just been awarded the contract for the supply of electricity to Saipan (largest island of the Northern Marianas, population 16,500).

Singapore

- Drinking water production in the Scudai and the Seletar-Bedok plants. The plant at Scudai was built by the Group in 1963 and has been regularly upgraded since. The Singapore plants employ the latest technologies for water treatment, such as ozone generators and the Group lamellar Pulsator clarifiers.

Sri Lanka

- Drinking water supply for the cities of Negombo, Kurunegala and Badulla, by the Group.

III. Lyonnaise des Eaux Group
A Few Key Figures

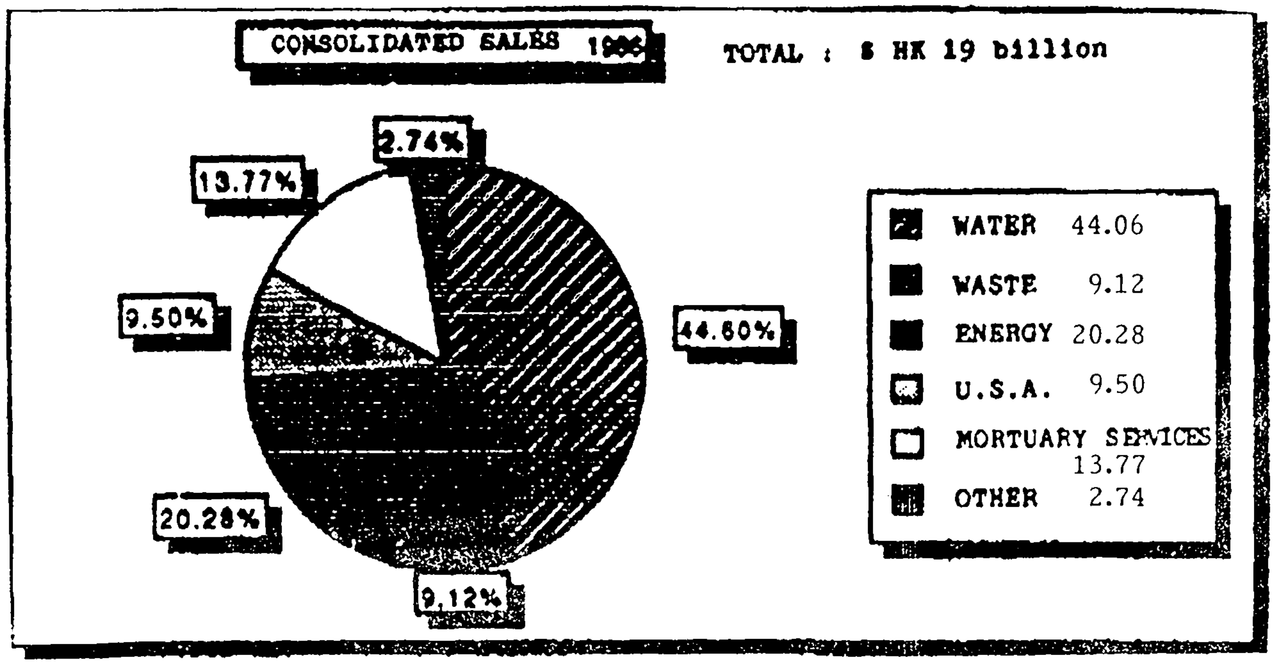
1986 was a good year for Lyonnaise des Eaux. Group revenues totalled HK$19 billion, with Group share of consolidated income at HK$448 million, up 32% over 1985. Group cash flow was HK$1,890 million.

Investments continued high during the last three years (at HK1$1,662 million in 1986). This figure will doubtless be far greater in the current year given Group plans for development.

All Group sectors showed satisfactory progress in 1986. International operations, especially in the US, Spain, Asia and the Pacific, made strong contributions to Group results. Sales in international markets amounted to 25% of results and represented 35% of earnings.

In 1987 each sector should reap the benefits of broadening international operations, particularly with waste and energy service companies signing their first contracts and creating joint ventures in the US and Asia.

The Group joint venture in Japan has made its first penetration of the international marketplace with a water treatment contract in Mexico under Japanese financing.



PACKAGE

MODERN TECHNOLOGY AND HARDWARE

Comparison of Declining Rate Coarse Media Filtration with Constant Rate Dual Media Filtration

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I. INTRODUCTION

Rapid filters have been extensively used in big or medium water supply schemes in view of their high rate of filtration (25 to 150 times higher) and smaller filter area required compared to slow sand filters. The main mode of removal action in a rapid filter is considered essentially to be physical and physico-chemical.

The conventional rapid filter generally uses sand with an effective size of 0.6 mm and a uniformity coefficient of 1.5-2.0. This results in stratification of the media after filter backwashing, in which the fine medium remains at the top and the coarse medium at the bottom of the filter bed. To overcome the problem of gradation, two alternative media have been proposed, notably, (1) dual-media and multi-media and (2) coarse size, narrowly graded media filters.

1.1 Modifications of filter media

In dual-media filtration, the size of the media must be carefully selected so that when the water is used for fluidizing and re-stratifying, the bed does not cause severe intermixing. Optimum conditions for minimizing the intermixing exist, depending on the media type, specific gravity and size involved. Various researchers have given different size ratios for minimum intermixing of media. Extensive researches have been carried out to study the advantages and disadvantages of intermixing of filter media in dual-media filtration (Conley & Hsiung, 1969; Deb, 1969; Dostal & Robeck, 1966). It is evident from these studies that two schools of thought prevail in the selection of grain size for the design of dual-media filtration.

One opinion is that the grain size of coarse antracite and fine sand should be chosen in such a way that the intermixing at the interface will be minimized. The second opinion indicates that the controlled mixing among filter media is beneficial because it reduces the tendency to form an impervious layer at the interface during filtration.

Another alternative is to replace a graded single medium with a coarse narrowly-graded medium. This arrangement results in deeper penetration of the suspended solids and thus higher storage capacities which would lead to a longer filter run. The selection of the size depends on the raw water and required effluent qualities. The commonly used size range is 0.9-1.1 mm. This arrangement facilitates an increase in demand in the existing units as it can be operated at a higher filtration rate. But, the deeper penetration of the solids would make the backwashing requirements high. The rate of air and water used in backwashing depends on the size of the medium. For example sand of 2 mm effective size needs washing rates of 90-110 $m^3/m^2.h$ of air and 19-24 $m^3/m^2.h$ of water.

1.2 Modifications of flow rates

Conventional rapid filtration operates at a constant rate of approximately 5 $m^3/m^2.h$. Researches performed on the variation of flow rate have indicated that high-rate filtration and declining-rate filtration are advantageous in most instances. If one achieves the desired filtered quality with a higher filtration rate operation at an operational and maintenance cost comparable to that of a conventional rapid filter, then one could achieve a significant capital saving by using a high-rate filter. Similarly researches have indicated that declining-rate filtration produces a better effluent quality than does the conventional process. Therefore, if one could obtain the same capacity of filtered water with equal capital investments, then declining-rate filtration would have a definite advantage over conventional rapid filtration. Another advantage of using declining-rate filtration is that it does not require automatic rate control.

The concept of declining-rate filtration is not new. Basically, no rate controller is used in this system, and instead it is replaced by a fixed orifice. The filtration rate in this system is allowed to decline from a maximum value at the beginning of the run when the filter is clean to a minimum value at the end of the filter run when the filter needs backwashing. In practice, several (a minimum of four) filters are used in series,and the water level is maintained essentially the same in all operating filters at all times. This is achieved by providing a relatively large influent header pipe or channel to serve all of the filters, and a relatively large influent valve or gate to each individual filter. Further details on the declining filter operational principles, design criteria and experiences in developing countries are given in the following references (Clasby, 1981; Clasby & Dibernado, 1980; Arboleda, 1974; Valencia, 1977).

On the other hand, high-rate filtration in which the filtration rate is about 10-15 $m^3/m^2.h$, as compared with the rate of conventional rapid sand filtration which is of the order of 5.0 $m^3/m^2.h$, is useful in upgrading existing filtration units.

This paper presents a comparison of laboratory-scale filter performance of (i) dual media filtration with coarse media filtration and (ii) declining rate filtration with constant rate filtration. A laboratory-scale comparison on backwash water requirement for each facility is presented briefly. In this study, the effluent from solid-contact clarifier from Bangkhen treatment plant was used as filter influent.

2. EXPERIMENTAL

Coagulated and settled water from the clarifiers at Bangkhen treatment plant was used as influent to the laboratory-scale filter as illustrated in Figure 1. Filter column used was made of PVC transparent pipe of 10 cm diameter and 180 cm length. Piezometer and sampling tubes were placed on the filter column every 10 cm apart.

The experimental conditions used are summarized in Table 1.

The parameters like turbidity of influent and effluent, and headloss were measured at regular intervals and at different filter depths. The filtration rate was also measured during the filter run in the case of declining rate filter.

3. COMPARISON OF PERFORMANCES OF DIFFERENT TYPES OF FILTERS

3.1 Coarse media filter with dual media filter

The dual media filter results (with duplication) at constant filtration rate of approximately 13.75 $m^3/m^2.h$ is presented in Figure 2. Although the filter effluent quality remained same at the two filters analysed, the initial headloss was very much different. This might be due to the difference in the degree of intermixing, sand compaction after backwashing etc. However, the headloss development during the run was same in both the filters (about 75 cm in 48 hours).

A set of experiments were carried out with two different sizes of narrowly graded sand (1.00-1.19 mm and 1.19-1.41 mm). The effluent concentration and headloss profiles measured at different depths are shown in Figures 3 and 4. It can be seen that at the lowest filtration rate of 10 $m^3/m^2.h$, the major removal was confined to top 40 cm i.e. beyond 40 cm, filter improvement in effluent quality was not significant. On the other hand, when the filtration rate was increased, a better distribution of removal throughout the bed was observed although the headloss development was significantly higher. For example, the headloss development was only 120 cm after 60 hours of filter operation at filtration rate of 10 $m^3/m^2.h$ whereas it exceeded 120 cm within 24 hours when the filtration rate was increased to 20 $m^3/m^2.h$.

Figure 5 shows the comparison of the effluent quality and headloss development of the two types filters when they were operated at filtration rates of 12.5-15 $m^3/m^2.h$. The dual media produced slightly better filtrate quality at the early stages than that of narrowly graded media, but after 24 hours of filtration the latter produced a better quality.

While producing the comparable filtrate quality, the narrowly graded media produced lower headloss than that of the dual media. Although the clean bed headloss of coarse sand (1.00-1.19 mm) filter was low, the headloss development during the filter run was higher than for dual media filter. On the other hand, the coarse medium filter of 1.19-1.41 mm sand, gave rise to comparable effluent quality as that of dual media while producing lower headloss development (Figure 5b).

For filter backwashing, the narrowly graded media required much more water than dual media (Table 2). For comparison, in Bangkhen water treatment plant, air-water process is used for filter backwashing. Thirty seconds of air flow at a rate of 72.5 m/h followed by 10 minutes of water flow at a rate of 50.6 m/h is used.

3.2 Constant rate and declining rate filtration

Past researches indicate that 1.00-2.00 mm unisized sand with deeper bed depth (1.2 m) is an improved alternative to conventional sand filtration. Also, the smaller medium size gives rise to a significant filtration rate reduction with time, which shortens the filter run. Taking these factors into account, the sand with sizes of 1.00-1.19 mm and 1.19-1.41 mm was used in this present study in order to compare the declining rate filtration with the constant rate filtration.

The concentration, headloss and water production profiles of constant and declining rate filtration experiments are presented in Figures 3, 4, 6, 7, 8, 9 and 10.

At the filtration rate of or less than 15 $m^3/m^2.h$, both coarse medium filters (1.00-1.19 mm and 1.19-1.41 mm sand sizes) produced comparable and satisfactory filtrate quality whereas at higher filtration rates (>15 $m^3/m^2.h$), the sand size of 1.00-1.19 mm gave better filtrate quality than that of the 1.19-1.41 mm. It was also noticed that declining rate filtration system gave rise to a better filtrate quality than constant rate filtration.

In view of turbidity removal or headloss development, increase in media size and filtration rate yielded better distribution along the bed depth.

The rational way of comparing the performance of the declining rate and constant rate filtration is through the comparison of the concentration and headloss development at identical water production, as presented in Figures 11 and 12.

From the Figure 12a, it can be seen that the declining rate filtration (1.00-1.19 mm sand size) gives rise to a lower

headloss development compared to the constant rate filtration for same water production.
In constant rate filtration, the effluent concentration remained almost same even when the filtration rate was increased. But on the other hand, headloss development was higher for high filtration rates. The headloss at various depths indicated that the headloss was more distributed at high filtration rate (Tables 3 and 4).

In declining rate filter, the effluent quality was comparable to that of constant rate filter. At the latter stages of filter run, the effluent quality was superior to that of constant rate filter which is an advantage of declining rate filtration. The headloss for the same water production was less in declining rate filter compared to that of constant rate filtration.

The effluent quality was superior in dual media filters compared to single coarse media filters. But the headloss was more in the case of dual media filter compared to constant rate coarse medium filter.

CONCLUSIONS

The two sizes of narrowly graded filter sand used indicated that the headloss development is lower in coarse medium filters compared to dual media filters. For example, when a sand of 1.19-1.41 mm size was used the headloss development was only 33 cm after 48 hours compared to 75 cm after 48 hours in dual media filtration.

The interesting phenomenon in coarse medium filtration is the wide distribution of particle deposition along the depth. This effect is more predominant when high filtration rates were employed.

The main short coming of coarse medium filter is the high backwash rate requirement compared to dual media filtration. The backwash requirement for 30% expansion of 1.00-1.19 mm and 1.19-1.41 mm sand media were 105 m/h and 127 m/h flow rate respectively where it was only 42 m/h for dual media filtration.

The rational way of comparing the declining rate and constant rate filters is looking into filter removal efficiency and headloss for same water production. In this study the declining rate filtration from 20.0 m^3/m^2.h to 13.2 m^3/m^2.h gave rise to 80 cm headloss compared to 106 cm headloss for constant rate filtration (15 m^3/m^2.h) at a water production of 3,000 litres. Another advantage of declining rate filter was that it produced better effluent quality especially at the end of the filter run compared to that of constant rate filter. The declining rate filters are cost effective because of the elimination of automatic rate controllers.

5. ACKNOWLEDGEMENT

The authors like to thank the staff of Bangkhen Water Treatment Plant, the MWWA for their great help in arrangement of the pilot scale filter.

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Table 1

a) Experimental Conditions Used for Comparison of Narrowly Graded Coarse Media Filtration and Dual Media Filtration

Run Number	Filtration Rate (v) $m^3/m^2.h$	Media Size	Remarks
A	13.75	Dual Media Anthracite: E.S. = 0.85 mm U max = 1.5 Depth = 80 cm Sand: E.S. = 0.5 mm U max = 1.5 Depth = 40 cm	1. Total Depth = 120 cm 2. The existing filters of Bangkhen Water Treatment Plant were observed for the Dual Media Constant Rate Filtration Operation.
B	12.5	Sand size = 1.00-1.19 mm	
C	15.0	Sand size = 1.00-1.19 mm	
D	12.5	Sand size = 1.19-1.41 mm	
E	15.0	Sand size = 1.19-1.41 mm	

b) Experimental Conditions Used for Comparison of Declining Rate Filtration with Constant Rate Filtration

(i) Constant Rate Filtration

Run Number	Filtration Rate (v) $m^3/m^2.h$	Sand Size, mm	Remarks
H	10	1.00-1.19	Total Depth = 120 cm
I	17.5	1.00-1.19	
J	20	1.00-1.19	
K	10	1.19-1.41	
L	17.5	1.19-1.41	
M	20	1.19-1.41	

(ii) Declining Rate Filtration

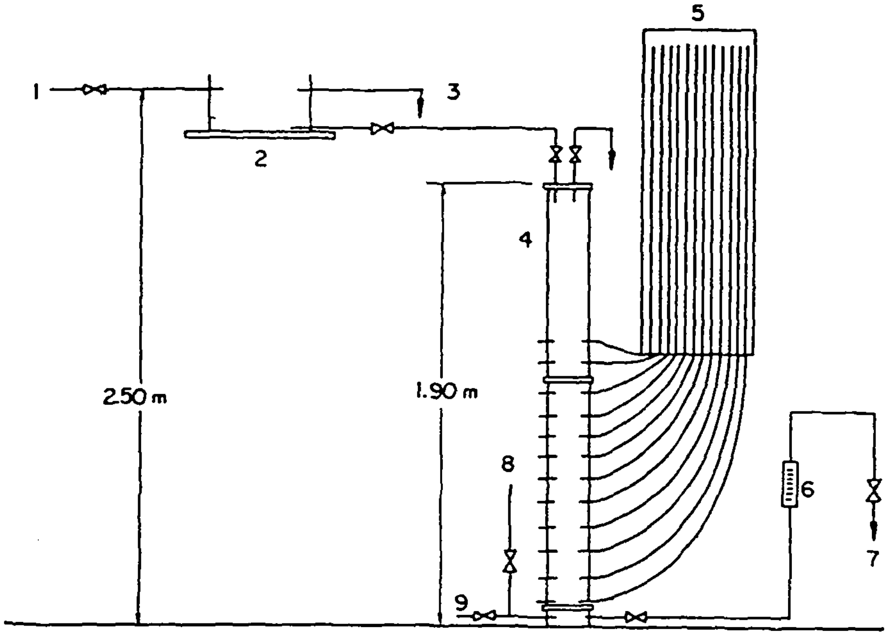
Run Number	Vi*, $m^3/m^2.h$	Sand Size, mm	Remarks
N	15	1.00-1.19	Total Depth = 120 cm
O	15	1.19-1.41	
F	20	1.00-1.19	
G	20	1.19-1.41	

Vi* = Initial filtration rate

Table 2

Water Flow Rates for Filter Backwashing
(Filter Bed Depth = 120 cm)

SandSize, mm	Water Flow Rate, m/n		
	20% Expansion	30% Expansion	40% Expansion
1.19-1.41	105.0	127.0	141.5
1.00-1.19	86.5	105.0	122.5
Dual media	33.0	42.0	48.5



1 Water from Clarifier at Bangkhen Treatment Plant
2 Constant Head Tank
3 Overflow
4 Filtered Column
5 Manometer
6 Rotameter
7 Filtered Water
8 Air Backwash
9 Water Backwash

Figure 1 – Experimental Set-Up

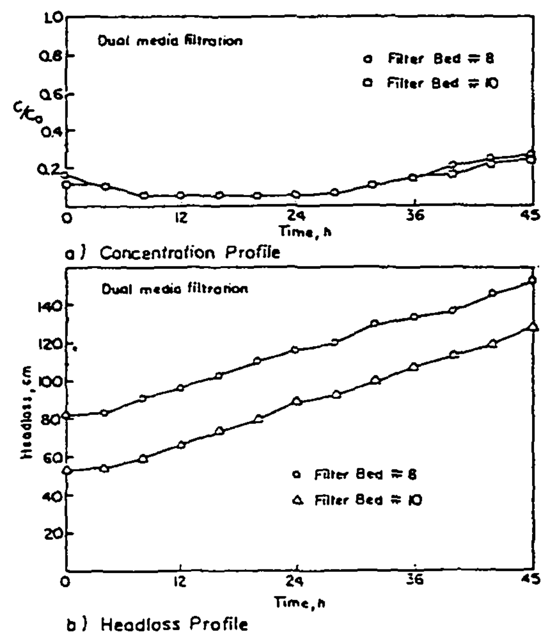
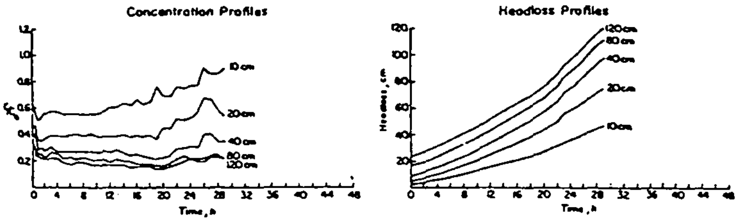
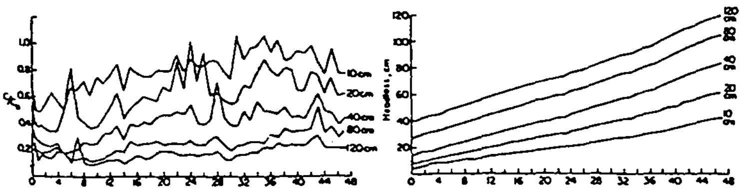


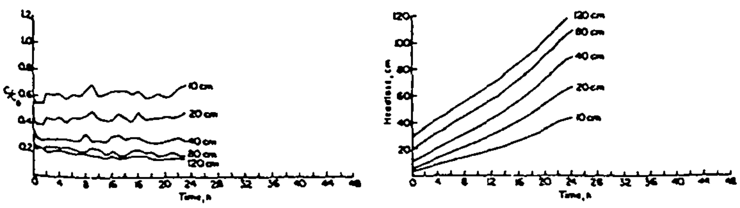
Figure 2 – Performance of Dual Media Filtration (Anthracite : ES = 0.85 mm , U_{max} = 1.5 , Depth = 80 cm ; Sand : ES = 0.5 mm , U_{max} = 1.5 , Depth = 40 cm ; V = 13.78 $m^3/m^2 \cdot h$)



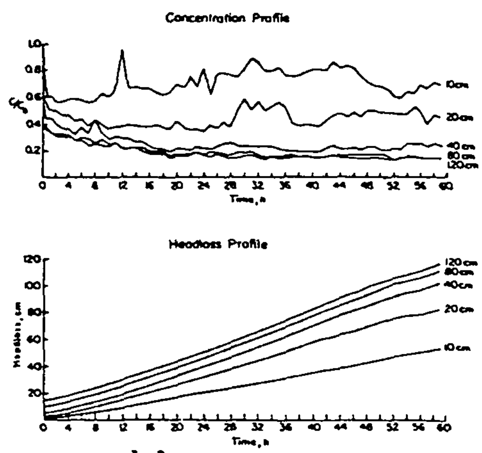
(c) V = 15 $m^3/m^2 \cdot h$



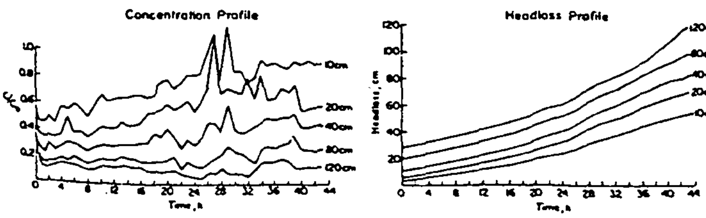
(d) V = 17.5 $m^3/m^2 \cdot h$



(e) V = 20 $m^3/m^2 \cdot h$

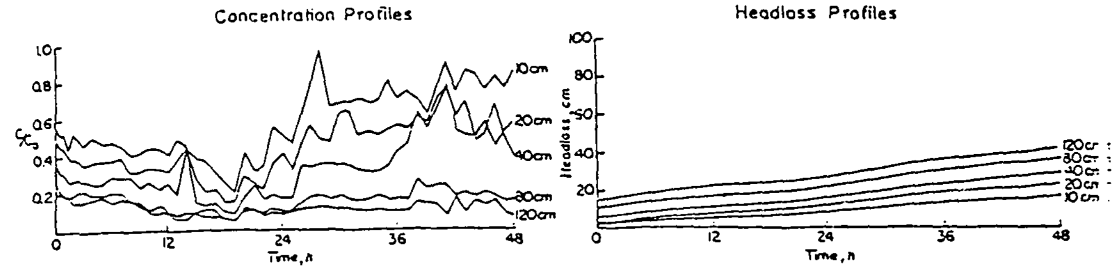


(a) V = 10 $m^3/m^2 \cdot h$

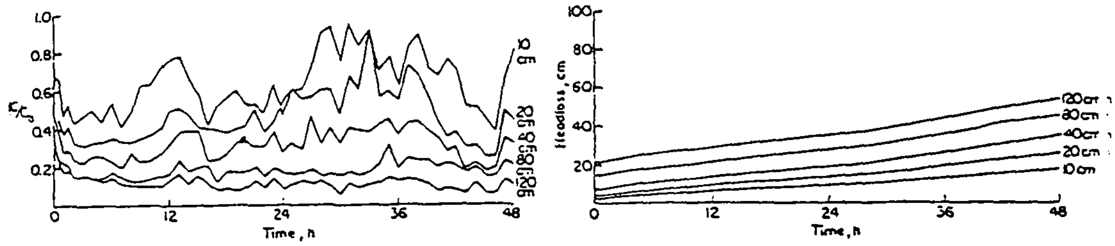


(b) V = 12.5 $m^3/m^2 \cdot h$

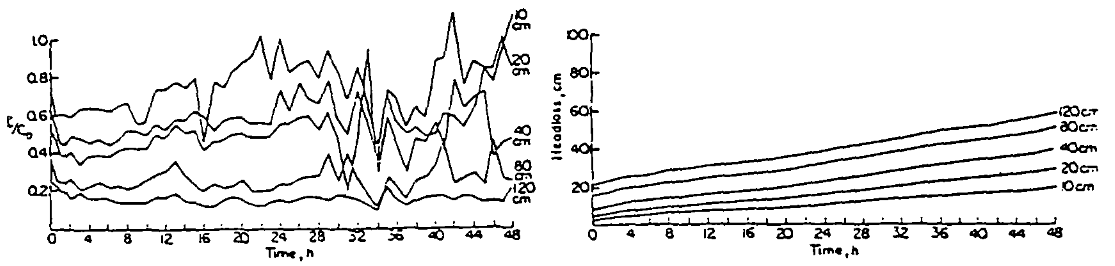
Figure 3 – Concentration and Headloss Profiles of Constant Rate Coarse Medium Filtration (Sand Size = 1.00 - 1.19 mm)



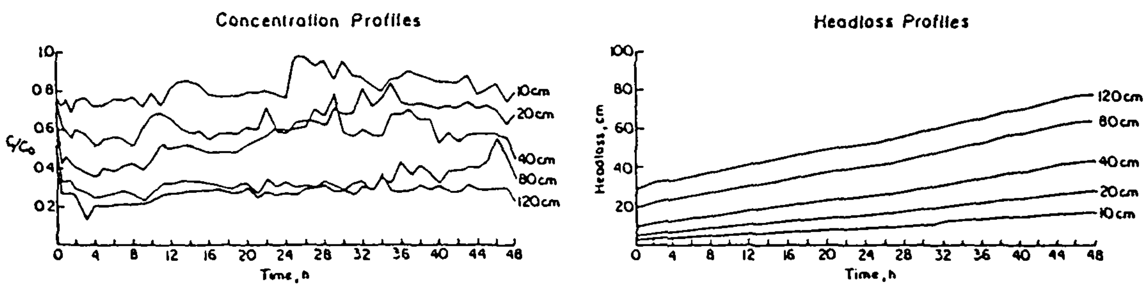
(a) V = 10 $m^3/m^2 \cdot h$



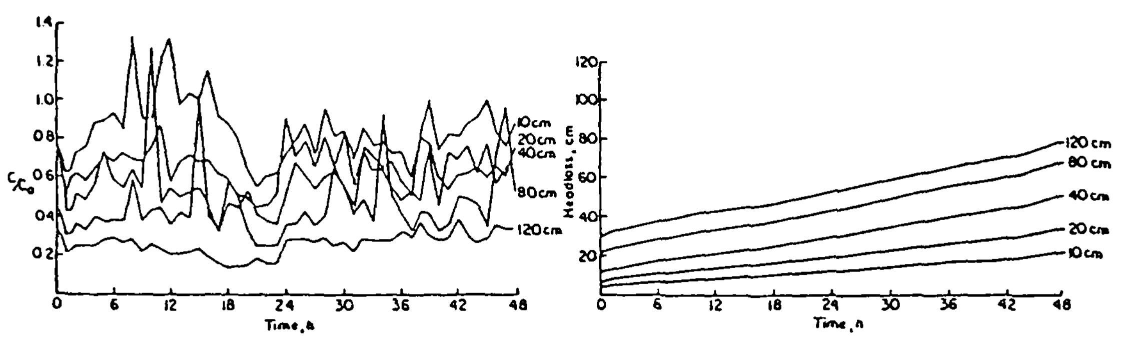
(b) V = 12.5 $m^3/m^2 \cdot h$



(c) V = 15 $m^3/m^2 \cdot h$



(d) V = 17.5 $m^3/m^2 \cdot h$



(e) V = 20 $m^3/m^2 \cdot h$

Figure 4 – Concentration and Headloss Profiles of Constant Rate Coarse Medium Filtration (Sand Size = 1.19 – 1.41 mm)

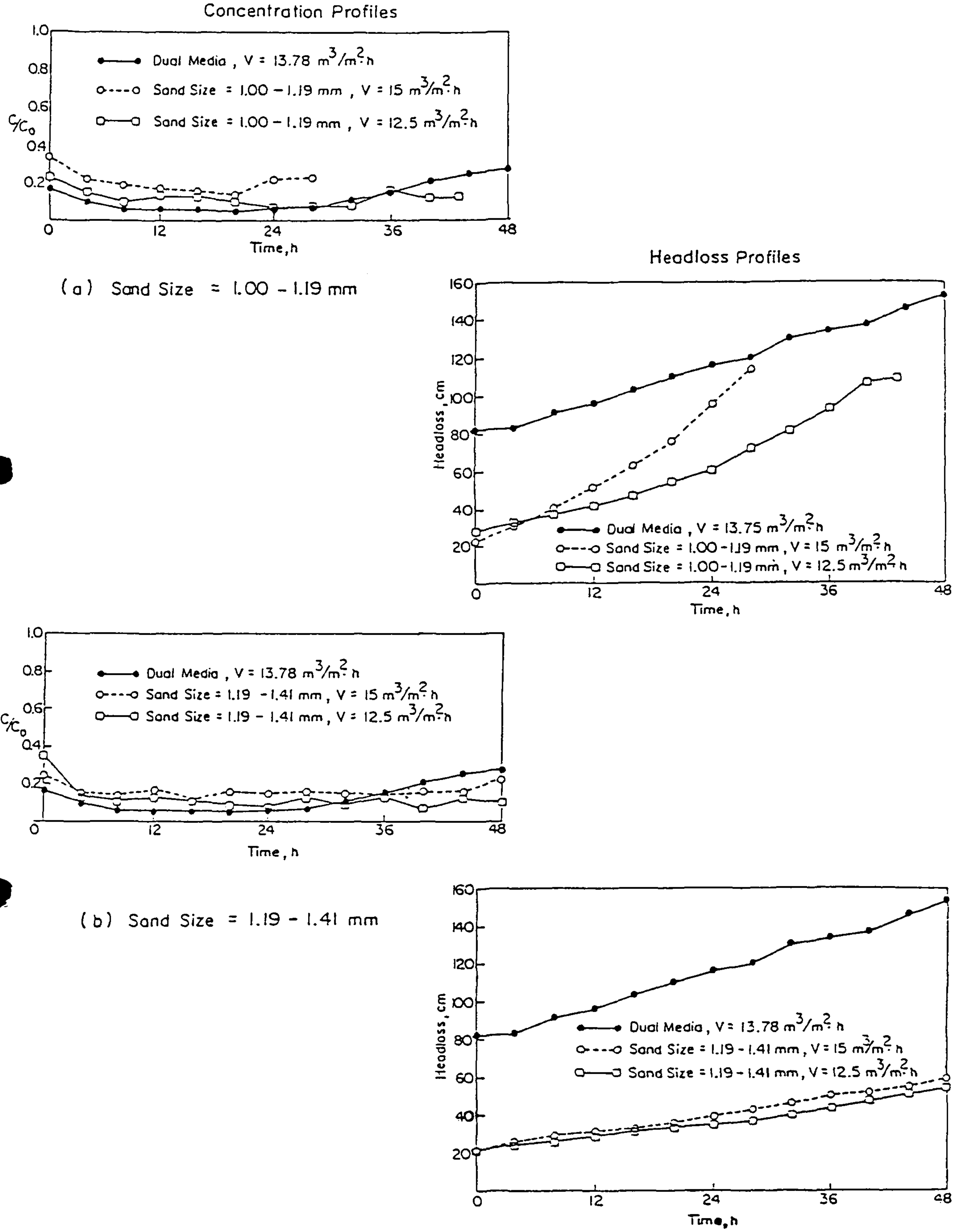


Figure 5 : Comparison of Concentration and Headloss Profiles of Constant Rate Filtration between Dual Media Filter and Narrowly Graded Sand Filters (Bed Depth = 120 cm)

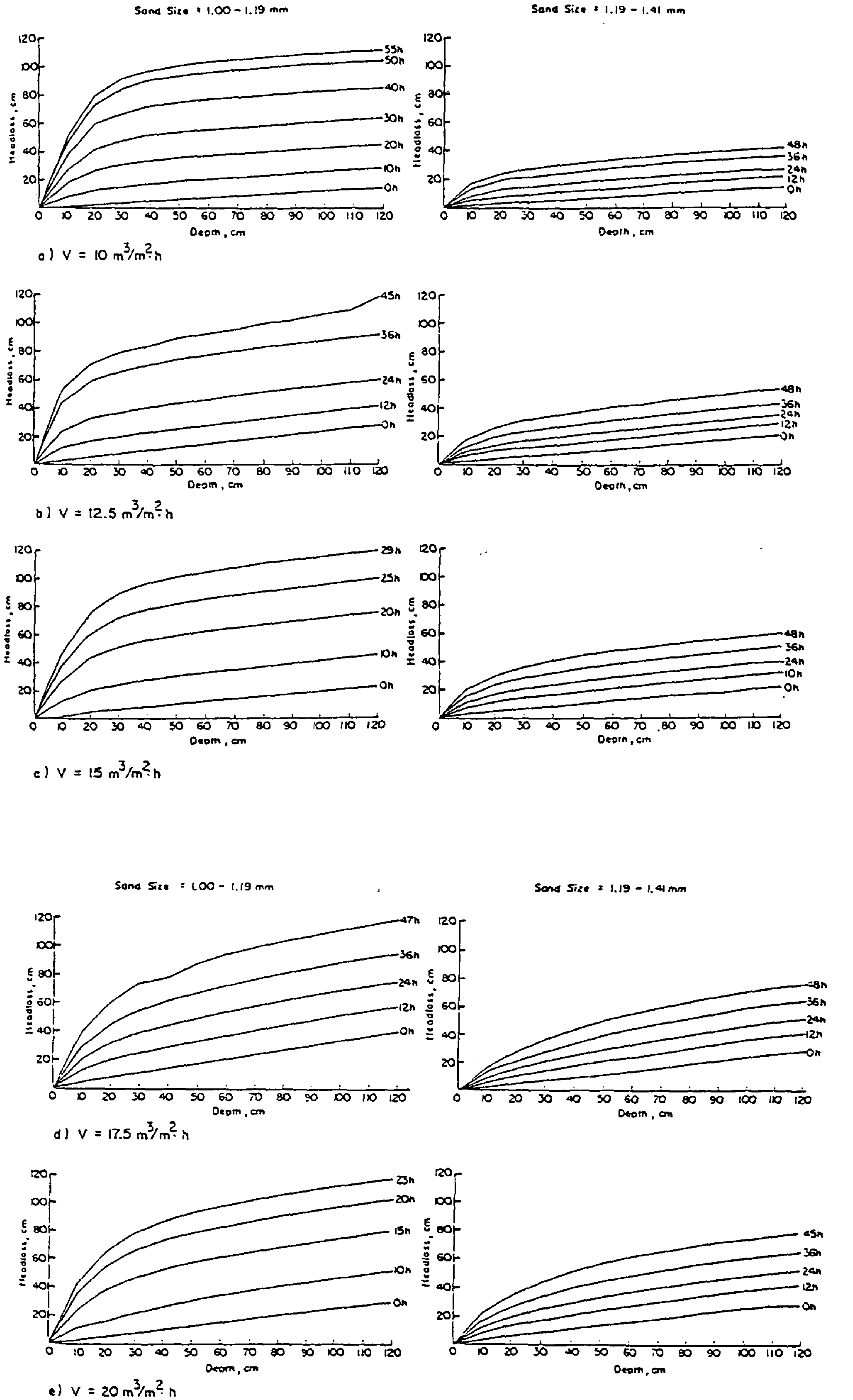


Figure 6 – Headloss Variation with Filter Medium Depth at Different Filtration Times

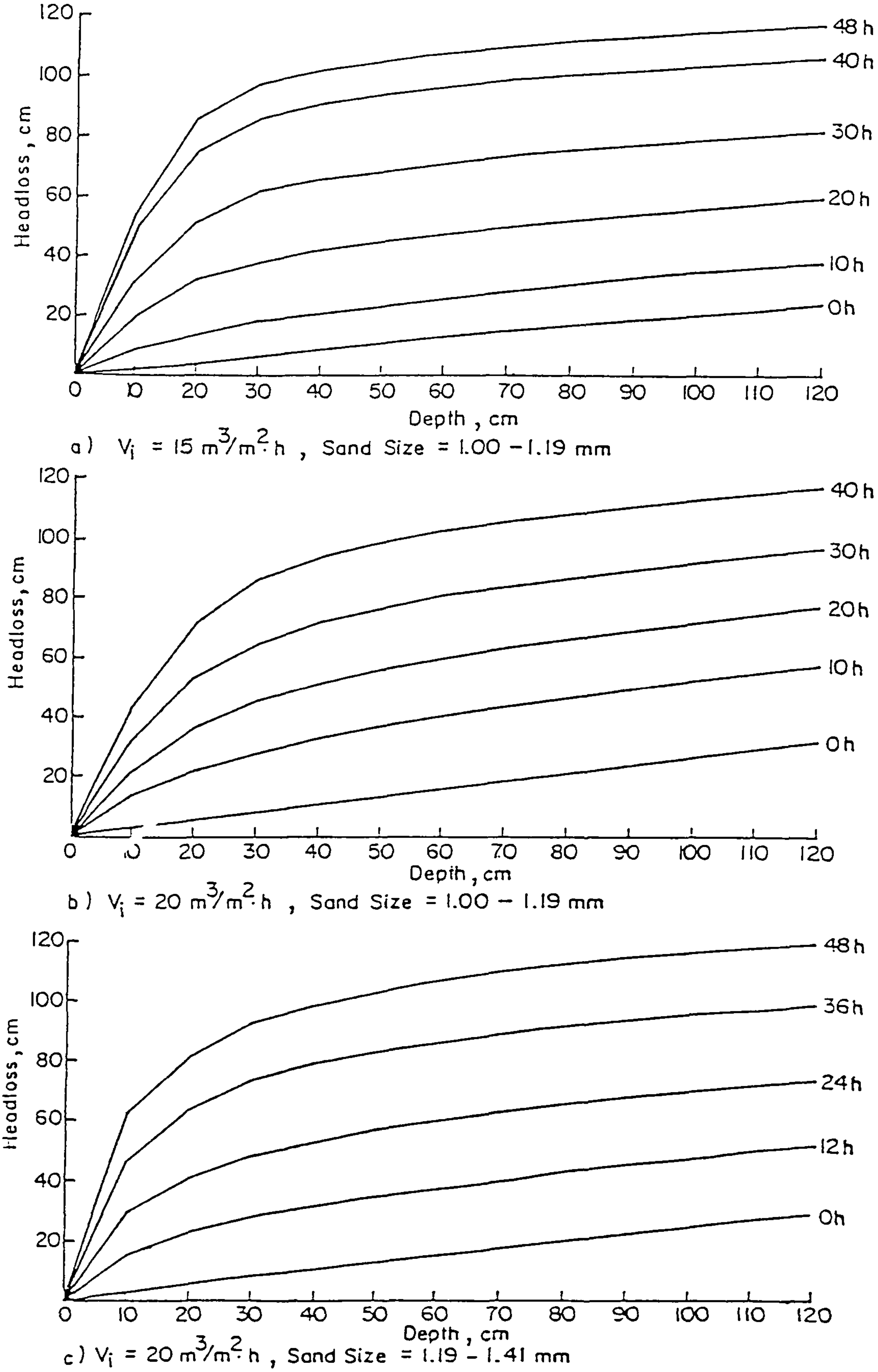
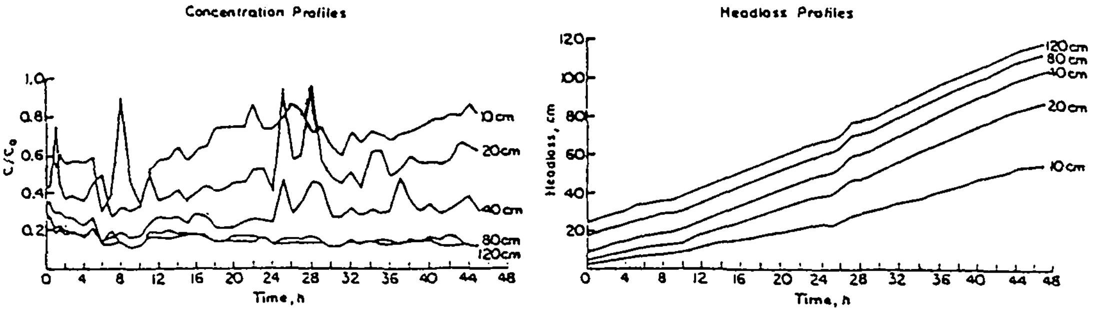
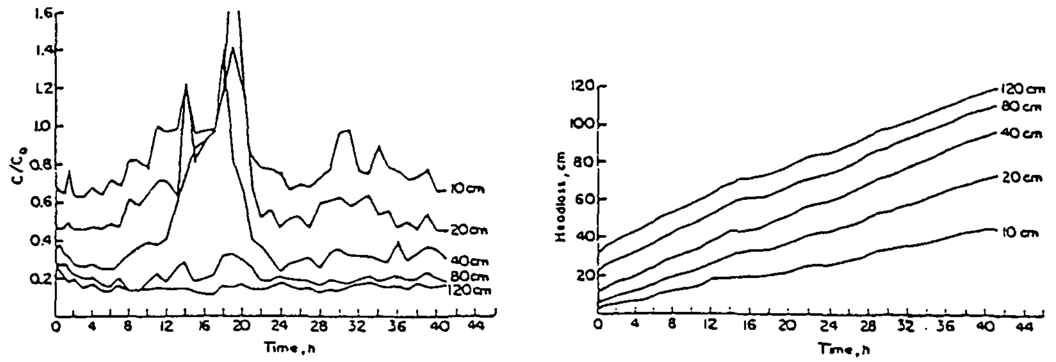


Figure 7 – Headloss Variation with Filter Medium Depth at Different Filtration Times (Declining-Rate Filtration)

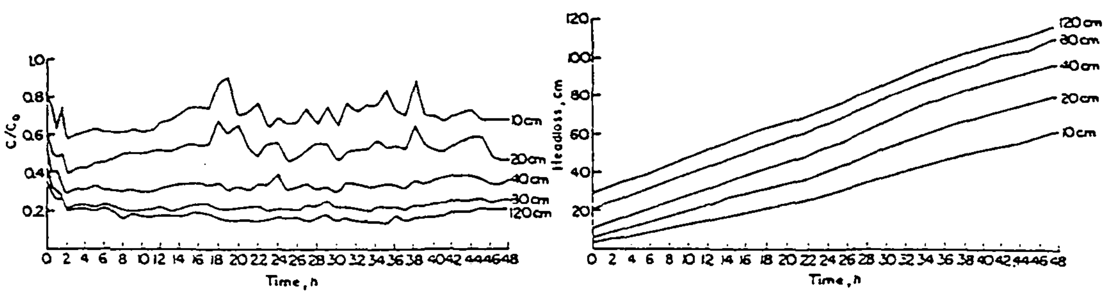


a) V_i = 15 $m^3/m^2 \cdot h$



b) V_i = 20 $m^3/m^2 \cdot h$

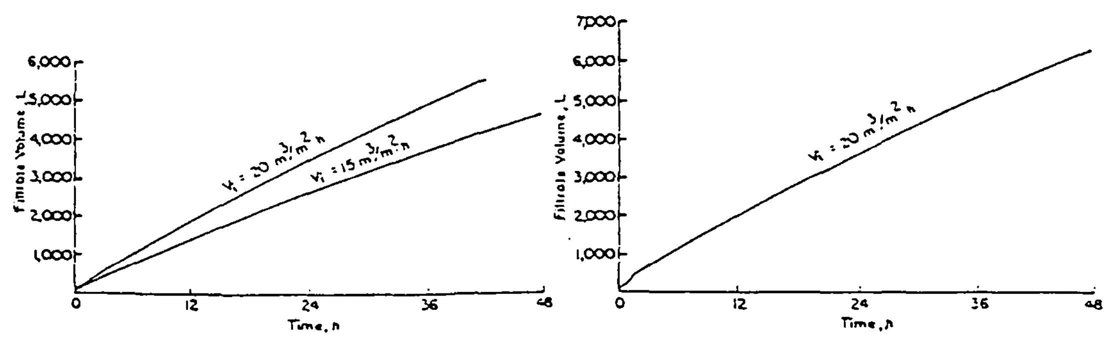
Figure 8 – Concentration and Headloss Profiles of Declining Rate Coarse Medium Filtration (Sand Size = 1.00 – 1.19 mm)



a) Concentration Profile

b) Headloss Profile

Figure 9 – Concentration and Headloss Profiles of Declining Rate Filtration (Sand Size = 1.19 – 1.41 mm , V_i = 20 $m^3/m^2 \cdot h$)



a) Sand Size = 1.00 – 1.19 mm

b) Sand Size = 1.19 – 1.41 mm

Figure 10 – Water Production Profiles of Declining Rate Experimental Results

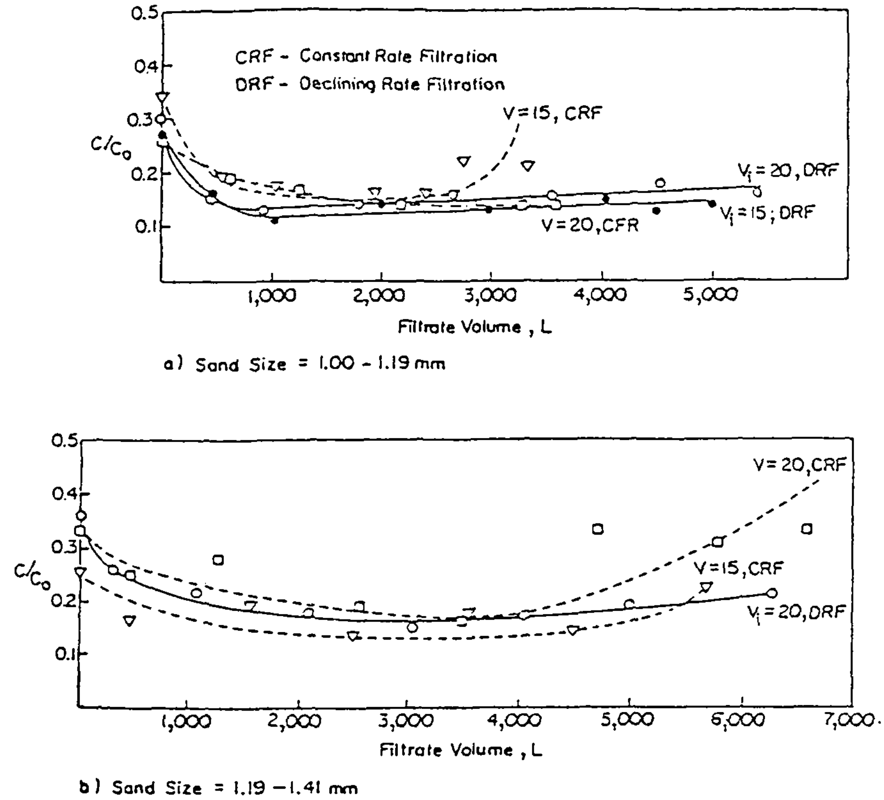


Figure 11 - Comparision of Concentration with Water Production
(Bed Depth = 120 cm)

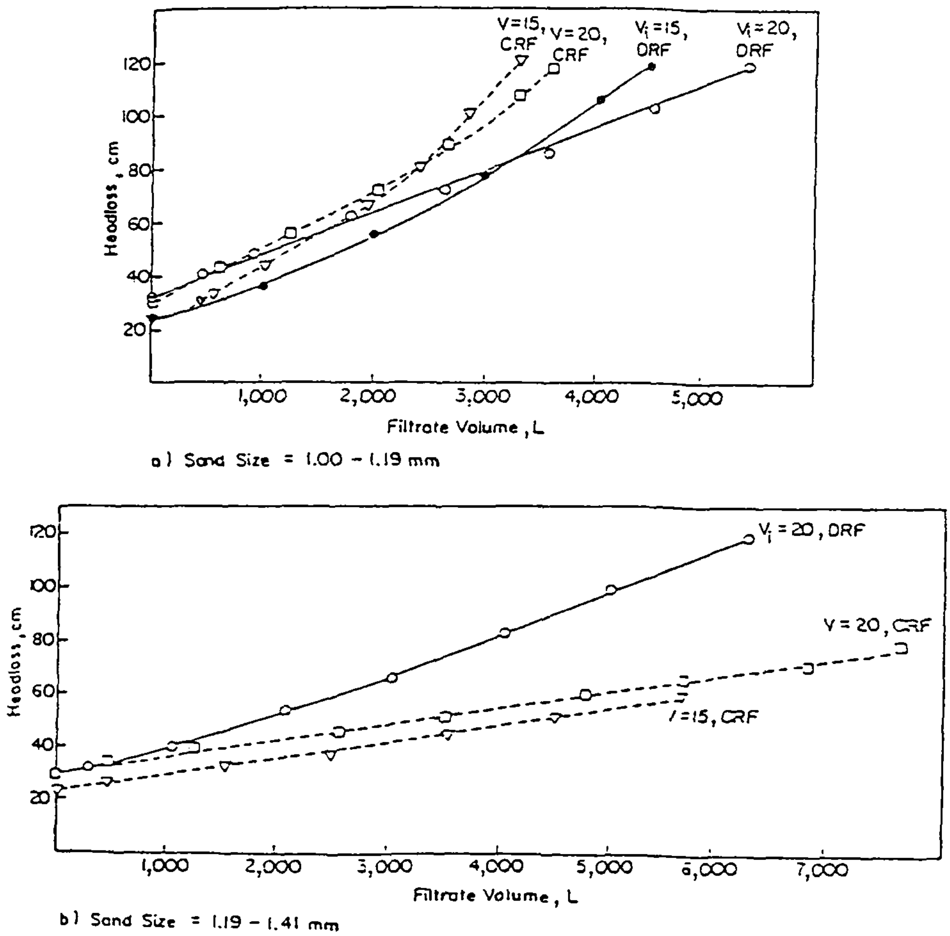


Figure 12 - Comparison of Headloss Development of CRF and DRF for
Same Water Production (L= 120 cm)

CHARACTERISTICS AND APPLICABILITY OF 'DUCMOLE' JACKING METHOD FOR MEDIUM AND SMALL SIZE DUCTILE IRON PIPES

by :
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KUBOTA, LTD.

1. INTRODUCTION

Recently, in the urban areas, new pipeline construction is restricted by some problems such as traffic jam, noises, vibration and subsidence of ground etc. arising from construction.

Furthermore, under roads and pavements underwhere the new pipeline is proposed, a lot of underground structures such as water, sewage, gas pipeline and conduit for power and telephone cable etc. are already installed.
So, it is very difficult to employ "Open-cut" method including trench excavation.

To solve above problems, direct jacking method for large diameter pipes was developed and became popular as "Non-trenching" method.

However, development of direct jacking method for medium and small diameter pipes was delayed because of difficulty of directional control.
At present, "Casing pipe jacking" method is mainly employed for medium and small diameter pipeline construction.
This "Casing pipe jacking" method consists of direct jacking of large diameter casing pipes and laying of medium and small diameter pipes into casing pipes.
Consequently, high cost and long period for construction is required.

Viewing the above situation, "DUCMOLE" jacking method is newly developed in 1983 by KUBOTA LTD., using the newest computer and electronics technology as direct jacking method for medium and small diameter ductile iron pipes.

This paper is prepared for presenting the characteristics and applicability of this "DUCMOLE" jacking method.

2. OUTLINE OF "DUCMOLE" JACKING METHOD

"DUCMOLE" jacking method is a mechanical direct jacking method for medium and small size (DN400 to DN800) ductile iron pipes.

Ductile iron pipes used for this method are "Push-on" type jacking pipe (TD-type) in accordance with Japanese standard.

This method is applicable to the straight pipeline construction of road crossing, railway crossing and other portions where "Open-cut" method is not applicable.

This method requires the jacking machine, jacking pipes, two pits for jacking and receiving and other appurtenant structure.

3. JACKING MACHINE

Jacking machine for "DUCMOLE" jacking method consists of a lead pipe, a jacking equipment, a hydraulic unit, a generator, a control panel, screw conveyors, a laser transit and other appurtenant equipment such as hoses, cables and pumps, etc.

The configuration of the jacking machine for "DUCMOLE" jacking method is shown in Fig.1.

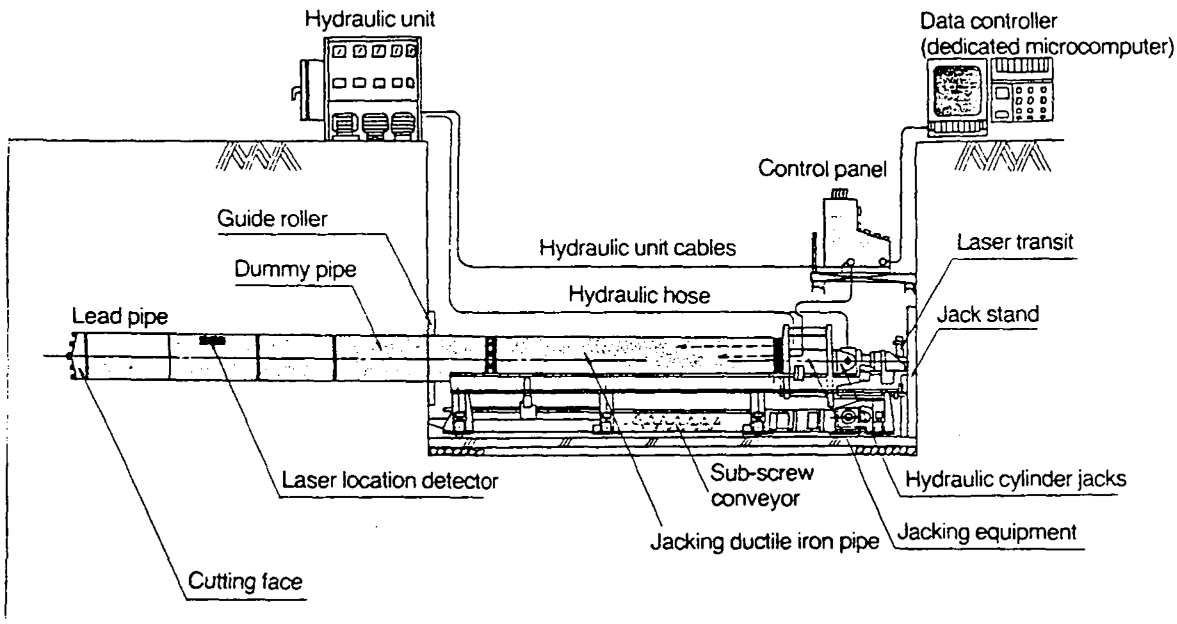


Fig. 1. Configuration of Jacking Machine

The structure of the lead pipe is shown in Fig. 2.

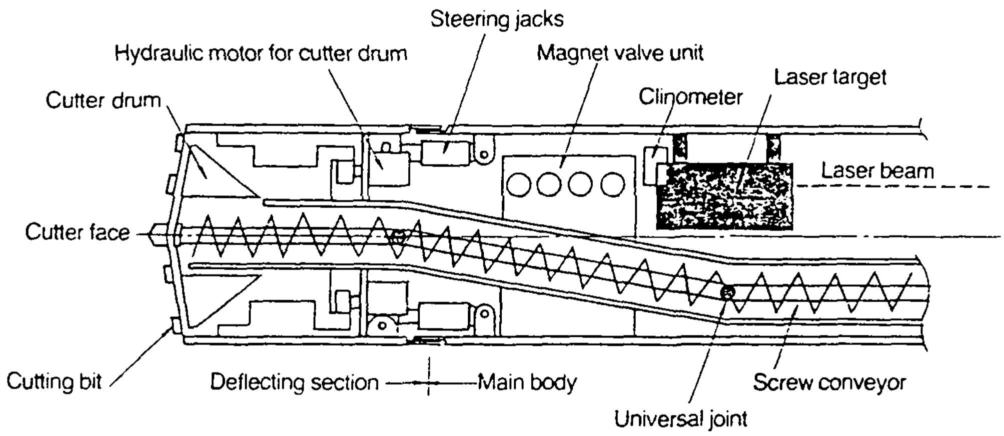


Fig. 2. Structure of Lead Pipe

3.1. Jacking Mechanism

The jacking mechanism of "DUCMOLE" jacking method is as follows;

a) Excavation
The cutter drum is rotated by the hydraulic motor in the lead pipe.
The ultra-hard alloy cutting bits fitted on the head of cutter drum excavates the soil into the cutter drum through the opening of the cutter face. Simultaneously, the hydraulic jacks in the jacking pit push the pipes into the soil.

b) Soil Removal
Excavated soil in the cutter drum is removed to the jacking pit by the screw conveyor set in the lead pipe and jacking pipes.

c) Location Check
Location check of the lead pipe is conducted automatically.

d) Direction Adjustment
Direction adjustment of the lead pipe is carried out by four steering jacks in the lead pipe.

3.2. Specification of Jacking Machine

Specificatins of jacking machine for "DUCMOLE" jacking method are listed below.

a)Applicable Pipe; TD-type ductile iron pipe, 400 mm to 800 mm diameter (Standard laying length: 4 m).

b)Applicable Soil; Wide range of soil conditions with N-value less than 50; maximum diameter of conglomerate to be disposed by the screw conveyor is approx. 40 mm.

c)Jacking Distance	;	Greater than 100 meters as a result of the high resistance of ductile iron pipe to jacking force.
d)Excavation	;	Excavation unit is driven independently of the soil removal unit to increase excavation efficiency. Ultra-hard alloy cutting bits can break up conglomerates. Amount of excavated soil can be adjusted by changing the opening ratio of the cutting face plate to reflect soil conditions. Hydraulic drive cutter can be rotated both clockwise and counterclockwise ; consequently, it is easy to compensate for rolling in the lead pipe as well as to cut through conglomerate material with minimal noise and vibration.
e)Soil Removal	;	Excavated soil is removed by the screw conveyor. Amount of soil removal can be adjusted by changing the rotational speed of the screw conveyor. Hydraulic drive motor can reverse the rotation of the cutter face to prevent blockage of cutter opening sections. The cutter drum is equipped with water adding equipment to facilitate excavation in the sticky soil. The screw conveyor casing is fitted with rubber casters on the bottom to avoid damaging the internal surface of the pipe.
f)Location Check	;	Position of the lead pipe is automatically detected by laser transit and target. Lead pipes are automatically measured in three directions: vertical, horizontal and circumferential.
g)Operaiton	;	Operation can be conducted automatically or manually. Direction adjustment, rolling correction and jacking speed can be controlled automatically. Execution data can be analyzed by the dedicated microcomputer. Warning display for values outside allowable range and overload protection mechanisms are provided.
h)Direction Adjustment	;	Adjustment in the direction of the lead pipe is accomplished by coordinated action of the four steering jacks. Required stroke for each steering jack is determined automatically.
i)Jacking Device	;	Max. jacking force: 400 tonf Max. jacking speed: 16.2 cm/min Jacking stroke: 400 mm Required electric capacity: 125 KVA (including that for lead pipe)

Under automatic control, jacking machinery runs by itself.

4. JACKING PIPE

Jacking pipes for "DUCMOLE" jacking method are "Push-on" type ductile iron jacking pipe in accordance with Japanese standard.
The structure and dimensions of the jacking pipes are shown in Fig.3 and Table 1.

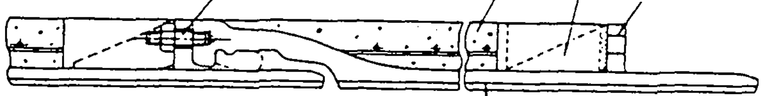


Fig.3 Structure of Jacking Pipe

Table 1 Dimensions of Jacking Pipe

NOMINAL	WALL THICKNESS (mm)				DIMENSIONS(mm)			
DIAMETER	CLASS 1	CLASS 2	CLASS 3	CLASS 4	D2	D4	D5	L
400	8.5	7.5	7.0	-	425.6	478	502	4000
450	9.0	8.0	7.5	-	476.8	530	555	4000
500	9.5	8.5	8.0	-	528.0	582	608	4000
600	11.0	10.0	9.0	8.5	630.8	685	713	4000
700	12.0	11.0	10.0	9.0	733.0	792	831	4000
800	13.5	12.0	11.0	10.0	836.0	897	938	4000

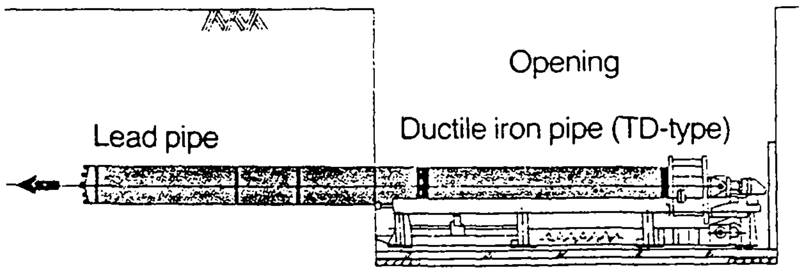
The allowable jacking forces of jacking pipes are listed in Table 2.

Table 2. Allowable Jacking force

NOMINAL	ALLOWABLE JACKING FORCE (tonf)			
DIAMETER	CLASS 1	CLASS 2	CLASS 3	CLASS 4
400	290	250	220	-
450	290	290	250	-
500	380	340	290	-
600	380	380	380	340
700	670	590	490	380
800	670	670	590	490

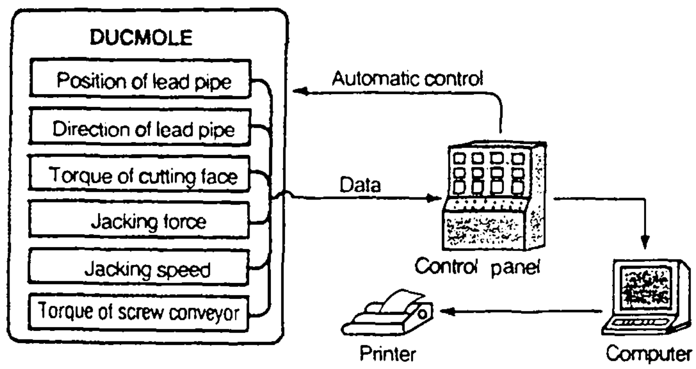
5. CHARACTERISTICS AND APPLICABILITY OF "DUCMOLE" JACKING METHOD

(1) Simple Execution and Shortened Construction Period
"DUCMOLE" is a method for jacking ductile iron pipe directly into the soil without using casing pipes. Together with the large excavation capacity of the jacking machine, this method significantly reduces the required construction period.

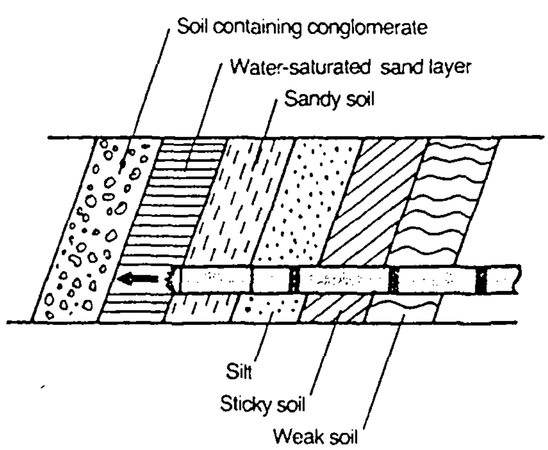


(2) Long Distance Jacking
"DUCMOLE" jacking method is designed to be used with TD-type jacking ductile iron pipe which has high strength to withstand the jacking force. With its large excavation capacity and efficient jacking performance, this method enables jacking over long distances spanning 100 meters or more.
In addition, this method features superior accuracy in executing the planned pipeline route.

(3) Safe, Reliable Automatic Control
"DUCMOLE" jacking method utilizes a dedicated computer to control the jacking process. The computer constantly monitors the position of lead pipe, jacking force, torque at the cutting face, and other important variables. As a result, jacking proceeds safely and reliably under automatic control.



(4) Extensive Application to Diverse Soil Conditions
"DUCMOLE" jacking method uses a high-torque hydraulic motor inside the lead pipe to rotate ultra-hard cutting bits. The powerful cutting force that is generated means that this system can be applied even to soil with N-values as high as 50.



(5) Superior Accuracy and accessibility

A precision laser measuring system combined with steering jacks in the lead pipe automatically control jacking direction to provide positioning accurate to within ± 50mm.

Jacking conditions and progress reports can be output through the computer printer.

(6) No Effect on Existing Groung Surface

In the "DUCMOLE" jacking method, the outside diameter of the lead pipe is the same as that of the TD-type jacking ductile iron pipe.

The amount of soil excavated can be adjusted by changing the opening ratio of the face plate at the lead pipe cutting face.

Close computer control over the jacking speed and excavation amount ensures that the existing ground surface is not affected and remains undisturbed.

(7) Low Noise and Low Vibration

"DUCMOLE" jacking method utilizes a hydraulic system resulting in low noise level with minimal vibration introduced into the environment. Jacking work can be carried out in urban areas or at night without disturbing local residents.

6. EXECUTION PROCEDURE

Execution procedure of "DUCMOLE" jacking method is indicated in below chart.

1. Jacking Machine Assembly and Set-up

Jacking direction and level are determined.
Laser transit is set up.

↓

2. Lead Pipe Set-up and Positioning

Hydraulic hoses and cables are connected.
Centering and test operations are carried out.

↓

3. Jacking of Lead Pipe

Pit wall through which jacking pipe is intruded are cut around. Jacking proceeds on lead pipe.

↓

4. Positioning of Pipe

Jacking equipment is retracted and jacking pipe is lowered into the pit.

↓

5. Connecting Pipe

Screw conveyors are installed and connected.
Hydraulic hoses and cables are connected.
TD-type jacking ductile iron pipes are jointed.

↓

6. Jacking

Jacking equipment is put into operation.
The next TD-type jacking ductile iron is set in position.

↓

7. Soil Removal

Soil can be removed during jacking or after jacking each pipe.

↓

8. Removal of Lead Pipe

The lead pipe is dismantled in the receiving pit and removed.

↓

9. Dismantling and Removal of Jacking Machine

Screw conveyor is removed through the jacking pit Jacking equipment is dismantled and removed.

↓

10. Completing

* Step (4) to (7) are repeated every 4 m jacking.

7. INSTALLATION RECORD

Successful installations using the "DUCMOLE" jacking method are listed in Table 3.

Table 3. INSTALLATION RECORD

Year/Month	Client	Pipe Dia. (mm)	Jacking Distance
1983, AUG. - NOV.	Sapporo Municipal Water Office	500 500 500 400 400	51 m 50 m 67 m 51 m 67 m
1984, SEP. - OCT.	Kawaguchi Municipal Water Dept.	600 600 600 600 600 600	76 m 66 m 120 m 48 m 96 m 96 m
1985, MAR.	Hamamatsu Municipal Water Office	400 400	92 m 24 m
1985, MAR.	Sapporo Municipal Water Office	700 700	64 m 54 m
1985, JAN. - FEB.	Sapporo Municipal Water Office	500 500 500	59 m 111 m 48 m
1986, JAN. - FEB.	Chiba Prefectural Water Office	400	31 m
1986, FEB. - MAR.	Saitama Prefecture, Southern Water Planning Board	400 400	12 m 12 m
1986, AUG. - DEC.	Sapporo Municipl Water Office	700 700 700	130 m 102 m 34 m
1986, NOV. - 1987, JAN.	Koshigaya - Matsubushi Water Planning Board	600 600	156 m 128 m
1987, JAN. - FEB.	Kokubunji Municipal Water Office	450	78 m
1987, MAR.	Tokyo Metropolitan Water Works	600	12 m

From the above table, following project is picked up to show the example of the installation using "DUCMOLE" jacking method.

< EXAMPLE OF INSTALLATION >

A. Outline of Project

Client	Kawaguchi Municipal Water Department
Project	Extension of Angyo Area Water Supply Phase 3
Location	Saitama Prefecture / Japan
Pipe Diameter	600 mm
Jacking Distance	120 m

B. Installation Condition

Soil Condition	Silt and Clay
N-value by S.P.T.	2 to 15
Depth of Cover	2.9 m (Jacking Side), 4.6 m (Recieving Side)
Gradient	10.38 o/oo

C. Installation Result

Construction Period	17 days (excluding the construction of jacking and recieving pits.)
Installation Rate	7 m/day
Jacking Force	Max. 290 tonf (as shown in Fig.4.)
Deviation of Lead Pipe	Max. 45 mm (as shown in Fig.5.)

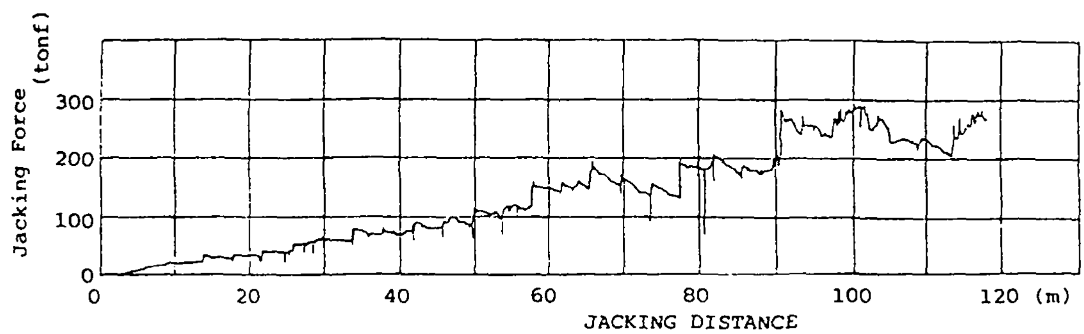


Fig.4. Jacking Force

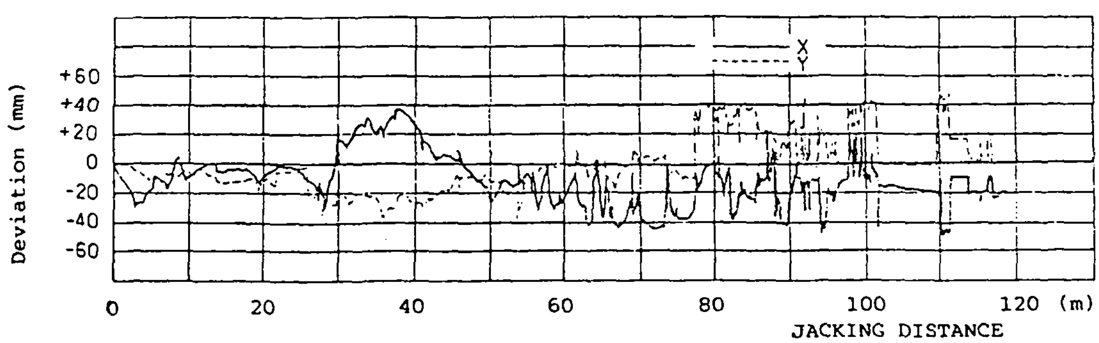


Fig.5. Deviation of Lead Pipe

8. CONCLUSION

Characteristics and applicability of the "DUCMOLE" jacking method is summarized as below.

(1) Safe and reliable automatic jacking method by computer control.
(2) Excellent execution performance and short construction period.
(3) Excellent directional control and long distance jacking.
(4) Excellent applicability for various soil conditions.
(5) Small noises and small vibration.

In the near future, the "DUCMOLE" jacking method will prevail in pipeline construction in the urban areas as the most economical and reliable method in the world.

SUBMERGED BIOLOGICAL FILTER PROCESS FOR TAP WATER SUPPLY

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1. INTRODUCTION

Recently, submerged biological filter process with "honey-comb" tube as fiter media for tap water suplly has been tried to cope with the deterioration of raw water at some plants in japan[1),2)]. Althogh several pilot plant studies and a full scale operation are now going on, comprehensive studies on the plant performance have not presented yet. Because each process ever reported has different configuration and operating conditions, and also is treating different quality of raw water. In this study, the performance of submerged biofilm process for eutrophic lake water was studied by introducing two different lake waters into pilot-scale plants with the same design and operational conditions.

Moreover, eutrophic lake water contains a large number of phyto-plankton and much metabolic products from them which are main subjects of biological treatment. However, the performance of submerged biofilm process is influenced largely by the algae existing in the raw water, because different species appears in different seasons and has different characteristics. In this reason, the treatment performance with every different species was studied using the artificial lake waters which could contain typical species seen in eutrophic lakes.

2. MATERIALS AND METHODS

2.1. Pilot Plants

Raw waters were taken from lake Kamafusa (eutrophic) and lake Kasumigaura (hyper-eutrophic). The same pilot-plants consisted of twelve reactors were placed at each lake side to introduce lake water continuously. The reactor is made of transparent vinyl chloride and the size is 500 x 500 mm and 800 mm deep (working volume = 170 l). It is filled with filter media called "honey-comb tube" (500 x 500 x 450 mm ; cell size = 20 mm) except for reference reactors in which no media was installed. There is a vertical hole at the center of the media (100 x 100 x 450 mm) to install mechanical mixing (propellar-type mixer) or aeration (ball-type diffuser) equipment.

Four reactors are equipped with a diffuser for aeration. The diffuser supplies oxygen into the water and enhances mixing in the reactor by lifting water in the center hole and by generating down flow through the filter media. Another four reactors have mechanical mixing apparatus. A propeller lifts water in the center hole and enhance down through the filter media. Two reactors are not mixed nor aerated and raw water is introduced into the bottom of the reactor. thus the water is discharged from the surface after passing through the filter media by upper-flow. The remaining two reactors are equipped with diffuser but no filter media is installed. The raw water is simply aerated.

Hydraulic retention time (HRT) were 1, 2, 4 and 8 hours for both aeration and mechanical mixing with filter media. HRTs of only 1h and 8h were assessed for upper-flow reactors and reactors without filter media. All the reactors were fed with lake water continuously at a constant rate.

2.2. Chemical Analysis

Suspended solid concentration (SS) was determined by filtrating through a glass-fiber filter (Whatman GF/C). Turbidity was determined by turbidimeter (Nihon Seimitsu Kogaku, POIC SEP-PT-205D or 201). Dissolved oxygen (DO) was analyzed by the Azide modification. Total organic carbon (TOC) analyzer (Shimazu,TOC-10B or Beckman MODEL 915B) was used for TOC and dissolved organic carbon (DOC) was analyzed for the filtrates. Ammonium nitrogen (NH_4-N) and nitrite + nitrate nitrogen (NO_{2+3}-N) were measured by the phenate method and the cadmium reduction method, respectively[3].

A thin sheet made of vinyl chloride (the same material as the filter media) was cut and formed into test pieces to just fit inside the cell of "honey-comb". One edge of the hexagonal test pieces was remained open to expand and to remove attached biomass. The removed biomass was suspended in distilled water and total mass as dry weight was determined by the same method of SS.

Once every two months, after mixing water completely in reactor so that the bottom sediment can be suspended uniformly, a little volume of inner water was sampled and SS of it was determined. The amount of bottom sediment was measured with the volume and SS of reactor. The period of study was from spring to autumn in this study.

2.3. Lab experiment using artificial lake water

The reactor is made of transparent vinyl chloride and the size is 100 x 100 x 120 mm (working volum = 1035 ml). It is filled with "honey-comb" (80 x 80 x 80 mm ; cell size = 8 mm) and has an aeration (ball-type diffuser; diameter = 10 mm) equipment.

The phyto-plankton cultivated purely are Chlamydomonas sp. as green algae, Synedra acus as diatom and Microcystis aeruginosa as blue-green algae.

Continuous pure cultivation was carried using the Gorham culture medium diluted to a fifth at water temperature of 20 °C for the former two algae and 30 °C for the latter. Light strength in cultivation was coordinated so that cell concentration of influent water to reactor can be 26 mg/l as dry weight.

TOC and DOC were determined as mentioned above. SS of infuent water was analyzed by caulter-counter (Coulter Electronics, COULTER MODEL-1 MHR) because all suspended materials were cells of algae. On the oter hand, SS of effluent water was determined by filtrating through a membrane filter (Milipore filter; 0.45 μm).

3. RESULTS AND DISCUSSION

3.1. Treatment performance of removal for suspended materials

Water temperature of influent water ranged from 10 °C to 25°C in lake Kamafusa and from 15°C to 29 °C in lake Kasumigaura. As a whole, the former had ca. 4 °C higher temperature than the latter.

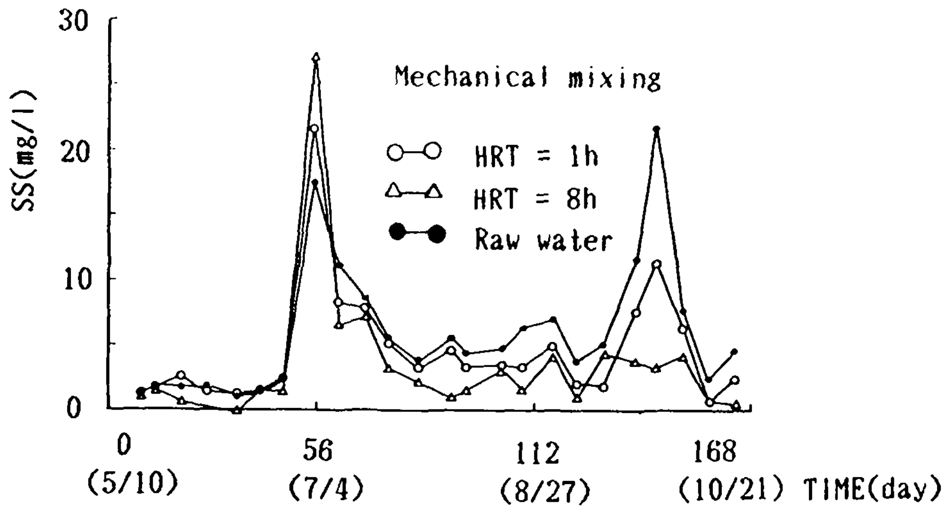

Fig. 1 SS of influent and effluent water in reactors in lake Kamafusa

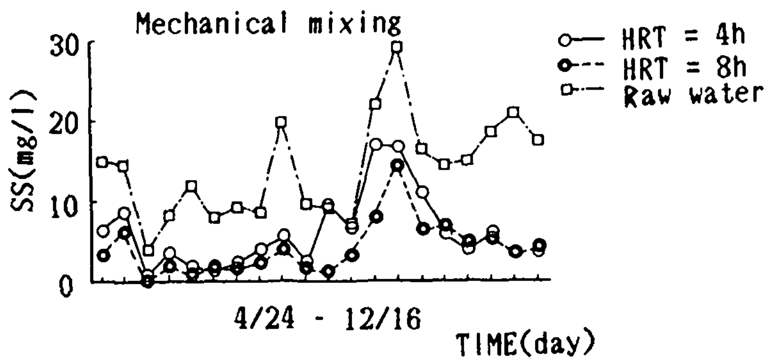

Fig. 2 SS of influent and effluent water in reactors in lake Kasumigaura

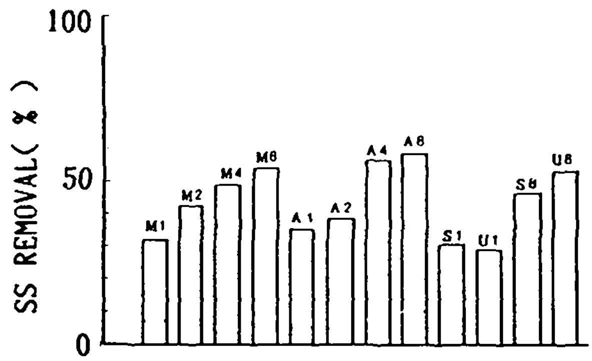

Fig. 3 Mean of percentage of SS removal in reactors in lake Kamafusa
(M = mechanical mixing ; A = aerated ; U = upper-flow
S = aerated without media ; Figure are HRTs)

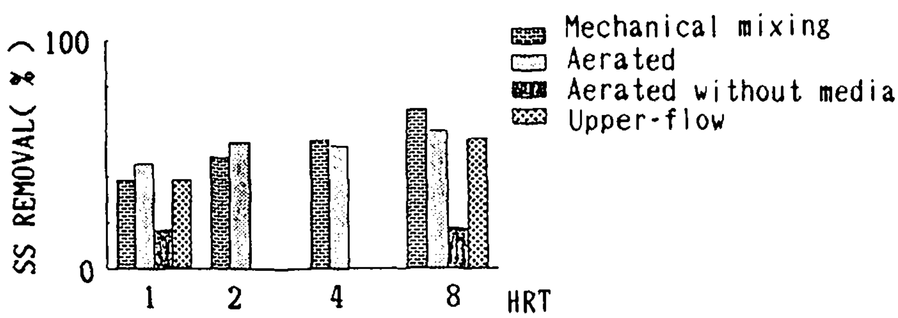

Fig. 4 Mean of percentage of SS removal in lake Kasumigaura

Fig. 1 and Fig. 2 shows SS of influent and effluent water in reactors using mechanical mixing with HRT of 1 and 8h in lake Kamafusa and with HRT of 4 and 8h in lake Kasumigaura, respectively. Influent SS values were about twice higher in lake Kasumigaura (mean 10 mg/l) than in lake Kamafusa (mean 4mg/l), except influence of flood caused by rainfall in lake Kamafusa. Effluent SS values intended to increase being accompanied with the increase of influent SS values both in lake Kamafusa and lake Kasumigaura. Removal percentages were higher in lake Kasumigaura .

Fig. 3 and Fig. 4 shows the mean percentage of SS removal during operating period in reactors with every operational conditions in lake Kamafusa and Kasumigaura, respectively. Removal percentage of SS raised higher as HRT was longer and reached to more than 50 % in HRT of 8h. SS removal of both "upper-flow" types and "aerated without media types was almost equal to that of mechanical mixing and/or aerated types. Removal percentage of turbidity was obtained similar results to SS. From that, removal percentage of suspended materials would be expected to be 50 % or more under usual operation which was not the beginning of operation nor has low values of influent SS.

2.2. Treatment performance of organic materials

Fig. 5 and Fig. 6 shows the total organic carbon (TOC) of influent and effluent water in reactors using mechanical mixing with HRT of 1 and 8h in lake Kamafusa and with HRT of 4 and 8h in lake Kasumigaura, respectively. In both lakes, removal percentages of TOC were ca. 20 % or less, and difference in treatment performances could not be seen distinctly.

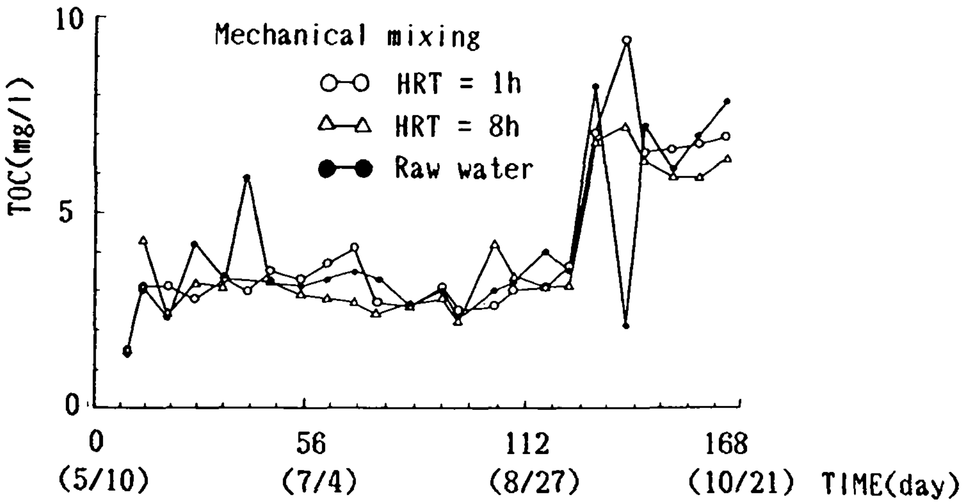

Fig. 5 TOC of inluent and effluent water in reactors in lake Kamafusa

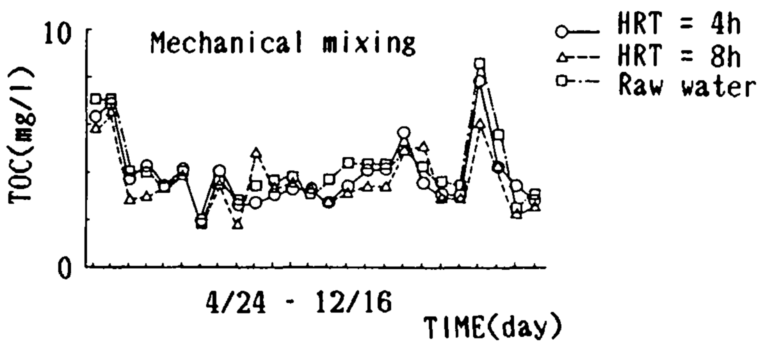

Fig. 6 TOC of influent and effluent water in reactors in lake Kasumigaura

Fig. 7 and Fig. 8 shows the mean percentage of TOC removal during operating period in reactors with every operational conditions in lake Kamafusa and Kasumigaura, respectively. It was found that the treatment performance of TOC had no connection with operational conditions such as mixing types or HRTs. It was similar to results of the study in autumn and winter. From thinking about the difference of removal in suspended and organic matters, it was conceivable that removed suspended materials by these submerged biofilm process were almost inorganic matters such as silt in both lakes.

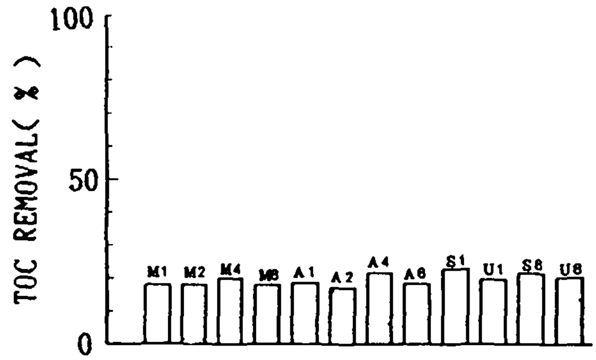

Fig. 7 Mean of percentage of TOC removal in reactors in lake Kamafusa
(M = mechanical mixing ; A = aerated ;U = upper-flow
S = aerated without media ; Figure are HRTs)

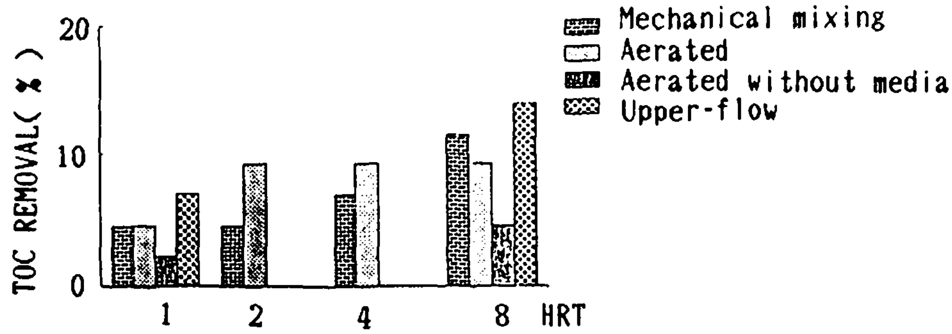

Fig. 8 Mean of pecentage of TOC removal in reactors in lake Kasumigaura

3.3 Groth of microbial film

Fig. 9 shows an example of the groth of microbial film on the filter media in lake Kamafusa. The amount of attached biofilm for first two months (in spring) was more than that for the last two months (in summer). It may be connected with this result that the removal of suspended matters was more stable in summer than in spring. The amount of attached biomass was 0.2 - 0.5 mg/cm^2 for HRT = 1h and 0.05 mg/cm^2 for HRT = 8h. It may be referable to the fact that organic and suspended matter loadings are high in reactors with short HRT. The amount of attached biomass in "upper-flow" reactors (ca. 0.05 - 0.25 mg/cm^2 for HRT = 1h) was smaller than that in mechanical mixing or aerated reactors (ca. 0.1 - 0.6 mg/cm^2 for HRT = 1h) which were almost equal. For the growth of attached biofilm, it was found that mixing in reactors should be usefull.

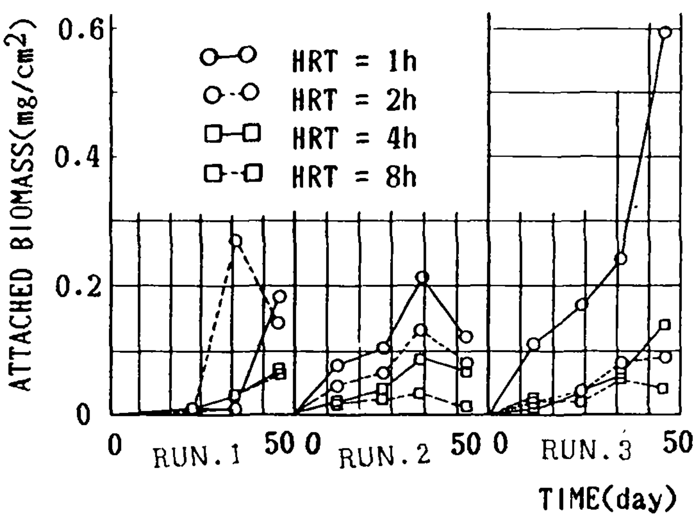

Fig. 9 Growth of microbial film in reactors with mechanical mixing in lake Kamafusa

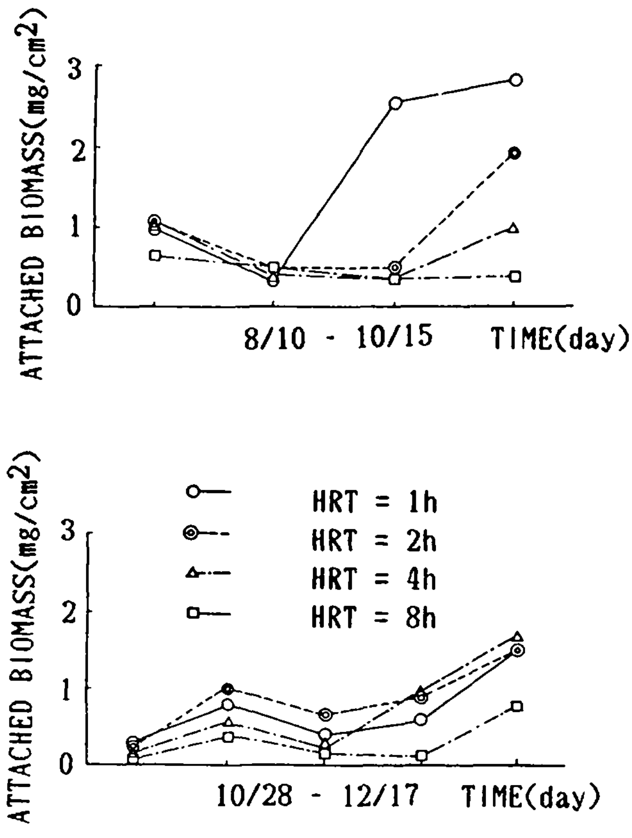

Fig. 10 Growth of microbial film in reactors with mechanical mixing in lake Kasumigaura

Fig. 10 shows an example of the growth of attached biofilm in lake Kasumigaura. It was 1.0 - 2.0 mg/cm^2 for HRT = 1h and 0.2 - 0.5 mg/cm^2 for HRT = 8h. In lake Kasumigaura, also, there was more amount of attached biofilm as organic and suspended matter loadings were high in reacters with short HRT. The amount of attached biofilm was more in lake Kasumigaura than in lake Kamafusa, because the former lake was more polluted than the latter. However, it was obtained that mixing should not be always useful for attachment of biofilm. In this point, the behavior in the growth of biofilm was different from that in lake Kamafusa which was less polluted and consequently brought about less organic and suspended matter loadings.

3.4. Mass balance on sludge in reactor

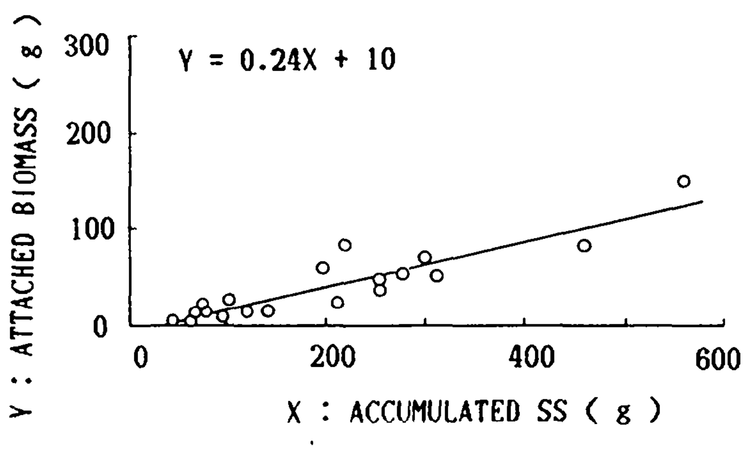

Fig. 11 Relation between attached biomass and accumulated SS in reactors in lake Kamafusa

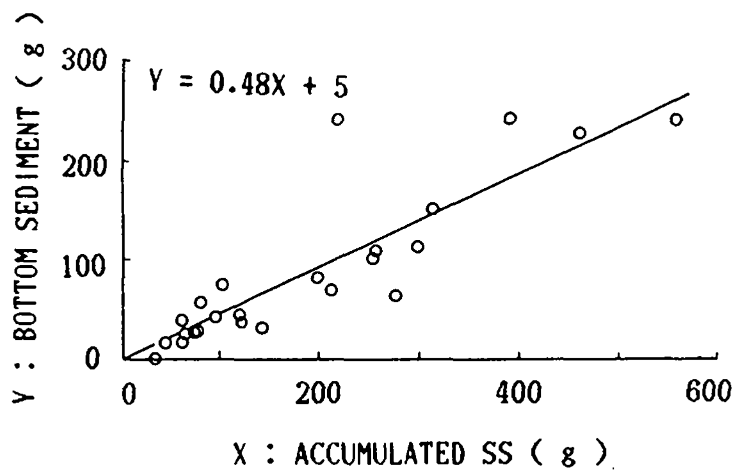

Fig. 12 Relation between bottom sediment and accumulated SS in reactors in lake Kasumigaura

It was defined that the accumulated SS was total amount of removed suspended materials by biological treatment reactor. Fig. 12 and Fig. 13 shows the relation of the amount of attached biomass and bottom sediment to the accumulated SS, respectively, in reactors in lake Kamafusa. It was found that 24 % of the accumulated SS remained as attached biofilm and that 48 % of the accumulated SS was left over as bottom sediment. Therefore, it was considered that 28 % of the remainder might be decomposed. Anyway, it became clear that the amount of sediment remained more than that of attaced biofilm in this reactors. On the other hand, in lake Kasumigaura, the amount of sediment was 5 - 10 times more than that of attached biomass and a little was decomposed. In both lakes, More than half of removed suspended materials was accumulated as bottom sediment in treatment reactors and therefore a great deal of sludge would be discharged in case of back-washing of reactors.

3.5. Experiment for treatment of artificial lake water

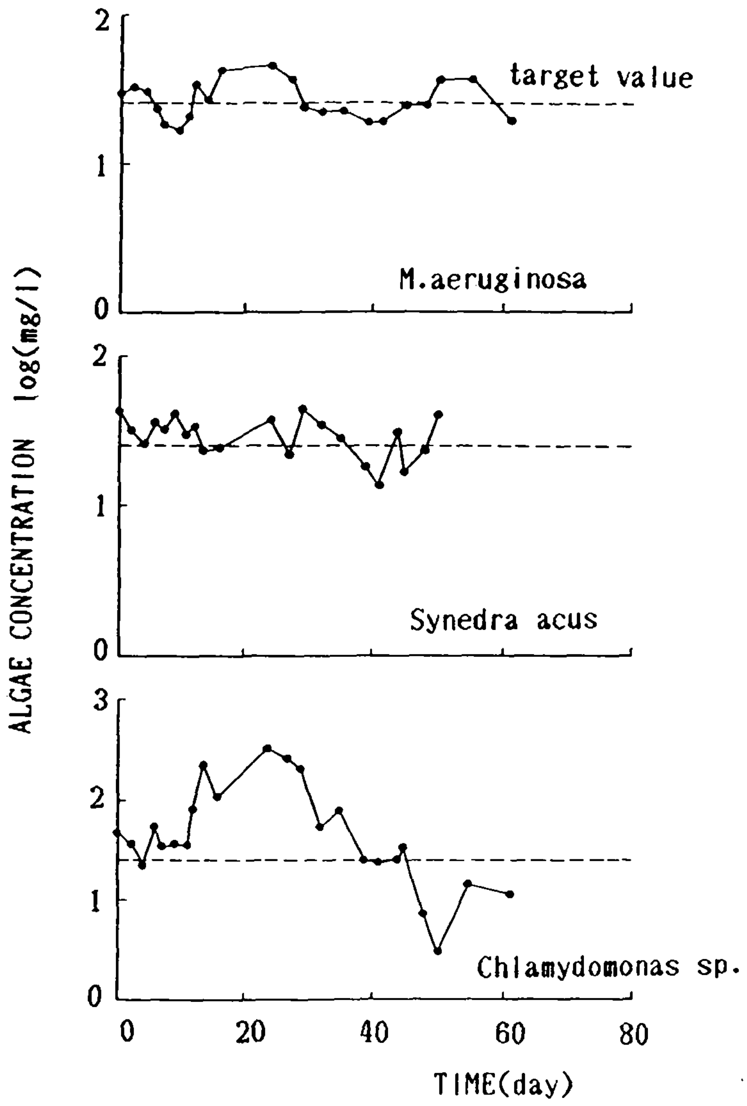

Fig. 13 Algae concentration during continuous cultivation

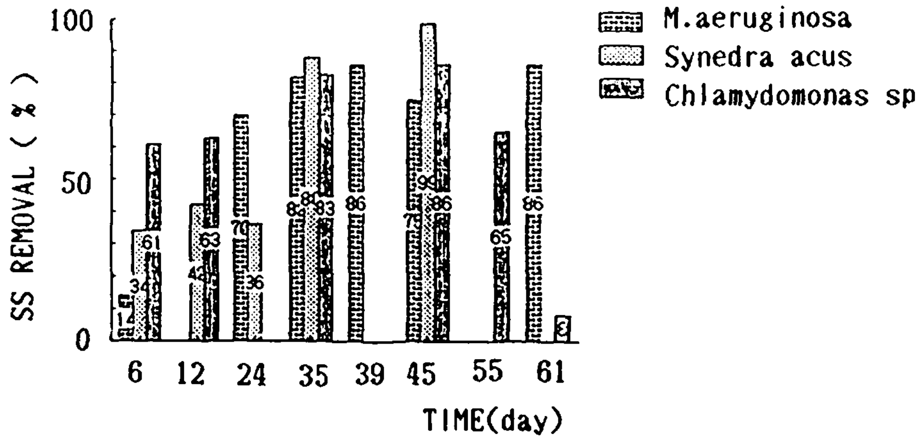

Fig. 14 Percentage of SS removal for man-made lake water

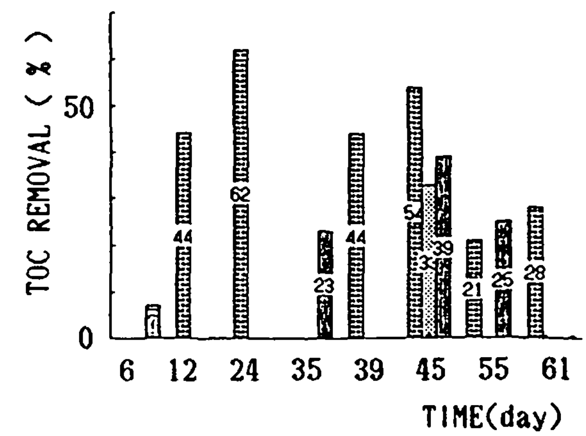

Fig. 15 Pecentage of TOC removal for man-made lake water

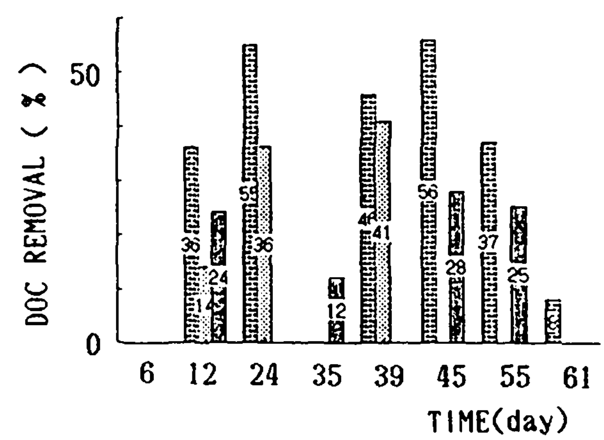

Fig. 16 Pecentage of DOC removal for man-made lake water

Fig. 14 shows the algae concentration during continuous cultivation for making artificial lake waters. A man-made lake water with Microcystis aeruginosa could get stable concentration near a target value. For Synedra acus, the concentration of man-made lake water could be stable at low light strength, although it was difficult to adjust the concentration by coordination of light strength because of the tendency for S. acus to attach on the inner-wall of reactor. Chlamydomonas sp has also the characteristics of tendency to attach and dettach on the inner-wall of reactor. Stable concentration could not be obtained because of difficulty in adjusting a light strength for this characteristics.

Fig. 15 shows the percentage of SS removal for man-made lake water. After a month, an excellent removal percentage such as mor than 65 - 90 % could be obtained in every three case. This result was very different from that of pilot-scale in situ experiment. Every species could not make remarkable difference in SS removal.

Fig. 16 and Fig. 17 shows the percentage of TOC and DOC for man-made lake water, respectively. The percentage of TOC and DOC removal with M. aeruginosa was the highest of all cases. However, difference in removal from every species could not be always found. It might be the reason that the artificial lake waters were not always cultivated successfully except in case of M. aeruginosa, and that therefore SS concentration was not stable in influent water. The removal percentages from this experiment were considerably higher than that from pilot-scale experiment in lake Kamafusa and Kasumugaura. From this fact, it might be generally possible that lake water should be treated with submerged biological filter process.

4. SUMMARY AND CONCLUSIONS

The performance of submerged biological fiter process for treatment of eutrophic lake water for tap water supply was studied by introducing two lake waters with different trophic state into reactors operated under various conditions. Furthermore, the performance with every different algae was studied using the man-made lake water purely cultivated which could contain typical species seen in eutrophic lakes. Specific conclusions derived from in situ operation during from spring to autumn and lab experiment for treatment of artificial lake-water are listed bellow :

1) In case of mechanical mixing and aerated type, the percentage of removal for suspended materials was higher as the HRT was longer. For "upper-flow" type, treatment performance was almost equal to that of the former two types and was different from the results obtained in autumn and winter.

2) In both lakes, percentage in the removal of TOC was ca. 20 % or less, and the difference in treatment performance could not be seen distinctly.

3) The reactors with larger loading of organic and suspended materials tended to have a greater deal of biofilm. Mixing in reactors was not always useful for attachment of biofilm for lake water with different trophic state.

4)The amount of bottom sediment in reactor was more than half of removed suspended materials and was more than that of attached biofilm. it was conceivable that ca. 30 % of removed suspended materials might decomposed.

5) In experiment for treatment of artificial lake water, an excellent SS removal percentage such as more than 65 - 90 % could be obtained, and whereas, the removal percentage of TOC and DOC was ca. 50 %.

5. REFERENCES

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DEVELOPMENT TRENDS IN SOME MALAYSIAN WATER SUPPLIES

by :

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SYNOPSIS

One of the oldest drinking water supplies in South East Asia, the water supply of Penang, has been existence for more than 180 years and it may therefore be used as a model to trace development trends of waterworks in Malaysia. This paper traces the development of this industry from its early beginnings where growth was at a leisurely pace of 2.3% per annum. The post Independence Era in Malaysia introduced a new dimension of change where substained periods of growth of above 6% per annum have become common place occurrences. This rate of growth has created stress in various aspects of waterworks management, planning and operations.

This paper discusses the issues facing the industry and highlights some underlying trends taking place in Malaysia. It concludes by stressing the need for a new approach to planning based on measuring parameters of performance so that projections can be made for future growth. In this way, water supply output which has often been outstripped by demand can resume an orderly pace of growth.

1. INTRODUCTION

This paper traces the historical development of the Penang Water Supply System and highlights trends and issues facing not only the Penang Water Supply System but also the Malaysian waterworks in general. This paper also looks at the problem that have intensified in the areas of water resources planning, technical arrangements, requirements and training and manpower development. It analyses cost increases as well as counter measures that may be taken to decrease these and finally concludes by recommending that systematic measurements and recording followed by analysis can make the industry as a whole more able to deal with changes that are taking place.

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Because of high rates of growth sustained since Independence, waterworks in Malaysia have been subjected to development stresses in almost every field of their development.

2. HISTORICAL NOTES

The first formal arrangements for a water supply were instituted in 1804, when the population in Penang had reached 10,000 people. "Water was brought from the Waterfalls in the Botanic Gardens in a long brick channel to the town, where earthen pipes were laid through the streets, while tin pipes conducted water to the houses." At the end of this aqueduct, a large tank was installed to supply water to ships in harbour. It is on record that the bricks of this aqueduct which were built by convict labour, were frequently dislodged, thus creating one of the first maintenance problems for this waterworks.

In 1823, a 6-inch diameter cast iron pipe replaced part of this aqueduct and by 1877, the whole of the aqueduct had been replaced by 16-inch and 14-inch diameter cast iron pipes running down Waterfall Road to Magazine junction. This is the earliest record of a mains laid. This pipe is still functional although severely corroded. It is thus over one hundred years old and still functional.

In 1894, a reservoir was built at the Waterfalls. This reservoir supplied clear water when after heavy rains the river was by-passed. Another reservoir was built at Air Itam in 1914 for similar reasons.

The first rapid gravity filtration plant was built at Air Itam in 1934. This was followed by a 6 m.g.d. filtration plant in Tanjung Bungah which was completed in 1941 immediately preceding World War II. The first in-house designed filtration plant was built at Waterfalls in 1954 and preceded the large scale development at Air Itam Dam in 1962.

By 1900, it was reported that a population of 100,000 was using 10 million gallons of water per day or just 100 gallons per head per day. This rate of consumption is still the upper limit of consumption returned almost ninety years later, by consumers who do not pay directly for water consumed, whether this be in labour lines or luxury hotels.

During the above period, shortages in the dry season were becoming common. It was proposed that to prevent wastage and to conserve water, metered supplies should be introduced. It is illuminating at this stage to quote a passage used to justify this procedure at that time. "To prevent waste, two remedies are generally proposed: those who are opposed to meters propose inspectors living, but not necessarily active nor faithful nor judicious; in any case only capable of being in attendance for a short time during the 24 hours. Those who favour meters recommend them as inspectors in constant attendance, night and day at every tap: strict, watchful, judicious, insulting nobody and taking no bribes."

Metering was introduced soon after this statement. Malaysia today enjoys waterworks systems which are 100% metered, no doubt because the pro-meter lobby won the day in 1900. The preference to mechanical and automatic means of controlling demand against fallible human resources are true today as they were in 1900. It underlies the basic thought processes behind the computer billing systems introduced by the Penang Water Authority in 1974.

Finally, a graded system of payment was introduced with the objective of discouraging wasteful use. This principle has survived upto the present systems and is the forerunner of today's two or three part domestic tarrifs which have recently gained almost universal acceptance as a means of giving cross-subsidies to low-income users and at the same time discouraging uncontrolled use of our piped water supplies.

3. GROWTH: THE NEW DIMENSION

Most of the elements of a modern water supply practice were established by the end of the Second World War. The present differs from the past mainly in the tempo of change. In his book FUTURE SHOCK, Toffler postulates that the accelerating pace of change has altered our relationship with our surrounding resources by expanding the scope of changes, by increasing their complexity, and by telescoping the time scale of events. All the above factors bring to test man's capacity for adaptation. The same can be said to apply to water supplies.

In 1803, there were 10,000 people residing in the island of Penang. By 1900, the number of residents had increased to 100,000. This corresponds to a compound rate of growth of 2.3% per annum. At a rate of consumption of 100 gallons per head per day, consumption in 1900 was 10 million gallons. If installation of meters had successfully curbed per capita demand to 40 gallons per day, a compound growth rate of 2.3% per annum would account for the daily consumption in 1950 of 12 million gallons. At this rate of growth, demand doubles every 30 years. This interval of time corresponds to a whole working life span - a comfortable rate of change. If however compound growth were to increase to 7% or 10% per annum, the "doubling" spans of time would reduce to 11 years and 7 years respectively - we would have entered into the realms of future shock postulated by Toffler. Some values for these doubling spans of time and their corresponding rates of increase are tabled below:-

Rate of growth	10%	9%	8%	7%	6%	5%	4%	3%
Doubling time	7 yrs	8 yrs	9 yrs	11 yrs	13 yrs	15 yrs	19 yrs	24 yrs

Today, population growth remains of the order of 2.3% per annum. However, since Independence in 1957, the water supply industry has been confronted by two other elements of growth: expansion of supplies into rural areas (this may account for between 2% to 3% per annum); and growth of industrial demand (this accounts for a further 2% to 3%). Therefore, sustained periods of growth of between 5% and 9% per annum are common (see Table K). This has created a new dimension of time through which every other activity of a water supply system must be evaluated.

A doubling of demand each 7 years or 10 years requires corresponding increases of resources: plant capacity, distribution systems, raw water resources, manpower resources, and finally most important of all, since water supplies are capital intensive industries, financial resources. Co-ordination of the growth of all the above resources is essential but few organisations and governments have achieved orderly growth because of lack of a full appreciation of the time scale of change. In the following paragraphs, key areas of performance of a water supply will be examined. Trends and issues and problems, always magnified by this time compression will be discussed.

4. WATER: THE DIMINISHING RESOURCE

Availability of water as a resource has become a more acute problem because of an increase in the quantum steps of growth that are taking place. The first two successive filter plants built in Penang were 3 million gallons and 6 million gallons per day capacity; incremental steps are now of the order of 30 million gallons per day capacity. In consequence, the catchment areas for supplying raw water to present day plants have increased from a few thousand hectares to a few hundred square kilometers in extent. Dependence on designated catchments restricted soley to water collection or shared catchments with joint use as forest reserves only, is no longer a practical proposition.

Sharing catchment areas with other water and land users introduces a new degree of complexity; insufficiency of the resource and pollution become points of contention. Rules and regulations for joint river usage become necessary. In fact, there is a plethora of rules and legislation derived from many sources, disciplines and under the jurisdiction of various Ministries. There is a need to focus these laws on the collective needs of all users of a particular river basin; enforcement procedures need to be co-ordinated. A start has been made in this direction but much remains to be done. Until some success is achieved in the above field, engineers tend to confine themselves to engineering solutions.

5. WATER RESOURCES: STORAGE OF WET WEATHER SURPLUSES

Shortages of surface water are caused by dry spells which are a feature of our Monsoon type climate. The obvious engineering solution is the building of impoundment dams. There had been small dams built in the 1930's. Bukit Panchor Dam, Cherok To'kun and Berapit Dams were examples to develop small streams for localised supplies, Klang Gates Dam in Selangor (1959) and Air Itam Dam in Penang (1962) ushered in the era of large dams and intra river basin transfers. Use of storage dams increases the percentage of river water utilisation but it introduces a new dimension to the magnitude of costs of headworks. Air Itam Dam and ancilliary works cost 15 million ringgit for a yield of 6 million gallons a day. This yields a cost factor of 2.5 million ringgit for each million gallons of capacity (1959 prices). Therefore unit costs of water were being driven upwards even before the incidence of double digit inflation and the energy crunch. Another issue to be considered is the long-term safety procedures to be adopted in the maintenance of these dams. A uniform Guideline for Dam Maintenance and Safety is currently under preparation.

The National Water Resources Studies (1981) conducted by the Japan International Co-operation Agency (JICA) has identified three water stress regions in this country. They are the Perlis/Kedah/Pulau Pinang region, the Selangor/Federal Territory area, and the Malacca/Muar area. The engineering solution to these problems is the building of more dams. The cost of large scale source works and their conveyance systems will almost certainly result in higher unit costs of water supplies. Inflation and energy costs will further add to these costs which will ultimately be reflected in water charges.

There is no certainty that engineering solutions alone will solve the problems of water shortages. It is clear that although feasible technically, not all dams proposed will be possible due to financial and other constraints. The management of shortages will then become a distinct future trend. Demand contention between the two major user sectors - irrigation and water supply - will be inevitable. It has been estimated that the total irrigation needs in Malaysia will increase from 8,600 cusecs in 1976 to 20,000 cusecs in the year 2000. The corresponding figures for industrial/domestic water supplies will be 710 and 2,200 cusecs respectively.[1] By this time, all possible dam sites recommended by JICA may have been built or have become unavailable.

Managment of shortages will raise certain issues, some of these are:-

a) Should the limitation of water be used as a constraint to the planned growth of some large urban areas?

b) Can some other form of cash crop or vegetable farming with low water demand be substituted in place of rice cultivation close to large cities?

c) Can our knowledge of weather conditions be improved in order to develop analytical and predictive procedures which can be used to manage future shortages? For example, the last 10 years are manifestly drier than preceding years. This has been observed as a world-wide phenomenon. Is this a long term trend or is it a long term cycle? Again, can the observation of some world-wide weather pattern such as the 'El Nino' effect be used to predict impending droughts and if so, their possible durations?

More immediate measures to be considered are:-

a) Improving efficiency of water use.

b) Reuse of drainage water from irrigated areas - either for further irrigation or for water supplies.

c) Introduction of a penalty drought surcharge for domestic/industrial supplies over and above the graded tariffs.

d) Conjunctive use of surface and ground water, including artificial recharge of limited or confined aquifers.

6. TECHNICAL TRENDS: TREATMENT AND FILTRATION

Since the first filters that were built in the 1930's, treatment technology has not changed fundamentally. However, the accelerated pace of growth of demand has created a need to upgrade existing facilities whilst awaiting new plant. In the process, operating parameters have been improved. For example, the Tanjung Bungah Filtration Plant has been upgraded from 6 to 14 m.g.d. To achieve this, surface overflow rates for sedimentation tanks have been increased from 2m/hour to 5m/hour. Filtration rates have been icreased from 1.2 gallons/sq.ft./min. to 4 gallons/sq.ft./min. (with a trade off against sparkling clarity). These improvements are now incorporated into new designs because they result in savings in capital costs.

The higher flows of sedimentation tanks have been achieved by use of multi-tray settlement tanks. Upflow sedimentation tanks are also under consideration. Apart from costs, ease of operation and uncomplicated maintenance are the yardsticks of choice. Fast recoveries from mistreatment, and fixed rather than rotating paddles in flocculators reflect the need to use unsophisticated labour at operating levels. Likewise, complicated and precise procedures are to be avoided.

Simplification at operational level does not imply simplification of theoretical considerations. An understanding of the colloidal destabilization theory has led to use of flash mixing, and proper implementation of the coagulation, flocculation, floc syneresis processes.[2] Aluminium sulphate dosage levels as low as 15 p.p.m. are attained. Currently, some work is being done on the use of polyelectrolytes but the resultant tougher flocs formed may lead to a demand for coarser sized filter media and increased backwash flows.

Recent focus on the incidence of B-hepatitis and other viral gastro intestinal disorders have highlighted the need to deal with viruses. The present consensus is that, provided proper sedimentation and filtration procedures are observed and provided that chlorine dosages of 1 p.p.m. are maintained for a minimum contact time of 30 minutes,[3] this problem can be effectively dealt with. However, since catchments need to be developed which are increasingly polluted by human habitation, a review of currently available disinfection techniques is indicated. For instance, should ultra violet radiation or ozone disinfection techniques be used for our more polluted waters? In any case, disinfection priorities and awareness of the dangers of contamination to water supplies needs to be drilled into the consciousness of filter plant operatives.

7. TECHNICAL TRENDS: DISTRIBUTION SYSTEMS

Examination of the financial records of the Penang Water Authority reveals that one-third of its assets is apportioned to the distribution systems. A substantial proportion of capital revenues has to be diverted to this resource.The pressure of growth, and in particular, the need to bring water to sparsely populated rural areas (see Table M) have created a demand for cheaper distribution pipes. Cast iron pipes have given maintenance-free service for over a hundred years but due to the cost factor, cheaper pipe materials are used. During the immediate post World War II period, asbestos cement pipes were used extensively. These have suffered a considerable degree of deterioration. At an I.W.S.A. conference held in Manila, an assertion was made that the expected life span of asbestos cement pipes was only 25 years, yet at another international exhibition in Kuala Lumpur, the writer was confronted with a sample of an A.C. pipe taken from an European sewer; it was in good condition, and alleged to be in excess of 25 years old. Further enquiries indicated that a cement low in tri-calcium aluminate conferred this resistance against sulphate attack. Clearly, further investigation into the long term durability of pipes is advisable.

In 1985, Penang's 2,200 km of distribution pipes averaged over 180 breakages per month or 1.0 breakage per kilometer each year. Detailed analysis indicate that over 90% of these breakages are in asbestos cement pipes. Most of these pipes have suffered a breakdown of their cement matrix; mode of attack is by external penetration, leaving a thin internal layer of sound cement. This type of damage is common near the sea, but is present in other localities with acidic soils. Sound asbestos cement pipes which are relatively new often suffer a vertical breakage perpendicular to the pipe axis, other common leakages involve corroded bolts and nuts of pipe joints.

It would appear that magnesium salts and sulphate attack have caused the softening of the pipes. Use of autoclaved A.C. pipes which have reduced tri-calcium aluminate could minimise such attacks, particularly if polyethelene jackets are used in areas of high soil aggressivity. Vertical cracks in relatively new pipes are obviously caused by improper bedding of pipes. A four-inch layer of sand laid as bedding and as backfill up to pipe haunching, may minimise these failures. Stainless steel bolts and nuts substituted in place of unprotected mild steel bolts and nuts will eliminate corrosive joint failure. Reduction of pipe failures not only reduces maintenance costs but it reduces unmetered losses and improves reliability of services.

In the meantime, the question of pipe replacements looms large in the future. Most of the failed post World War II A.C. pipes still have a thin layer of sound cement in their internal surfaces, if this should break down, what then? As a conservative estimate, 10% of Penang's pipes need replacement. This estimate yields 220 km. of pipe. A ten-year programme would require 22 km. of annual replacements at a cost of half a million ringgit per year. Will these pipes last a further ten years? Can some form of night pressure reduction device gain time? This aspect has not gained universal attention - a start must be made. It is pointless to carry out leakage detection in an area that would spring leaks 4 to 5 times in one month.

Other materials used or under consideration are:-

a) Wrapped Steel Pipes

b) High Density Polyethelene (HDPE)

c) Glass Reinforced Plastic (GRP)

d) Ductile Iron Pipes

e) Unplasticised Polyvinyl Chloride (UPVC)

In general, costs are traded off against long term durability. Each particular pipe material has its range of advantages and disadvantages. Some form of cost discounting against life expectancy allows rational choices to be made in this surfeit of options.

8. TECHNOLOGY: INSTRUMENTATION

Neither the Treatment Process nor the Distribution Systems can be monitored properly without adequate instrumention. Yet instrument failures or improper maintenance of instruments has been a frequent feature in operations in the Penang Water Authority. The pressures of growth and improperly trained staff makes this weakness a common problem in the industry. Instruments used in waterworks measure mainly flows and pressures. Electro-mechanical devices of the past have proven to be extremely stable - some flow recorders installed in the 1930's still perform to this day. However, rising costs have made their continued manufacture impractical. Such instruments that still remain functional do not have the flexibility to increase their operating ranges to cope with plant modifications. They have become obsolete. Increasingly, electronic devices are being used. Analoque instruments are merged with digital convertors and micro-processors perform square rooting, digital displays and graphical displays.

Although electronic instruments are extremely versatile and are getting cheaper with time, they have a much shorter obsolescent time slot. They are subject to drift and to breakdowns caused by lightning and other transient currents. Adaptive use of micro-processors from other mass production baselines such as video equipment or Personal Computers can reduce the danger of quick extinctions and at the same time adequate replacement of components can be assured. Popular Personal Computers can provide ready-made software.

Maintenance of these instruments needs to emulate maintenance procedures and training procedures used for VCR or PC maintenance shops. In particular, technicians from these shops can be recruited to carry out instrument repairs at the same time they service the mass market.

One final advantage of the computer age is the telecommunication facility. Performance data can be transmitted over long distances for immediate display. Data also can be stored digitally in magnetic devices and with the advent of optical discs, archival storage of data becomes possible.

Both the instrument vendors and the waterworks users have not fully realised all the above implications. Adaptation has only just started.

9. TECHNOLOGY: THE REDUCTION OF WASTE

In order to cope with unprecendented growth of demand, reduction of waste is imperative. Metering in 1900 reduced waste and conserved the water resource. In Penang, this delayed the need to build large dams for another 50 years. Present distribution losses are said to range between 20% and 40%. It is the writer's opinion that there are two components of such losses: Pipe leakages which result in losses into the ground, and unrecorded usage which includes all forms of meter irregularities and illegal tappings. The immediate consequence of the latter increases demand of the resource whilst the former reduces revenue, resulting in higher costs for water. Each of these requires different techniques to minimise.

Revenue losses are controlled by regular billing and prompt cut-off procedures; analysis of billing data and follow through where action is required and checking systems implemented on the performance of readers. All the above have been successfully performed by instituting a computerised billing system in Penang.[4] A programme to carry out regular and systematic changing of meters has not been so successful. In practice, unscheduled meter cut-offs and replacements of non-functioning meters (a by-product of the computer reports) have taken precedence over systematic programmes. It is not yet clear, given that all choked or jammed meters are removed, what the accuracy levels of performing meters will be, taken as a class that is 7 years or 14 years in service.

Leakage reduction is first and foremost, a management technique. A complete plan of pipes and valves inclusive of updating procedures of control plans is a prerequisite. Instrument techniques and systematic programmes follow, not least of which should be checking on the accuracy of bulk flow meters at production facilities. These are often grossly over-ranged because filtration capacities have often been doubled, but the mechanical components of these instruments have not been easily modified. Much thus needs to be done internally by managements before outside aid is resorted to. Therefore, failure in this field is an internal management defect because no resources are provided for these functions. Unless this is rectified, nothing constructive will be derived from reports of experts.

Unsatisfactory performance in this field highlights the lack of proper manpower training.

10. MANPOWER: GROWTH, STRUCTURE, PLANNING

It has been stated that the absolute limit of manpower growth is a doubling of this resource once every five years. A 7-year or a 14-year doubling period is less stressful; nevertheless, it is not a pace of change that can be sustained by a year to year establishment list exercise. As practised, this procedure is not rational, it is not tied to the growth and needs of the organisation. Often times also, lagtime for training new personnel is not allowed for. All the above are allowable when growth did not exceed 2.3% per annum; the new growth rates require more dynamic planning.

Planning parameters should be tied to the rate of growth and needs envisaged for 5 years ahead. Some of these parameters that may be used are the following ratios:-

		1973	1985	
a)	No. of meters or accounts per employee	117	129	
b)	Output (volume of water treated)/employee	247	296	(Cu.M)
c)	Output per Production Div. employee		765	(Cu.M)
d)	Mains (km) per Distribution Div. employee		5.2	
e)	Service Meters or Accounts & Management employees		639	
f)	Meters read per cycle per meter reader		2000	

(See also Tables N, NA, NB and NC)

The figures given above and in subsequent charts pertain to the Penang Water Authority; it is not presumed to establish industry standards but to provide a yardstick to develop operating parameters for further comparison and references. It must be emphasized again that rational planning tools must be developed and that these must be tied to long term growth projections so that recruitment and training can proceed in time to meet growing needs.

If revenue is 50 million ringgit a year and the provision of ten individuals in a waste-water detection unit can lead to a reduction of waste by 5% which can result in increased annual revenues of 1.5 million ringgit, surely this could justify an annual salaries increment of 90 thousand ringgit.

Apart from the numbers game, there are several structural weaknesses:-

a) There has never been a lack of graduates from tertiary institutions to fill officer vacancies. However, the size and command structure of waterworks are broad based pyramids which are relatively small. There is little room for branching out to purely technical specialists jobs, therefore the ability to maintain discipline must be a prerequisite for graduate employees. Often however, engineering education has concentrated on purely technical matters. Formal training on motivation techniques and disciplinary procedures must become a feature of training programmes of graduate staff.

b) In the Industrial/Manual sector, the class of worker known as a foreman is disappearing. By definition, a foreman has risen from the ranks and has had several years' exposure to the work environment. He will be chosen for maturity and known leadership qualities. In their place, we are substituting the class of worker known as the Junior Technician whose only prerequisite is a lower school certificate of education (LCE). A raw recruit without any maturity and experience may be asked to lead a unit of workers. The resultant loss in discipline and motivation is costing the industry millions of ringgit each year.

c) In the field of the skilled tradesmen, overseas experts have advised that the LCE be made a prerequisite of entry into apprenticeship training. They have failed to advise that the product of such training should get equal or better pay than the class of Junior

Technician, who enters a better scheme of pay straight from school. The resultant instability has made impossible the formal training of skilled tradesmen. In the old system of slow growth, the traditional craftsman/apprentice relationship, on-the-job training is provided by the master workmen; such informal training worked very well, but not any more. With our accelerated timescale of change, we have not found a satisfactory replacement of that system.

11. TRAINING: A DILEMMA

Many of the preceding paragraphs have highlighted either the lack of proper training or the inadequate quality of the raw manpower material. Training by "osmosis" where a worker absorbs skills from his work environment is no longer possible. Quick growth leads to quick promotions. Inadequately trained personnel who are frequently harassed and overworked are expected to give training to inadequately prepared recruits. In the Penang Water Authority, some cognisance has been given to this problem, but much still remains to be done.

The main problem is the lack of a waterworks orientated training staff: technical workers who have adequate knowledge of the business have no adequate knowledge of training techniques. On the other hand, "trained" trainers from outside the industry have no adequate knowledge of the business - at best they can only give general training to workers. This is not always helpful and the industry leaders are certainly correct in expressing a reluctance of abdicating their right to oversee such trainers. Perhaps the solution is to train an experienced staff member in the art of training and to accord to him a senior posting in the organisation.

12. COSTS AND FINANCIAL PLANNING

Not only has demand doubled in short spans of time but unit costs of production have been doubling every seven to ten years. The first factor for such an increase is the advent of the large dams and intra-river systems transfer of water. Large dams, large pipes and increased pumping were heralded by the advent of Air Itam Dam and Klang Gates Dam. The oil shock and inflation have accelerated costs, yet because water is a social amenity, prices are not free to follow costs. This makes money scarce at a time when growth accelerates.

Table Z is a summary of unit costs in the Penang Water Authority from 1979 to 1985, a period of 7 years. During this time, loan servicing and depreciation charges have doubled, wages and maintenance charges have increased by 50%. Energy costs have also doubled, only chemical costs have remained stable.

Capital, loan, interest and depreciation charges are tied to enlargement of assets and facilities needed to service increased needs; there is not much that management can do to minimise these. Wages can be minimised by increased efficiency, better structure and improved planning, training and motivation. Tighter control on maintenance costs requires modern control systems, hopefully available by use of micro-computers to control stock and inventories.

Present technology available in Malaysia has enabled treatment costs to be optimised. They are unlikely to be improved further. Energy costs however begin to loom large. Savings are possible by better design and planning. Some possible areas are:-

a) Introduction of better electricity tariff arrangements.

b) Increased efficiency of pumps and engines - usually available for larger units.

c) Variable speed pumping substituting the usual throttling of valves on fixed speed pumps. The technology is available and should be more widely desseminated.

Another area where significant cost reductions can be made is in reduction of distribution losses. Large scale pipe replacements and a refocus of management energy into this objective can increase revenues by 5% to 10%.

All the above cannot still obviate the need to increase water tariffs, so that a strategy for structuring such increases is mandatory.[5] Water is a social amenity, nevertheless affordability, rather than unlimited subsidies should be the guideline. Penang Water Authority records show that over the last one hundred years, domestic consumption has remained at 40 to 45 gallons per capita per day; by providing for lower charges for lesser consumption by providing judicious cross-subsidies, we can still meet the criterion that a man on the poverty line should not pay more than 4% of his income for water supplies.

In the water tariff structure of the Penang Water Authority, industrial charges and excess use tariffs are used to cross-subsidize the marginal consumer. However, maximum charges do not exceed the cost of new water, i.e. the marginal cost of new projects. Taken by and large, costs for water have not outstripped wages which have increased on the crest of inflation, so that although it requires advance planning, financing waterworks has not been unduly challenging so far. Increases in tariffs introduced every two or three years and limited to increments of 10% to 15% each time, are part of an accepted strategy for implementing new projects.

13. CONCLUSION

The present day waterworks in Malaysia have had to adapt to a faster tempo of change and growth. This acceleration of growth demands more objective methods of manpower planning. It puts severe stress on resources and more costly systems have to be implemented to secure production. Costs have to be optimised because social constraints do not allow prices to follow costs freely. Technology not only must cater for greater output but it must do so at optimum costs. It must also deal with more highly polluted waters. In one area at least, use of a cheaper material for distribution pipes has created large scale failures in distribution systems - the impact of cheaper materials on the future has to be assessed carefully. In another area, manpower planning and training have not received due attention.

All the above emphasizes the need for water supply industry managers, all of whom are engineers, to develop improved techniques to cope with the increasing complexities and pressures caused by accelerated change. To encourage better forward planning, performance parameters have been included in this paper in the hope that they can be further compared and discussed so that ultimately, industry accepted standards can be established. This paper thus highlights areas of interest for future studies to be made.

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TABLE K

PENANG WATER AUTHORITY

DOMESTIC SUPPLIES : PERCENTAGE OF POPULATION SERVED BY WATER

Year	Population (X 1000)		DOMESTIC SERVICES (X 100)		AV. HEAD PER D. SER.		WATER POPULATION (X 1000)			% POP. SERVED		
	S.Pr.	Pg.Is.	S.Pr.	Pg.Is.	S.Pr.	Pg.Is.	S.Pr.	Pg.Is.	TOT.	S.Pr.	Pg.Is.	TOT.
1976	397	465	299 *	542	6.4	7.5	221	405	627	56%	87%	73%
1977	407	471	319 *	550	6.4	7.5	234	411	645	58%	87%	73%
1978	417	476	345 *	570	6.4	7.5	251	425	676	60%	89%	76%
1979	428	482	380 *	595	6.4	7.5	273	443	716	64%	92%	79%
1980*	439	488	409 *	611	6.4	7.4	292	455	746	66%	93%	81%
1981	452	502	447 *	629	6.4	7.4	316	467	783	70%	93%	82%
1982	465	517	507 *	658	6.4	7.4	354	488	843	76%	94%	86%
1983	479	533	559 *	680	6.4	7.4	388	504	892	81%	95%	88%
1984	493	549	611 *	713	6.4	7.4	421	528	949	85%	96%	91%
1985	508	565	651 *	736	6.4	7.4	446	544	990	88%	96%	92%
1986	524	582	689	766	6.4	7.4	470	565	1035	90%	97%	94%
1987	538	600	727	796	6.4	7.4	493	587	1080	92%	98%	95%
1988	553	618	765	825	6.4	7.4	517	607	1124	93%	98%	96%
1989	569	636	803	853	6.4	7.4	540	627	1167	95%	99%	97%
1900	585	655	841	881	6.3	7.3	563	647	1210	96%	99%	98%

NOTES

Population figures are interpolated between 1970 and 1980 census, Beyond 1980 population figures are extrapolated.

Average no. of heads per domestic service is derived from av. dom. consumption divided by observed consumption of 200 litres per head per day. Water population is derived from no. of domestic supplies multiplied by the average no. of heads per domestic service. A further 30,000 people serviced by standpipes is added to Seb. Perai.

Seberang Perai's % of population served by water has increased by 2% to 5% per annum. Penang Island's population served by water increased by 2% per annum but is now nearer 1% per annum. After 1990, domestic supplies will grow at the same rate as natural population growth.

TABLE M

PENANG WATER AUTHORITY

ANALYSIS OF MAINS AND BREAKAGES

Year	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
METERED SERVICES (S)	89643	93058	98475	104960	110051	116237	126214	134227	143478	150115
PENANG IS.	57321	58377	60815	63570	65492	67604	70997	73390	76937	79470
SEB. PERAI	32322	34681	37660	41390	44559	48633	55217	60837	66541	70645
LENGTH OF MAINS (Kilometres)	1496	1569	1694	1713	1798	1925	1980	2094	2183	2211
PENANG IS.	557	568	579	591	601	616	630	644	661	671
SEB. PERAI	938	994	1054	1121	1197	1307	1349	1450	1522	1542
METRES/KILOMETRE	60	59	58	61	61	60	64	64	66	68
PENANG IS.	103	103	105	108	109	110	113	114	116	118
SEB. PERAI	34	35	36	37	37	37	41	42	44	46
BREAKAGES	NA	NA	NA	NA	NA	NA	NA	1832	2281	2065
PENANG IS.	NA	NA	NA	NA	NA	NA	NA	651	745	688
SEB. PERAI	NA	NA	NA	NA	NA	NA	NA	1181	1536	1377
BREAKS/KILOMETRE	NA	NA	NA	NA	NA	NA	NA	0.9	1.0	0.9
PENANG IS.	NA	NA	NA	NA	NA	NA	NA	1.0	1.1	1.0
SEB. PERAI	NA	NA	NA	NA	NA	NA	NA	0.8	1.0	0.9

TABLE N

PENANG WATER AUTHORITY

ANALYSIS: METERED SERVICES TO STAFF RATIOS

YEAR	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
METERED SERVICES (S)	89643	93058	98475	104960	110051	116237	126214	134227	143478	150115
CATEGORY OF WORKER										
A:PROFESSIONAL	9	10	11	13	14	18	20	18	18	21
B:SUB-PROF.	5	6	6	8	8	8	8	9	9	9
C:CLER.& TECH.	55	59	70	66	104	104	125	120	126	129
D:IND.& MAN.	837	838	832	852	922	922	968	943	986	1005
TOTAL EMP.	906	913	919	939	1048	1052	1121	1090	1139	1164
S/TOT. RATIO	99	102	107	112	105	110	113	123	126	129
S/(A+B) RAT.	6403	5816	5793	4998	5002	4471	4508	4971	5314	5004
S/C RATIO	1630	1577	1407	1590	1058	1118	1010	1119	1139	1164
S/IMG RATIO	107	111	118	123	119	126	130	142	146	149
O/IMG RATIO	64	56	53	44	47	39	39	39	41	38
D/C RATIO	15	14	12	13	9	9	8	8	8	8

NOTE: Services to Total Staff ratio has slowly increased from 99 to 129.
At the same time services per Officer ratio has improved from 6403 to 5005
Again IMG per Officer has reduced from 64 to 38.
Industrial & Manual to Clerical & Technical has reduced from 15 to 8.

MANPOWER ANALYSIS (1986)

CATEGORY	ENGINEERING TRTMNT.	DIST.	CONS.	ADM/ PRJ.	SUB-TOT.	ADMINISTRATION GEN.	COMP.	AUDIT	ACCOUNTS BUDGET & PRJ.	BILL& COLL.	TOTAL	PERC. OF TOTAL
GEN. MANAGEMENT	0	0	0	2	2	2	1	0	1	0	6	0.5%
PROFESSIONAL	2	2	2	3	9	3	2	1	0	1	16	1.3%
SUB-PROF.	0	0	1	1	2	0	2	1	1	2	8	0.6%
CLERICAL & TECH.	13	17	17	17	64	9	13	4	9	38	137	10.8%
SUB-CLER.& TECH.	50	40	65	11	166	8	17	4	4	69	268	21.2%
TRADESMEN	8	71	18	2	99	0	0	0	0	0	99	7.8%
SKILLED & SEMI	58	85	19	0	162	2	0	0	1	1	166	13.1%
GENERAL LABOUR	320	208	36	2	566	0	0	0	0	1	567	44.8%
TOTAL BY SECTION	451	423	158	38	1070	24	35	10	16	112	1267	1.0
% SECT. TO TOTAL	35.6%	33.4%	12.5%	3.0%	84.5%	1.9%	2.8%	0.8%	1.3%	8.8%	100%	

NOTE: *Engineering Treatment and Distribution Sections employ high component of general labour. It is in these sections that competent foremen are required.
*A large component of general labour in Engineering Treatment is for ground maintenance.
*Preferably, only seasoned sub-technical and technical workers from Engineering, Distribution and Consumers Sections are to be transferred to Projects/Adm. Section to supervise contractors
*Tradesmen are generally without LCE and without formal training.

TABLE N A

PENANG WATER AUTHORITY

RELATIVE GROWTH INDEX (VALVE 1973 = 100)

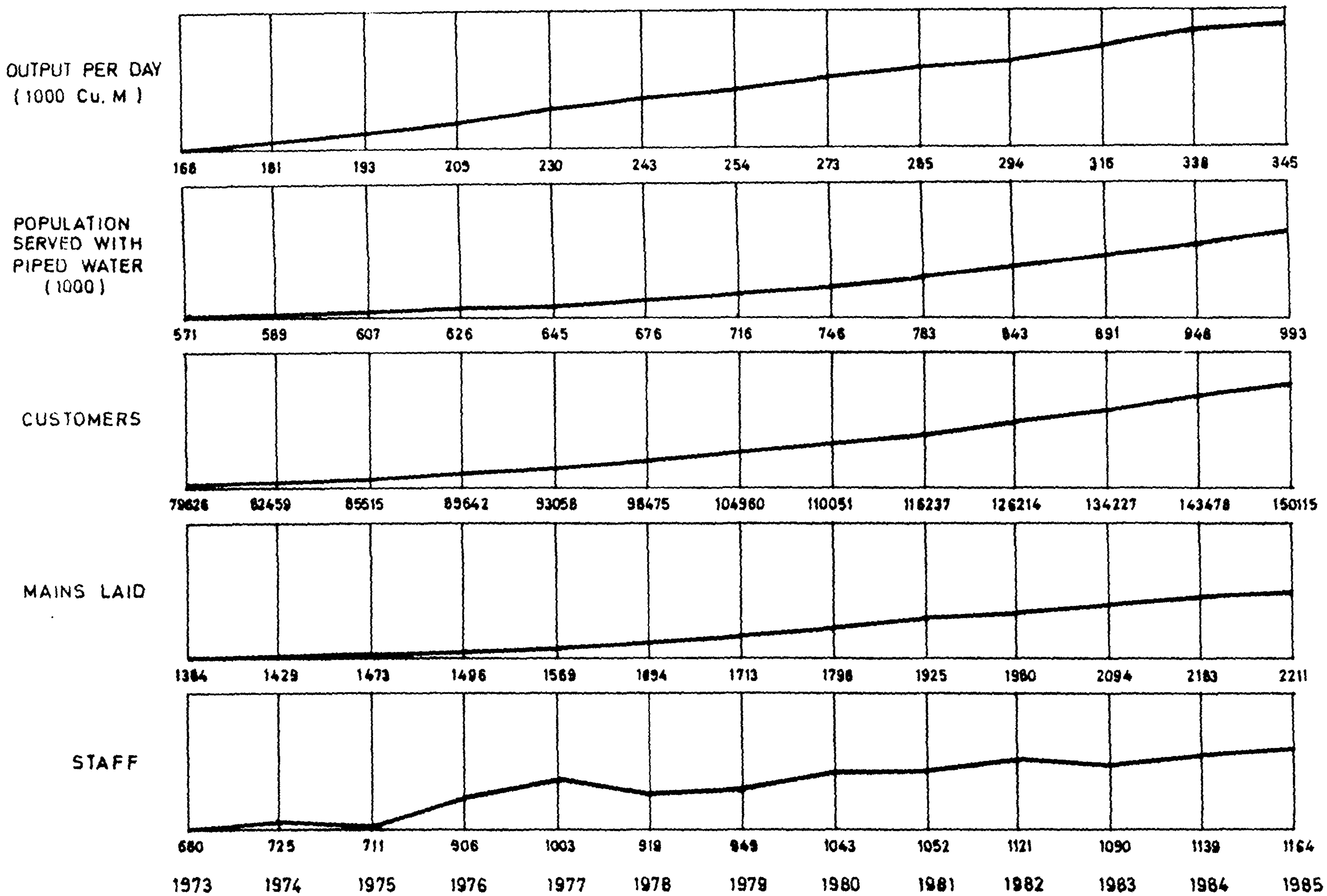

TABLE NB

PENANG WATER AUTHORITY

PERFORMANCE INDEX (VALUE 1973 = 100)

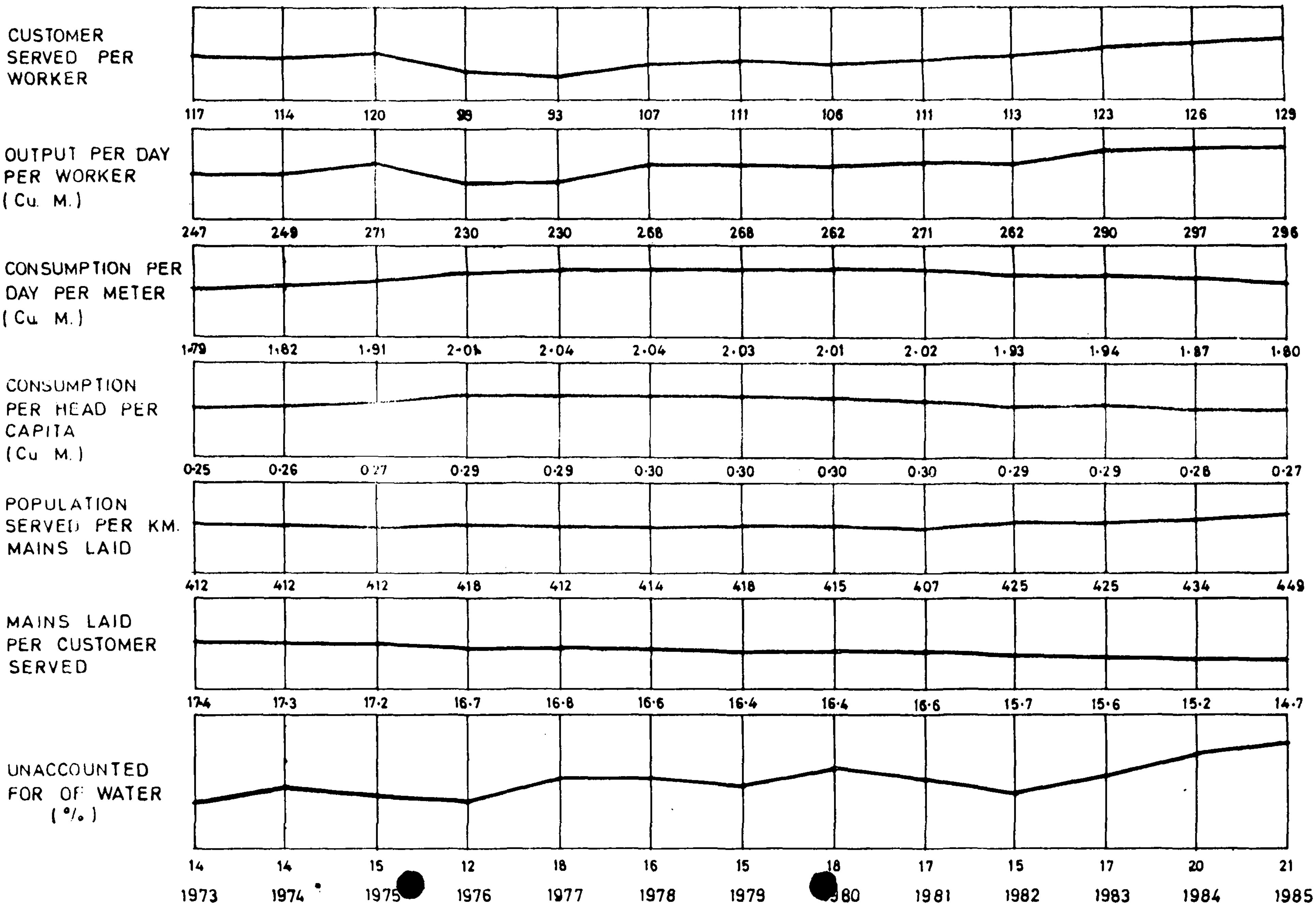

TABLE NC

PENANG WATER AUTHORITY

CONSUMPTION ANALYSIS

YEAR	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
PENANG ISLAND DOMESTIC										
SERVICES	54167	54988	57049	59469	61098	62943	65858	68011	71276	73647
CONSUMPTION	32145	31318	31387	32422	33608	35067	36474	38127	38836	40021
CONS/SERV.	593	570	550	545	550	557	554	561	545	543
AV. OCCUPANCY	7.9	7.6	7.4	7.3	7.4	7.4	7.4	7.5	7.3	7.3
SEBERANG PERAI DOMESTIC										
SERVICES	29858	31929	34547	38029	40910	44700	50748	55895	61092	65049
CONSUMPTION	16920	17572	19364	21748	22571	24653	26740	29257	30713	32257
*ADJ. CONS.	15720	16372	18164	20548	21371	23453	25540	28057	29513	31057
*CONS/SERV.	534	519	532	546	528	529	507	506	486	480
*AV. OCCUPANCY	7.1	6.9	7.1	7.3	7.0	7.1	6.8	6.7	6.5	6.4
PENANG ISLAND INDUSTRIAL										
SERVICES	3154	3389	3766	4101	4394	4661	5139	5379	5661	5823
CONSUMPTION	6302	7745	8399	9265	10469	11067	11803	12781	13725	12910
CONS/SERV.	1998	2285	2230	2259	2387	2374	2297	2376	2424	2217
SEBERANG PERAI INDUSTRIAL										
SERVICES	2464	2752	3113	3362	3649	3933	4469	4952	5449	5596
CONSUMPTION	10607	12723	14209	14206	14016	14714	14182	15018	15652	13362
CONS/SERV.	4305	4623	4564	4225	3841	3741	3173	3033	2872	2388

* ADJUSTED FOR 400 STANDPIPES AND SUPPLY TO KEDAH
UNITS OF CONSUMPTION ARE IN 1000 CU. METRES

TABLE Z

PENANG WATER AUTHORITY

COST ANALYSIS

COST PER CU.M OF WATER SOLD (CENTS)

YEAR	1979	1980	1981	1982	1983	1984	1985
WAGES	4.9	5.9	6.7	6.9	6.9	6.7	7.1
ELECTRICITY	2.9	3.2	5.1	5.3	5.8	5.3	6.0
DIESEL (PUMPS)	0.4	0.6	0.9	1.0	0.9	1.1	1.2
CHEMICALS	1.3	1.3	1.3	1.6	1.8	1.4	1.4
INTEREST ON LOANS	3.7	3.5	3.1	4.1	5.1	6.6	7.8
MAINTENANCE	3.1	3.4	3.5	3.5	4.0	4.0	4.4
DEPRECIATION	3.3	3.6	3.6	3.7	3.7	4.2	4.9
TOTAL COSTS	19.6	21.5	24.2	26.1	28.2	29.3	32.8
TOTAL REVENUE	22.6	25.4	26.0	27.7	31.6	32.8	36.3
SURPLUS	3.0	3.9	1.8	1.6	3.4	3.5	3.5
CAPITAL REPAYMENTS	2.6	3.4	3.1	2.8	2.7	4.9	5.3
METERED CONSUMPTION (X 10^6 CU.M)	77.6	80.7	85.5	89.2	95.2	97.9	98.6

DETAILED ANALYSIS

COST PER CUBIC METRE SOLD (CENTS)

YEAR	1981				1983				1985			
	MAN.	TRT.	DST.	TOTAL	MAN.	TRT.	DST.	TOTAL	MAN.	TRT.	DST.	TOTAL
WAGES	2.27	2.34	2.07	6.68	2.30	2.18	2.39	6.87	2.41	2.30	2.35	7.06
ELECT.	0.09	4.55	0.42	5.05	0.10	5.32	0.35	5.77	0.08	5.59	0.37	6.04
DIESEL	NIL	0.74	0.19	0.93	NIL	0.68	0.26	0.94	NIL	0.86	0.32	1.18
CHEM.	NIL	1.35	NIL	1.35	NIL	1.80	NIL	1.80	NIL	1.44	NIL	1.44
INTEREST	3.14	NIL	NIL	3.14	5.11	NIL	NIL	5.11	7.77	NIL	NIL	7.77
DEPR.	0.17	1.24	2.19	3.61	0.18	1.21	2.35	3.74	0.20	2.79	3.25	4.87
MAINT.	0.14	0.77	0.67	1.59	0.13	0.84	1.20	2.18	0.26	1.00	1.41	2.66
RENTS	0.44	0.06	0.01	0.51	0.46	0.09	0.01	0.56	0.47	0.06	0.01	0.53
STAT.	0.32	NIL	NIL	0.32	0.49	NIL	NIL	0.49	0.51	NIL	NIL	0.51
OTHERS	0.78	0.08	0.18	1.04	0.43	0.08	0.20	0.71	0.49	0.12	0.07	0.68
TOTAL	7.35	11.13	5.74	24.22	9.21	12.22	6.76	28.17	12.17	12.81	7.77	32.74

MAN. = MANAGEMENT TRT. = TREATMENT DST. = DISTRIBUTION
CHEM.= CHEMICALS DEPR.= DEPRECIATION STAT.= STATIONERY

Removing Humic Acid Complexes of Cr(VI), Pb(II) and Zn(II) from Natural Water by Coagulation Process

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ABSTRACT

The objectives of this study were to inquire the feasibility of the removal of Cr(VI), Pb(II), Zn(II) by coagulation process and to determine the effect of the humic acid on the removal of the aforesaid heavy metals. The results indicated while the removal of Cr(VI) using coagulant of ferrous sulfate was very effective, using alum and ferric chloride was ineffective. The removal of Pb(II) and Zn(II) using alum and ferric chloride was very effective and the higher the pH the better the removal efficiency. The removal of Cr(VI) using alum could be benefited by the input of humic acid. However, the removal of Pb(II) could be obstructed when the humic acid was not completely removed by coagulation. As the pH was greater than 8, the removal of Zn(II) was impeded by the input of the humic acid. In contrast, as the pH was less than 8, the removal of Zn(II) was improved.

KEYWORDS

Heavy metals; humic acid; natural water; equilibrium dialysis; coagulation.

INTRODUCTION

Owing to the intrusion of mining and metal finishing wastewaters, the necessity of removing heavy metals from contaminated natural surface water for drinking water supply gradually becomes more important than ever. In a conventional water treatment plant, the coagulation process is commonly used for the removal of heavy metals by forming the flocs of metal hydroxides and then being adsorbed on aluminum hydroxide or ferric hydroxide induced from coagulants, which is subject to the mechanism of adsorption and/or copprecipitation. Sorg(1979) has pointed out that the solubility of heavy metal itself is the key factor for its own removal. Furthermore, Vuceta (1978) has indicated that the distribution of various heavy metal species in natural water is most likely influenced by many factors which include the concentrations of various heavy metals, organic ligand, inorganic ligand and pH.

Steelink (1977) has described humic substances as polymers of high molecular weights. Several researchers (Reuter, 1977; Saar, 1982; Kerndorff, 1980) have noted that humic substances tended to chelate heavy metals. In other words, the solubility of heavy metal will increase to a certain degree when the chelate effect occurs. As a result, this chelation will affect the removal of heavy metals in the coagulation process.

The principal objective of this study was to determine the effect of humic acid on the removal of heavy metals in the conventional coagulation process. Thus, a series of experiments were conducted to thoroughly resolve the effects of types of coagulants, pH and the humic acid on heavy metals removal. Besides, the degree of complex between humic acid and heavy metals was also pursued.

EXPERIMENTAL

Synthetic raw waters used in this study were respectively prepared by adding various amounts of potassium dichromate, lead nitrate, zinc chloride and humic acid (Aldrich Chemical, Milwaukee, Wisc., U.S.A.) into distilled water.

The detailed procedure of batch coagulation operated in this study is described as follows: first, placed 1 liter of synthetic raw water which contained the heavy metal and incorporated with or without humic acid in 1 liter beaker on the six jar laboratory stirrers, and started 30 seconds rapid mix at 100 rpm. The pH value of each test water was adjusted by adding either nitric acid or sodium hydroxide as it was necessary, and followed by settling for 30 minutes. Then various amounts of coagulants including alum ($Al_2(SO_4)_3 18H_2O$ ferric chloride ($FeCl_3 .6H_2O$) and ferrous sulfate ($FeSO_4 \cdot 7H_2O$) were added into test waters followed by the pH adjustment and 2 minutes rapid mix. Afterwords, a 30 minutes slow mix at 20 rpm proceeded and one hour settling period followed. In so doing, the batch coagulation procedure for the removal of heavy metal incorporated with or without humic acid was completed.

Dialysis bags of 1,000 MWCO Spectral/Por 6 (Spectrum Industries, Los Angeles, CA., U.S.A.) were used to separate the complexed heavy metal from free heavy metal. All the dialysis bags were carefully cleaned before they were used. Then, a 30 ml of 0.001 N potassium nitrate was introudced into each bag which was then completely immerged in a 500 ml of synthetic test water. Owing to the requirement of keeping the same pH value in both sides of bags, 0.1 N sodium hydroxide and 0.1 N nitric acid were used to adjust. As the dialysis equilibrium reached after 24 hours, samples were taken from inner side of bag and the concentration of free heavy metal was then analyzed. Meanwhile, the concentration of heavy metal complex was calculated by using the following equation: $C_c = C_o - C_f (V_o + V_i)/V_o$, where C_c= heavy metal complex concentration, mg/l; C_o=heavy metal concentration of synthetic test water, mg/l; C_f=free heavy metal concentration mg/l; V=solution volume at outer side of bags, ml; V=solution volume at inner side of bags, ml.

The heavy metals of Cr(VI), Pb(II) and Zn(II) were all measured by atomic adsorption spectrophotometer (Model AA-875, Varian, Australia). The UV spectrophotometer (Model 21, Bausch and Lomb, Rochester , N.Y., U.S.A.) at wavelength of 254 nm (A 254) was used to monitor the removal of humic acid. Furthermore, because the absorbance of humic acid changed significantly at different pH values, all standard solution and samples were analyzed only after their pH values being exactly adjusted to 7.0.

RESULTS AND DISCUSSION

Complexation Between Humic Acid and Heavy Metals

Kerndorff's study (1980) has showned that hydrogen ion was very easily dissociated from the functional groups of humic acid, such as carboxy, ketone and phenol, as the pH of solution raised. As a result, those alkaline ligands will be able to form complex of metal ions. This could be confirmed by the results of Tables 1-3 that the concentrations of humic acid complexes of Cr(VI), Pb(II) and Zn (II) did increase with increasing pH values ranging from 4 to 9. In addition, Tables 1-3 showed that the concentrations of humic acid complexs of heavy metals slightly increased when the concentration of humic acid increased. This phenomenon was most likely to occurr because the high concentration of humic acid would provide more complex capacity. Finally, the sequential order of the degree of complex between humic acid and heavy metals showned in Tables 1-3 Pb(II)>Zn(II)>Cr(VI).

TABLE 1. Results Obtained from Dialysis Equilibrium for Separating Humic Acid Complex of Cr(VI) at Various pH Values (1.0 mg/l Cr(VI), Temp. 25°C)

pH	4			5			6			7			8			9		
Humic Acid mg/l	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20
Humic Acid Complex of Cr(VI), mg/l	0.02	0.02	0.05	0.03	0.02	0.06	0.05	0.07	0.10	0.11	0.12	0.15	0.23	0.29	0.34	0.18	0.45	0.51

TABLE 2. Results Obtained from Dialysis Equilibrium for Separating Humic Acid Complex of Pb(II) at Various pH Values (4.14 mg/l Pb(II), Temp. 25°C)

pH	4			5			6			7			8			9		
Humic Acid mg/l	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20
Humic Acid Complex of Pb(II), mg/l	1.01	1.35	1.64	1.80	2.38	2.50	3.76	3.80	3.91	3.38	3.68	3.74	3.39	3.70	3.83	3.68	3.76	3.95

TABLE 3. Results Obtained from Dialysis Equilibrium for Separating Humic Acid Complex of Zn(II) at Various pH Values (1.3 mg/l Zn(II), Temp. 25°C)

pH	4			5			6			7			8			9		
Humic Acid mg/l	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20	5	10	20
Humic Acid Complex of Zn(II), mg/l	0.13	0.13	0.20	0.19	0.23	0.41	0.39	0.48	0.58	0.52	0.72	0.74	0.47	0.85	0.79	0.71	0.76	0.82

Effect of Humic Acid on the Removal of Cr(VI)

Sorg (1979) has pointed out that Cr(VI) is the predominant form of chromium existed in natural water, and is uneasily removed by coagulation due to its high solubility. Figure 1 showed that about 20% of Cr(VI) was removed by the coagulant of alum at the dosage of 40 mg/l as 10 mg/l of humic acid was incorporated to the test water. On the contrary, only less than 5% of Cr(VI) was removed by the same coagulant dosage as no humic acid was added. The afore-said results simply indicated that Cr(VI) was extremely difficult to be removed as the form of free heavy metal. Instead, it could only possibly be removed by first forming complex of humic acid and then copprecipitated with the floc of aluminum hydroxide which was induced from coagulant of alum. Besides, there was another evidence shown in Figs.1-2 that the % removal of humic acid at various coagulant dosages paralleled with that of Cr(VI).

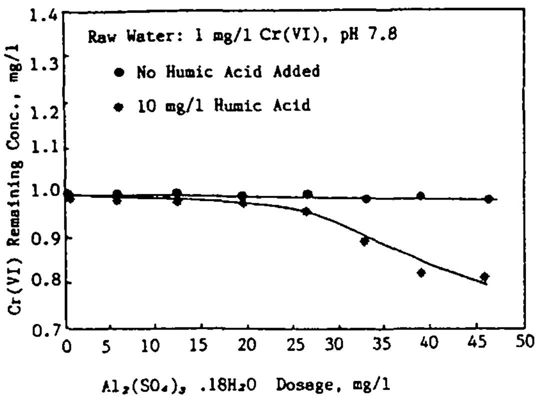

Fig. 1. Effect of alum dosages on the removal of Cr(VI) incorporated with or without humic acid.

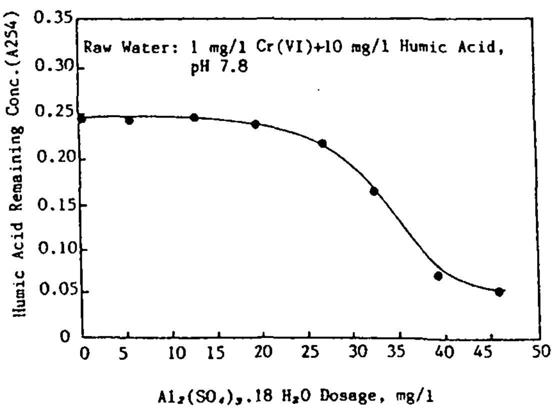

Fig. 2. Effect of alum dosages on the removal of humic acid incorporated with Cr(VI).

The results obtained from the effects of different types of coagulants and various dosages on the removal of Cr(VI) were shown in Fig.3. It showed that ferrous sulfate was the most effective coagulant for the removal of Cr(VI) with the addition of 10 mg/l humic acid. This phenomenon was most likely to occur because Cr(VI) was reduced to Cr(III) by ferrous sulfate and meanwhile Fe(II) was oxidized to Fe(III) by Cr(VI), resulting in the formation of flocs of both chromium hydroxide and ferric hydroxide. Consequently, the chromium concentration of the test water would be greatly removed. Figure 4 showed that Cr(VI) removal using ferrous sulfate increased with increasing pH values ranging from 4 to 9, but its removal was

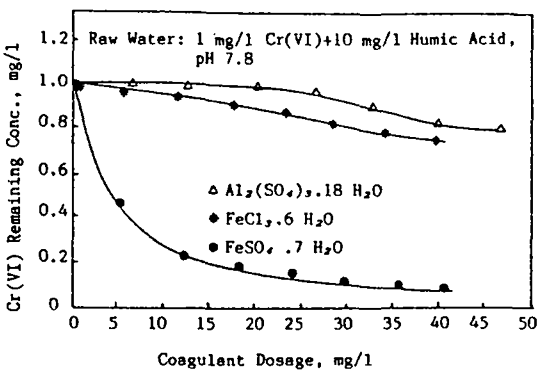

Fig. 3. Effect of various coagulants dosages on the removal of Cr(VI) incorporated with humic acid.

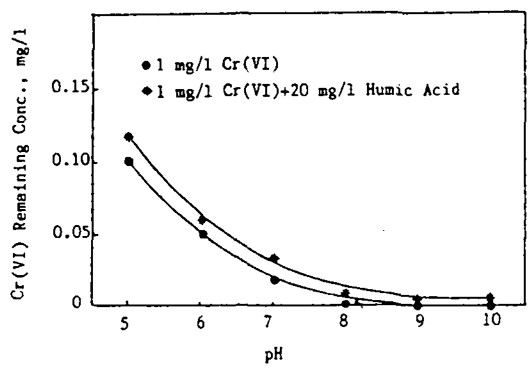

Fig. 4. Effect of pH on the removal of Cr(VI) incorporated with or without humic acid ($FeSO_4.7H_2O$ dosage of 35 mg/l).

slightly obstructed by the input of humic acid. The latter part of discovery was not consistent with that of using alum as a coagulant for the removal of Cr(VI). This could be explained by the results shown in Fig.5 that the removal of Cr(VI) decreased with increasing concentration of humic acid. In a word, as both humic

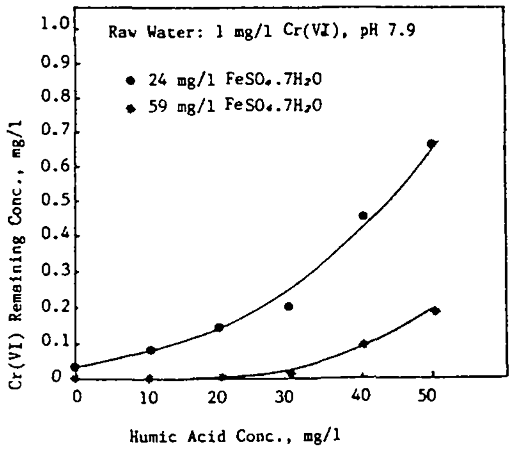

Fig. 5. Effect of various humic acid concentrations on the removal of Cr(VI).

acid and Cr(VI) existed in the test water, the coagulant of ferrous sulfate tended to induce the formation of humic acid complex of Cr(III) which was relunctant to be removed by copprecipitation. On the contrary, the coagulant of alum tended to induce the formation of humic acid complex of Cr(VI) which was relatively easy to be removed by copprecipitation.

Effect of Humic Acid on the Removal of Pb(II)

By comparing the effect of alum with that of ferric chloride on the removal of Pb(II), Fig.6 showed that both coagulants could significantly remove Pb(II) at the dosage about 20 mg/l as humic acid was not incorporated to the test waters, but could not remove Pb(II) any further even if the dosages of coagulants continued to increase. On the contrary, as the test waters contained 5 mg/l of humic acid, the alum at the dosage greater than 35 mg/l could effectively remove

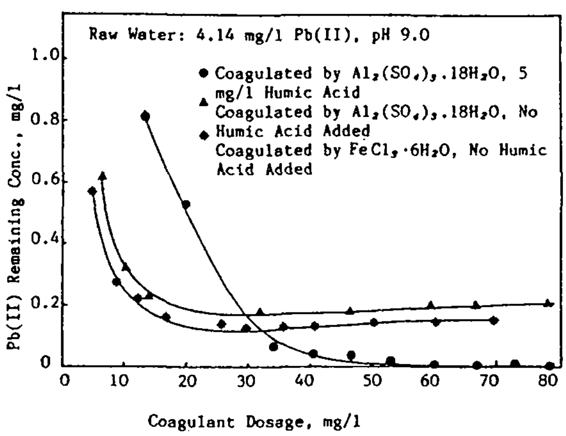

Fig. 6. Effect of various coagulants dosages on the removal of Pb(II) incorporated with or without humic acid.

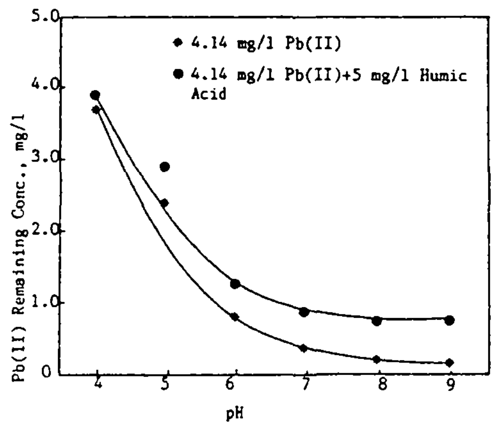

Fig. 7. Effect of pH on the removal of Pb(II) incorporated with or without humic acid ($Al_2(SO_4)_3.18H_2O$ Dosage of 13 mg/l).

Pb(II) to a level as low as 0.05 mg/l. Therefore, it was safe to conclude that the coagulant dosage required for attaining to the optimum removal of Pb(II) increased with increasing concentration of humic acid. In addition, only when humic acid was significantly removed by coagulation could the humic acid complex of lead be effectively removed. In other words, the removal of Pb(II) could be obstructed when the humic acid was not completely removed by coagulation. Figure 7 showed that the removal of Pb(II) increased significantly with increasing pH values ranging from 4 to 9. Besides, a 13 mg/l of alum dosage could not effectively remove Pb(II) because this coagulant dosage could not completely remove humic acid. Moreover, the removal of Pb(II) could be seriously impeded when the conentration of humic acid was raised as Fig.8 indicated. This result was similar to that of Cr(VI) shown in Fig.5.

Effect of Humic Acid on the Removal of Zn(II)

Figure 9 showed that ferric chloride was a better coagulant for

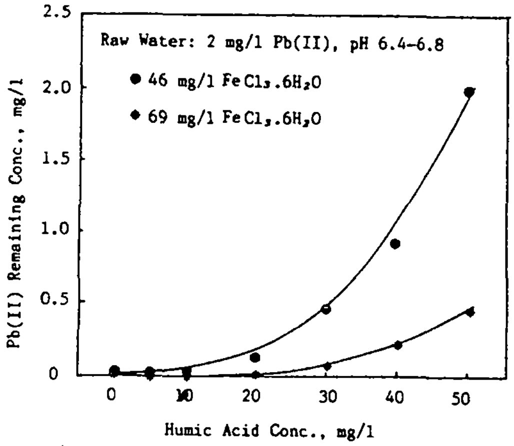

Fig. 8. Effect of various humic acid concentrations on the removal of Pb(II).

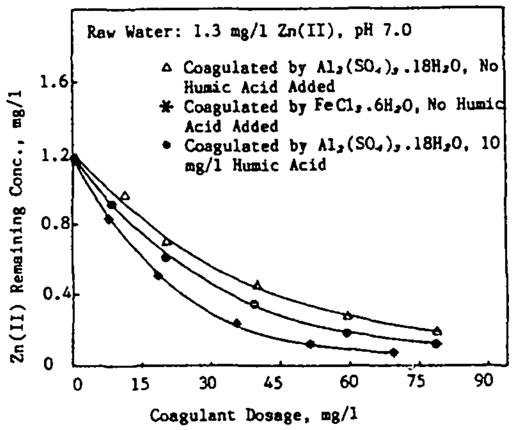

Fig. 9. Effect of various coagulants dosages on the removal of Zn(II) incorporated with or without humic acid.

the removal of Zn(II) than alum was. In addition, the input of 10 mg/l humic acid would result in a better removal of Zn(II) when alum was used as a coagulant. Figure 10 showed that the removal of Zn(II) significantly increased with icreasing pH values ranging from 4 to 9. In addition, as the pH was greater than 8, the removal of Zn(II) was impeded by the input of 10 mg/l humic acid. In contrast, as the pH was less than 8, the removal of Zn(II) was improved. Figure 11 showed that the removal of Zn(II) slightly increased when the concentrations of humic acid of test waters were less than 10 mg/l. Beyond this concentration of humic acid, the removal of Zn(II) significantly decreased.

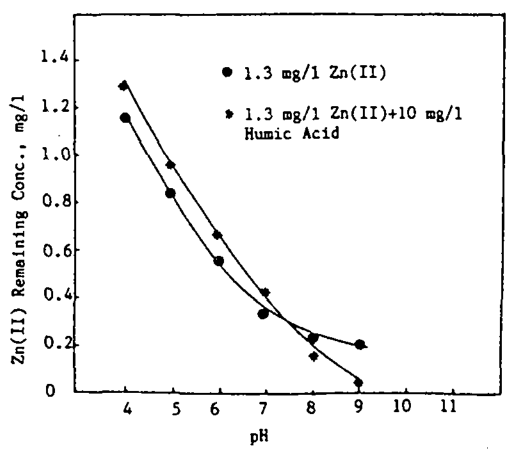

Fig. 10. Effect of pH on the removal of Zn(II) incorporated with or without humic acid ($Al_2(SO_4)_3.18H_2O$ Dosage of 54 mg/l).

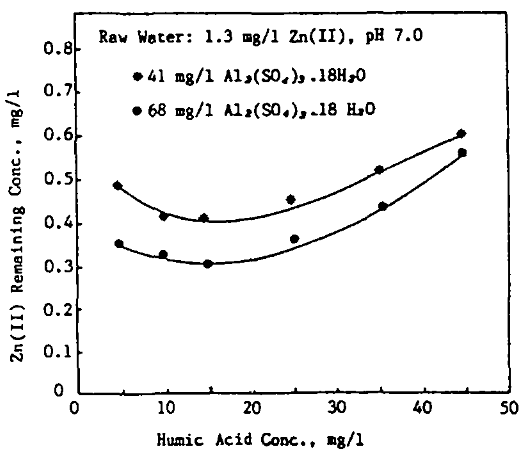

Fig. 11. Effect of various humic acid concentrations on the removal of Zn(II).

CONCLUSION

Ferrous sulfate was the most effective coagulant for the removal of Cr(VI) by reducing Cr(VI) to Cr(III) resulting in the formation of insoluble chromium hydroxide and ferric hydroxide. However, coagulants of ferric chloride and alum could only remove a few amount of Cr(VI) which formed a complex of humic acid. The removal of Pb(II) was obstructed when the humic acid was not completely removed by coagulation. As the pH was greater than 8, th removal of Zn(II) was slightly impeded by the input of humic acid. In contrast, as the pH was less than 8, the removal of Zn(II) was improved by the input of humic acid. In addition, the removal of Cr(VI), Pb(II) and Zn(II) significantly increased with increasing pH values ranging from 4 to 9 as the test waters were incorporated with or without humic acid. The sequential order of the complexation degree between humic acid and heavy metals was Pb(II)<Zn(II)<Cr(VI).

ACKNOWLEDGEMENT

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PLAD (Pipeline Laying Method)

by :
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Civil Engineering & Marine Construction Div.

1. SUMMARY

PLAD method, using horizontal directional drilling technique, is one of unique pipeline laying methods for crossing such obstacles as a river, a bay, a road and so on. It is quite different from conventional methods ; e.g. pipe jacking method, bridging method, dredging method. This PLAD method eliminates the drawbacks of these conventional methods and offers many advantages as follows.

- Long drilling distance up to 1,500m without vertical shaft construction·
- Safety and environmental protection
- Short construction period

Nippon Steel Corporation has constructed water mains, sewage pipelines and other pipelines by use of this method. This paper introduces the construction procedure, machinery and experiences of this PLAD method.

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** Manager of PLAD Gr., Energy Facilities Engineering div. Nippon Steel Corp.
*** Field Engineer of PLAD Gr., Energy Facilities Engineering div. Nippon Steel Corp.

2. DEVELOPMENT OF PLAD

It was started to develop a new pipeline laying method for crossing beneath the obstacles without vertical shafts late in 1977. We found directional drilling technique, which is commonly used for oil or geothermal well drilling, as seeds of development. We co-developed this method with Teiseki Drilling Co. which is initial of skillful drilling contractors in Japan. In less than one year, we completed the development and applied this method for commercial use. We laid four pipelines less than 100m during first two years by this method. And in 1981, we succeeded to lay the first long pipeline more than 300m at Tatara river in Fukuoka prefecture. Since then, we have improved construction procedure and equipment, at present, we can construct the pipeline less than 1,500m by this PLAD method. In addition, in 1982, we had the technical tie-up with InArc Drilling Inc. (formerly : Reading & Bates Horizontal Drilling Co.) in U.S.A., that has many pipeline construction experiences with similar process in worldwide.

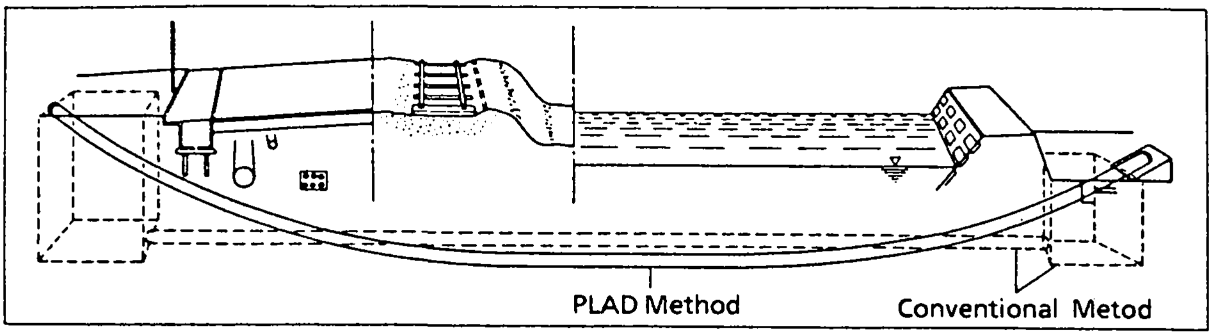

Figure-1 PLAD method and conventional metod

3 ADVANTAGES

1) PLAD can cover a drilling distance of 1,500 meters without vertical shaft construction.

2) The entire drilling operation can be performed on the ground without fear of landslide or groundwater gush. Accordingly, PLAD provides greater safety and stable operation than conventional methods.

3) PLAD causes no ground subsidence or river and sea water contamination, because it requires neither chemical grouting nor well point.

4) A very high arrival accuracy is guaranteed by a specially developed survey tool for this drilling system.

5) The construction period can be shortened because shaft construction or soil improvement is not required, therefore, we hope the construction cost also can be reduced.

4. CONSTRUCTION PROCEDURE

Figure-2 shows the typical PLAD construction procedure.

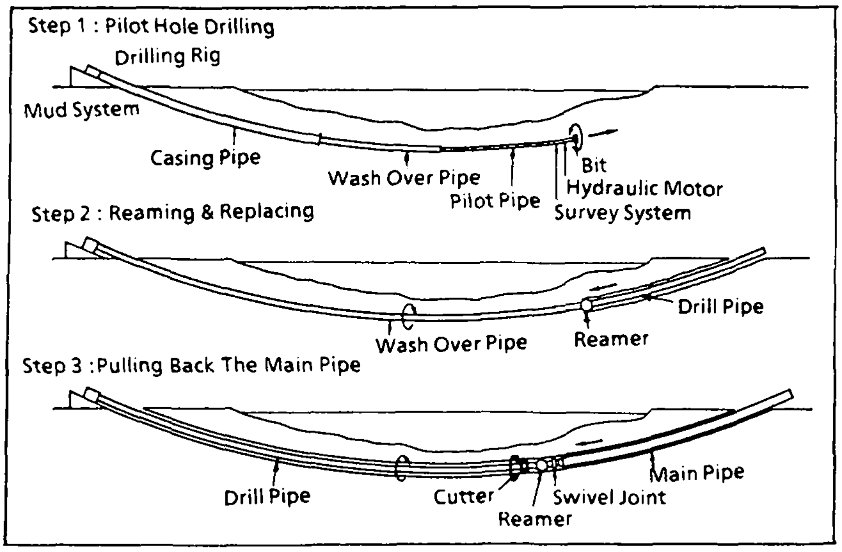

Figure-2 Construction Procedure

(1) Investigation and Survey

The profile of ground surface, soil condition, underground water level and other buried objects are investigated to determine the pipeline route.

(2) Site Preparation

According to the pipeline route, work space is graded and compacted.

(3) Facilities Installation and Rig-up

A drilling rig, mud tanks, mud pumps and other necessary equipments are installed. Then, electric wiring and piping for the mud system etc. are performed.

(4) Pilot hole Drilling

A pilot hole is drilled with a drilling bit, hydraulic down-hole motor, NDC (Nonmagnetic Drill Collar) and small diameter drilling pipes (pilot pipe). And this pilot pipe is covered by wash-over pipe that follows each approximately 100m to reduce the friction resistance between pilot pipe and soil. The hydraulic down-hole motor driven by the mud supplied from the ground, rotates only the drilling bit at the top of pilot pipe. And the rig provides only thrusting force to the pilot pipe. Controllability of the pilot route of the pilot pipe is the big merit for this method. And in this pilot drilling process, the rotation of bit only except the following string makes route controllable. The route is controlled by the basic theory of directional drilling. That means the sharp turn is made by small mud rate and fast thrusting speed, and the loose curve is made by big mud rate and slow thrusting speed, with the aid of a bent housing at the top of the pipe. The bore-hole survey system at the center of NDC detects the position and transmit the data to the control room on the ground. The soil cutting is mixed with the mud water and carried out through the space between pipe and wall of the drilling hall to the ground surface.

(5) Reaming and Replacement of wash over pipe

After the drilling out of pilot and wash-over process, the pilot pipe in the wash over pipe is pulled back to the starting side and the wash-over pipe keeps drilling route. And a reamer and drill pipes stronger than wash-over pipe are connected to the end of wash-over pipe at the arrival site. Next, the wash-over pipe, reamer and drill pipes are rotated and pulled back to the starting side by the drilling rig for reaming the hole and for replacing the wash-over pipe with high strength drill pipes. The different point from pilot drilling is that whole pipe string is rotated by the drilling rig. And the soil cutting is mixed with the mud water and carried out through the annular space between pipe and wall of the drilling hole. This reaming and replacing process is sometimes omitted according to the soil condition and /or pipe diameter.

(6) Pulling back the main pipe

After the reaming, a hole opening cutter, a reamer, a swivel joint, and main pipes are connected to the end of replaced pipe at the arrival side. And the process of hole opening and pulling back the main pipe are performed at same time. In this process, since the swivel joint doesn't transmit the torque, the main pipe is pulled back without rotation. At this time, if there is enough space, it is desired to pre-fabricate the main pipe as long as full drilling length. And in the case that the pre-fabrication is impossible, the connecting time should be shortened to escape from adherence of soil.

(7) Rig Down and Clean Up

Drilling rig and other equipments are removed from the site, after that, tied-in and clean up work is performed.

5. MACHINE AND EQUIPMENTS

(1) Drilling Rig

A rig (figure-3) provides thrusting force and torque required for drilling. We have two types of rigs which are designed and built exclusively for PLAD method.

Figure-3 Drilling Rig

The small one is used for middle distance (less than approx. 400m).In this case, because the short range pipe (range 1 ; 6m drill pipe) is used, the space for operation is relatively narrow. And the other one is used for long distance (more than approx. 400m) and operated with long drill pipes (range 2 ; 9m drill pipe) in consideration of the working efficiency. Rigs are designed in consideration of efficiency of drilling work , convenience of rig up and down, transportation, safety, and construction noise and vibration and so on.

(2) Drill Pipe

Drill pipes are seamless pipes attached screws called tool joint at each of the ends. Material quality, shape and strength of these pipes meet the API specification. The feature of this pipe is that the pipe part and joint part have almost same strength (60 - 80 kg/mm). In this method, drill pipes are used as pilot pipes and wash-over pipes. The pipe length is approximately 6m (range 1), and approximately 9m (range 2) as mentioned above.

(3) Hydraulic Down Hole Motor

The hydraulic down hole motor is the system to change the energy of mud flow into the rotation force of drilling bit, and it is used at the time of pilot hole drilling. This motor consists of driving part, transmission part, and bearing part. Figure-4 shows the general configuration of hydraulic motor.

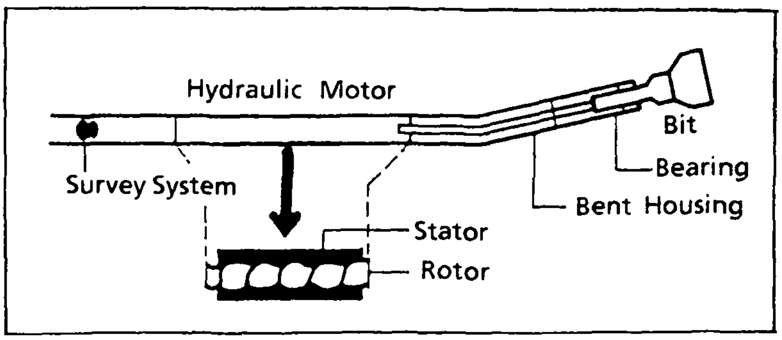

Figure-4 Hydraulic Motor

(4) Bore-hole Survey System

NDC : non-magnetic drill collar (quality of stainless steel) is used in the rear of the hydraulic motor. The bore-hole survey system, that is able to detect the direction (azimuth and inclination) and the rotation of pipe, is set at the center of NDC. The result of detection is transmitted to control room on the ground surface. We have two types of survey systems. The difference between these two systems is the transmission mechanism. One is the cable type system with T.V. camera that is able to transmit the data continuously, and the other one is the cableless system that is good at working efficiency. Each system is used properly according to the construction length, circumstances and so on. The result of the detection is processed by computer to get the position of the pipe and indicated on CRT.

(5) Drilling Tool

The bit for pilot drilling, cutter and reamer have hard tips to cut the soil and nozzles to jet out the mud water. The swivel joint for reaming and pulling is used to avoid the transmission of the torque to the main pipe at the time of pulling back of the main pipe. And the universal joint is used to reduce the stress concentration in front of main pipe.

(6) Mud System

Mud mixers, mud tanks, mud pumps and de-sander are designed to be able to circulate the mud and to control the mud quality. The mud material is changed by the soil condition and the salt ratio in water. Basically, bentnite and polymer are used .

6. AVAILABLE PLACE TO APPLY

Figure-5 shows the applicable range of PLAD method. In accordance with the soil conditions, this method can be easily applied from in clay layers to in sand layers or soft rocks. Especially, PLAD is superior to conventional methods in such a condition that the underground water is high or the ground condition is very weak. Figure-6 shows the image of place that PLAD can be applied.

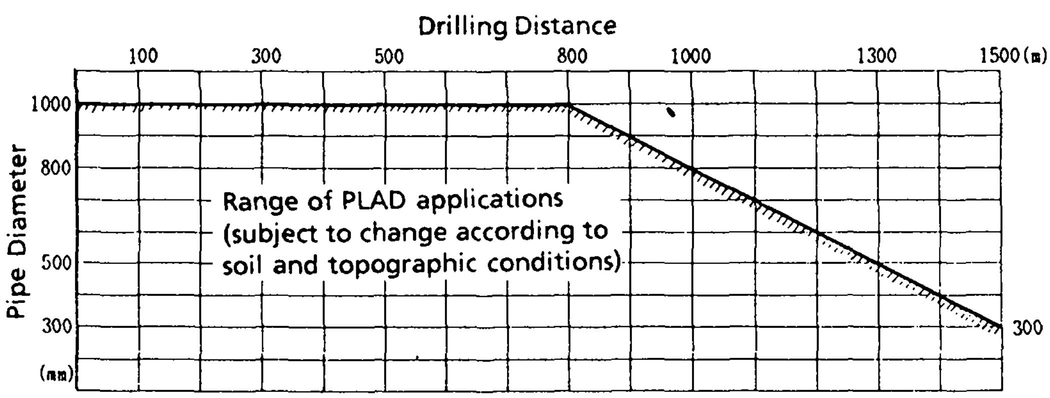

Figure-5 Application Range

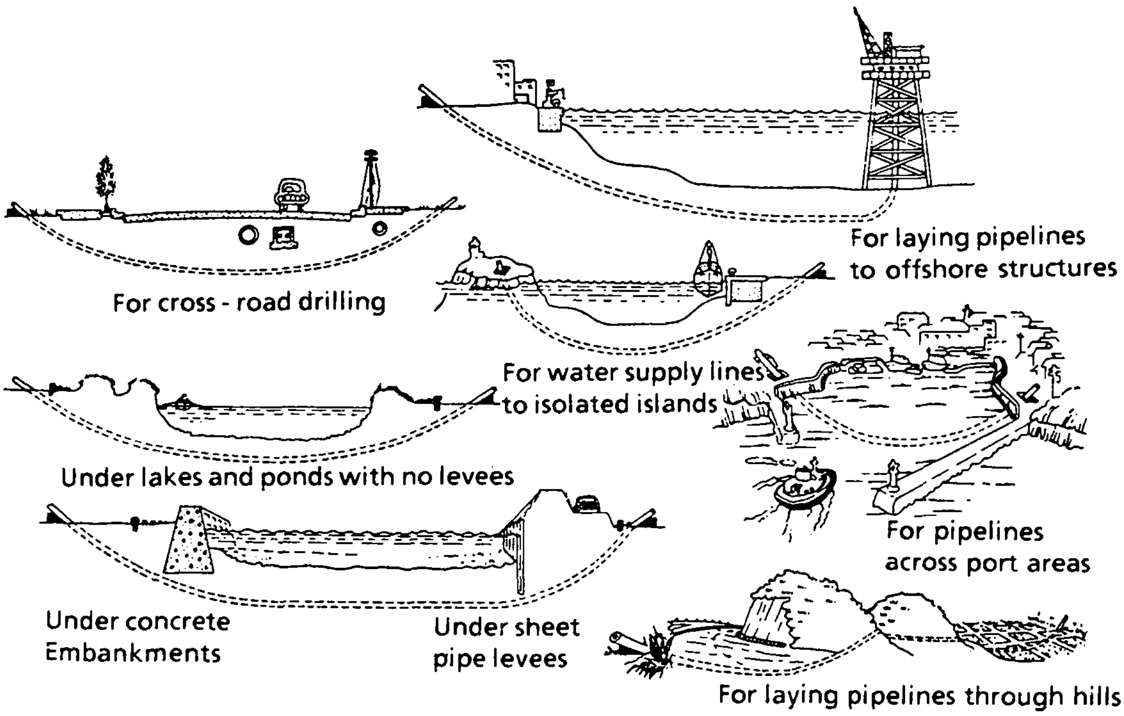

Figure-6 Applicable Place

(1) Crossing beneath a river, a pond or a bay

In such a situation, bridge method, pipe jacking method, shield tunneling method or bottom-pull method was used. In case of using bridge method, piers must be constructed in the water. And in case of bottom-pull method, dredging must be performed. And these methods break out the water pollution, removal of a part of embankment and reconstruction and so on. Especially, these are the big problem in the fishing area and frequent traffic zone. The pipe jacking method or shield tunneling method requires deep vertical shaft construction under the level of underground water or soil improvement such as chemical grouting or well point. These methods break out the pollution and/or drying up of underground water. Against the drawbacks of these conventional methods, PLAD is the non-excavation method without vertical shafts, and has great merit that there is no influences to the environment above the pipeline route.

(2) Crossing beneath a road or a railroad

The biggest subject in this case is the subsidence or rising of ground surface under or after construction. In case of using PLAD method, because no underground water is occurred and pipe diameter is not so large, there is no need to be afraid of such a problem .

(3) Shore line approach of pipeline

In this case, keeping shore line is the most important matter. PLAD is effective to apply, because of the same reason of case (1). In case of using the bottom-pull method, shore line structures must be removed for long term and the big temporary structure must be constructed for the severe sea weather. All these problem is solved by using PLAD method.

7. CONSTRUCTION EXPERIENCES

(1) Chronology of Experiences

Table-1 shows the chronology of experiences of PLAD. In case of 2) and 3), these were the main road crossing constructions and construction pollution (including ground subsidence) was limited severely. In case of 5), two parallel pipes (ϕ 500 and ϕ 700) were constructed at same time. Case of 6) was the first construction at the shoreline, and the great merit of this method was confirmed. In case of 7), the orbit had a horizontal curve of 7 degrees. To get high accuracy the gyroscope was used. Case of 10) is the longest construction (1380m, ϕ 400), and the main pipe was prefabricated beforehand on the arrival site.

<u>Chronology of Experience</u>

Information current to	:	August 20, 1987
Total number of job to date	:	11
Comulative total of meters of pipe installed	:	4,808 m
Longest drilled distance to date	:	1,380 m
Largest pipe diameter to date	:	28" (310 m)

<u>Table-1 Chronology of Experiences</u>

JOB (DATE)	DESCRIPTION (Length × Dia.)	DESIGN PRESSURE	OBSTACLES	SOIL CONDITION N - VALUE	CLIENT
1) (Nov.,1979)	123 m of 2"	-	City Road (Longitudinally) Nagaoka City Niigata Pref.	Fine &Medium Sand N=15	Teikoku Oil Co.
2) (May ,1980)	40 m of 16"	10 kg/cm²	Prefectual Highway Misato City Saitama Pref.	Sandy silt & Clay N=0 - 20	Tokyo Gas Co.
3) (Aug.,1980)	75 m of 16"	10 kg/cm²	National Road (R-17) Toda City Saitama Pref.	Fine Sand & Silt N=0 - 20	Tokyo Gas Co.
4) (Mar.,1981)	76 m of 28"	7.5 kg/cm²	Koito River Kimitsu City Chiba Pref.	Sand (Gravel Layers) & silt N=1 - 30	Kimitsu Water Supply
5) (Dec.,1981)	310m of 28" 310m of 20" (Dual)	7.5 kg/cm² 7.5 kg/cm²	Tatara River Fukuoka City Fukuoka Pref.	Sandy Silt N=0 - 20	Fukuoka City

6) (Sep.,1983)	720m of 12"	ANSI 600#	Pacific Ocean (Shore Approach) Fukushima Pref.	Mud Stone qu=50 kg/cm^2	ESSO Production Japan
7) (Dec.,1983)	370m of 12" 370m of 12"	7.5 kg/cm^2	Hakata Harbor Fukuoka City Fukuoka Pref.	Sandy Silt N=0 - 20	Fukuoka-Kitakyushu Urban Express Way Public Co.
8) (May ,1984)	400m of 10"	36 kg/cm^2	Niigata East Harbor (Shore Approach) Niigata Pref.	Medium Sand N= 20	New Japan Sea Exploration Co.
9) (Dec.,1984)	284m of 24"	5 kg/cm^2	Tsurumi River Yokohama City Kanagawa Pref.	Sandy Silt N = 0 - 20	Yokohama City
10) (Aug.,1985)	1380m of 16"	9.9 kg/cm^2	Dohkai Bay Kitakyushu City Fukuoka Pref.	Silt N= 0 - 20	Saibu Gas Co.
11) (Feb.,1987)	350m of 14"	3 kg/cm^2	Hino River Omi-hachiman City, Shiga Pref.	Sand (Gravel layers) N=20 - 30	Shiga Pref.

(2) Construction Example of River Crossing

In our experiences of this method, there is the pipeline of maximum length 1380m above mentioned. In this paper we would like to introduce the latest pipeline construction concerning with water works.

(a) Construction Outline

In 1987, at Omi-Hachiman city in Shiga pref., a water pipeline for agriculture was constructed. In this construction, PLAD method was applied to the Hino-river crossing part.

Construction Name : Hino River Crossing Pipeline Construction

Construction location : Omi-Hachiman city, Shiga Pref.

Pipe : Steel Pipe (STPG38 : JIS G 3454)

Dia., Thickness : Dia.: 355.6mm, Wall thickness : 7.9mm

Coating : external polyethylene (t=4.0mm)

: internal tar-epoxy (t=0.5mm)

Distance : 350 m

Curvature Radius of Route : 450 m

Client : Shiga-Prefecture

Construction Period : 1987 January - March

(Drilling Period 1987, February)

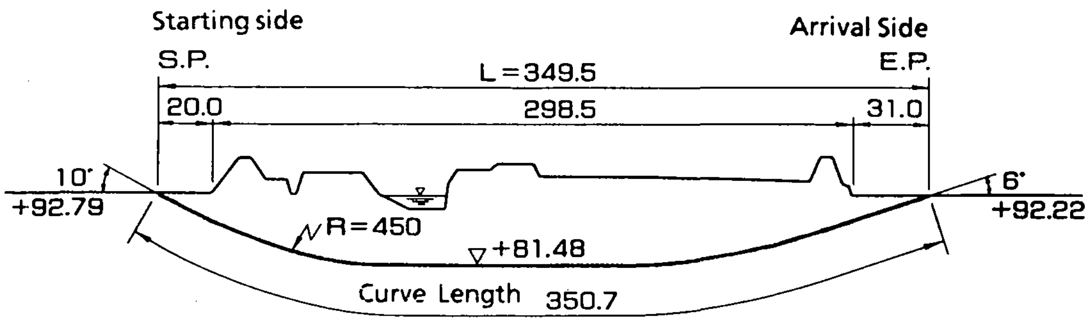

Figure-7 Construction Profile

(b) Construction Condition

1) Soil Condition

The soil condition is sandy clay with gravel sand layer like lens shape. The grain size of gravel sand is explained that D_{50} is 2 mm φ , D_{80} is 6 mm φ and maximum size of grain is over 30 mm φ . And in the gravel sand, the penetration value of standard (N value) is over 50.

2) Working environment

Both sides of river are rice fields. Accordingly, the working space for construction was secured enough. Starting site (approx. 50 × 60 m) and arrival site (approx. 10 × 350 m) were prepared. The term of construction was selected in winter, because of escaping from the agricultural season. Above the drilling route, a high voltage cable is crossing. And in the near of the site, there is a railroad of Shinkansen (Japanese super express train). These construction environment were anxious for giving some bad influence to the drilling survey system.

3) River Condition

Hino river is famous as a river of rising up the water level higher than the land level of both sides in the case of heavy rain. And competent authorities of this river was very nervous about this point.

Figure-8 Construction Site

(c) Selection of Construction Method

Some other methods were investigated comparing with the PLAD method. The bridge method had a problem of piers' safety in such a rapid flow under flood. In the case of pipe jacking method, the soil improvement such as chemical grouting or well point was required. It costs very expensive and break out the water contamination. And PLAD method, that is economical, clean and speedy was selected.

(d) Construction Situation

In January 1987, starting and arrival site preparation was started. At the end of January, the drilling rig was carried into the site. And the pilot drilling started at the beginning of February. After two weeks' pilot drilling, the pilot bit was arrived at the arrival site accurately. In the arrival side, the main pipe, that is as long as construction length, was pre-fabricated before the arrival of the pilot pipe. In this crossing, because the pipe diameter is not so large, the process of reaming and pulling back the main pipe was performed at the same time. It took about 8 hours to pull back the main pipe from the arrival site to the starting site. Next, the rig and other equipments were downed and carried out from the both sites, and clean-up work was performed until the end of February.

8. Conclusion

We introduced our PLAD method in above. And we hope that this method will be applied to the place of pipeline construction that requires any crossing beneath the obstacles. If you are facing to some problems and/or subjects, e.g. to construct for larger diameter pipe, to extend the construction length, to improve the working efficiency, to apply this method to other severe soil condition, and so on, please let us know. We are ready to research and develop about such subjects for your purpose. And we would like to give thanks to the committee of this conference for giving such a good opportunity to us.

THE CHANGE OF WATER QUALITY CHARACTERISTICS WITH ARTIFICIAL LAKE CIRCULATION

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1. Introduction

The conservation of water resources is one of the major problems in Japan. In many places of Japan, the water resources in surface water are becoming unsuitable for water supplies and water treatment systems, and many restration techniques will becoming to improve the actual stage of eutrophication. One of the major concerns resulting from eutrophication in lakes and reservoirs is hypolimnetic oxygen depletion in deep water bodies. The oxygen deplation causes release of phosphorus, manganese and/or iron from sediments. Released phosphorus may enhance primary production in the overlying water. Anoxic condition increased reduced compounds (ammonia, hydrogen, manganese and/or iron, etc.) may render water unsuitable for the dircct use of water, and the constraction and operation of water treatment proceess to remove these ions would increase the cost of water supply. The oxygen depletion and low water quality would also restrict fish habitant and damage other habitants of aquatic life. Artificial circulation on destratification is possible to decrease those reduced compounds and increase oxygen concentration in deep water bodies. This technique has been carried out since 1960's in Europe and U.S.A.[1] for water quality control in reservoirs and lakes. Many reports showed that circulation or destratification was generally employed in an attempt to overcome the classical problems of water quality drgradation. However, no detailed assessments have been made by the quantitative importace of oxygen concentration and nutrient condition in relation to oxygen and nutrient budgets in reservoirs. The purpose of this study is to assess the internal load changes caused by the lake sediments in water bodies. in order

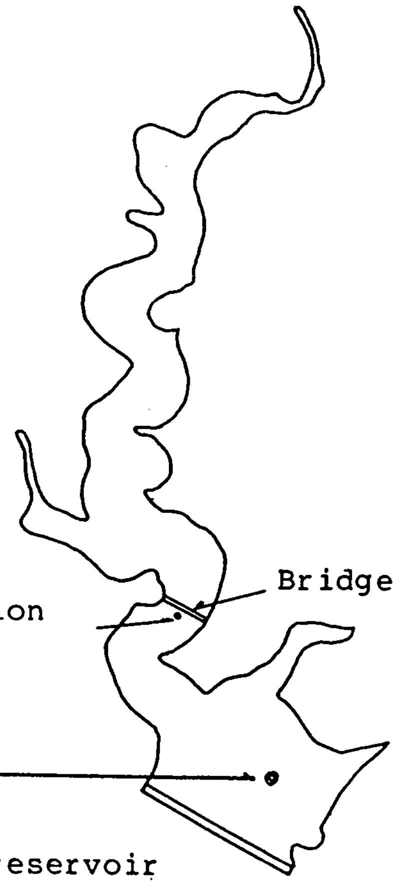

Fig 1 Masuma reservoir

to understand the change of water quality characteristic with artificial circuration, field survey was conducted before and after lake circuration. There is no point source in catchment area in Masuma reservoir but the water quarity is classificated hyper-eutrophic lakes. The average concentration of T-P is ranged 0.10 to 0.12 mg/l and average chlorophyll-a is ranged 10 to 40 ug in summer, and hypolimnetic oxygen deficit appeares in every summer stratificated period. In the past, many reports are discuss about effect of artificial cercuration or aeration, containing any point source in catchment area. Masuma reservoir has no point source in catchment area except forestory, and to discuss the effects about these lake for artificial cercuration system of great interest. This reservoir is typical of small man made lake in south-central area in Bohsoh peninsula located south district in Tokyo, an is used for water supply. The outline of the reservoir is serpentine in configuration with surface area of about 0.06 km^2 , maximum depth is about 22 m. The distance between sampling station and the instrument of artificial cerculation is about 150 m and is screened with promontory.

2. Materials and Methods

2 - 1. Aeration system

The artificial circurator we built was a submeged free-floating column. The shape looks like a cylindrical appearence with a air chamber at the bottom, and is made of fiberglass. The diameter of cylinder is 0.5 m and length is 8 m. One 2.2 kw rotary vane compressor was installed concrete shed near the shoreline and connected to the air chamber by weighted airline. Water flow in the circulater is intermittently and range of water velocity is 0.59 m/s to 1.58 m/s and mean velocity is 1.01 m/s (30 minutes average) at intervals of 20 - 22 seconds. This intermittent flow caused by constructure of siphonic air chamber.

2 - 2. Sampling

Water quality were measured at 1 - 4 m intervals. Field experiment and in laboratory experiment were also carried out to understand the PO_4-P release rate from the bottom sediments. Several core with bottom sediments were submerged at bottom layers and sampled every two or three days for PO_4-P determination. The sampling point is about 150 m from artificial circulation point. Fig. 1 shows profiles of Masuma reservoir. Laboratory experiment uses same core as field experiment, water temperature is controled to the temperature of the bottom layers in Masuma reservoir and aeration is continuously done for estimation to PO_4-P release rate to according to artificial circulation.

3. RESULTS AND DISCUSSION

Lake circulation started on 18 June 1986 with one aeration system. It is well-known that water characteristics changes gradiently in summer stratificated period. In lake however it is expected to be changed in water characteristics more rapidly against an annual stratificated period. To discuss about effects of lake circulation, it is necessary to know water characteristics changes after short period with circulation and an annual stratificated period. In order to know for short period changes of water quality, field survey is carried out before and after circulation period, on 14, 20 and 28 June and July 1986. And to know annual water quality in summer field survey is also carried out on July 1985 and June 1986. The annual average of major water quality in summer stratificated period, SD is about 0.4 m, chlorophyll - a is about 10 - 40 ug/l in epilimnion and T-P is about 0.10 - 0.12 mg/l. In water column, Masuma reservoir has contained very fine suspended materials that caused by geological feature.

Fig. 2 shows vertical distribution of water temperature in Masuma reservoir from on 18 July to on 29 July 1985. The thermocline is formed along the depth of 1 to 4 m. Although the surface temperature is about 27 - 28 °C yet hypolimnetic temperature is less than 15 °C. It shows typical summer stagnated period in lakes. Fig. 3 shows vertical distribution of water temperature which observed almost one month after since circulation started. As comparison with summer stagnated period, vertical distribution of water temperature shows almost uniform distribution without surface area. Fig. 4 and Fig. 5 shows vertical profiles of dissolved oxygen concentration in July 1985 (before circulation) and in July 1986 (after circulation), respectively. To compare the hypolimnetic oxygen deficit, during the circulation period (July 1986) shows more remarkably good condition than the stagnated period (July 1985). The vertical profiles of water temperature and dissolved oxygen concentration mean sufficient effect of circulation in Masuma reservoir, although the sampling point is separated with small promontory and distance between the circulation equipment and sampling point is about 150 m.

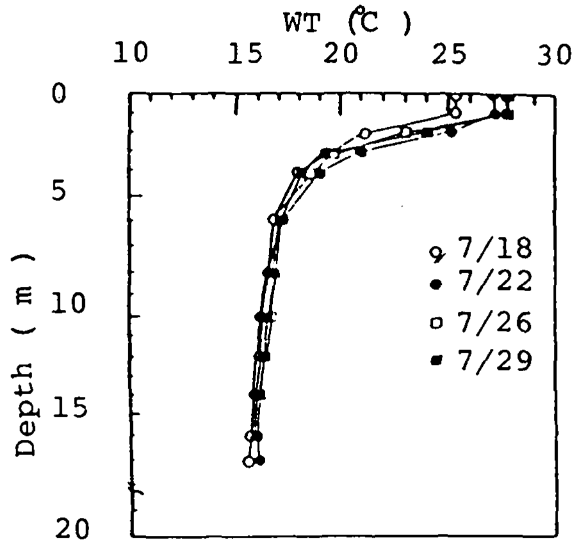

Fig 2 Vertical distribution of water temperature(July 1985)

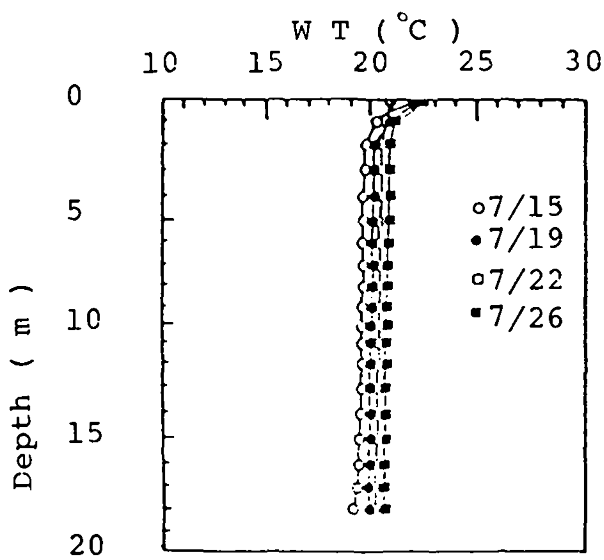

Fig 3 Vertical distribution of water temperature(july 1986)

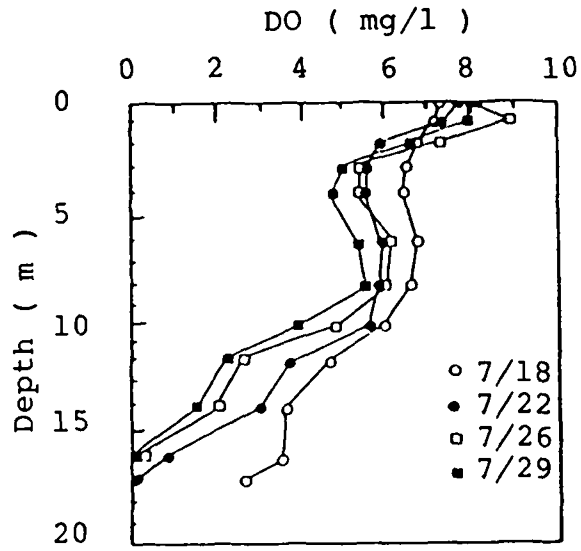

Fig 4 Vertical distribution of dissolved oxygen concentration

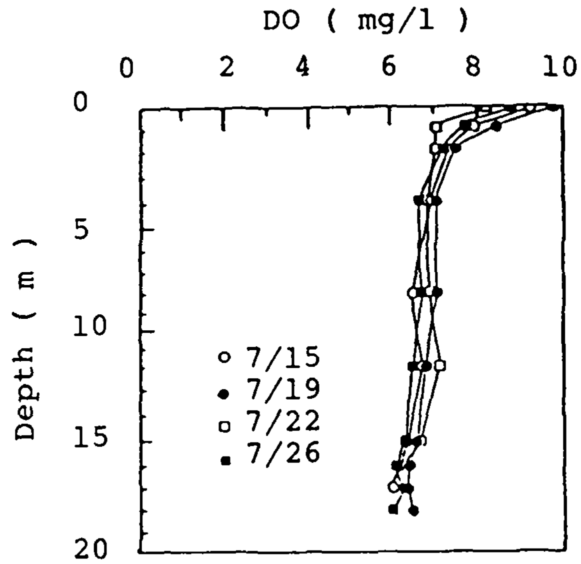

Fig 5 Vertical distribution of dissolved oxygen concentration

Fig. 6, Fig.7 and Fig. 8 shows vertical profile of T-P, SS and chl-a, respectively, which is compared the summer stratificated period (July 1985, June 1986) and after circulation period (July 1986). There are no particular change of predominant phytoplankton and chlorophyll-a concentration in the hypolimnion for each period. Therefore difference of the T-P concentration in the hypolimnion between July 1985 and June 1986 causes difference of the suspended materials concentration. The vertical profiles of T-P in after circulation period (July 1986) similarity to that of before circulated period (July 1985 and June 1986) collectively.

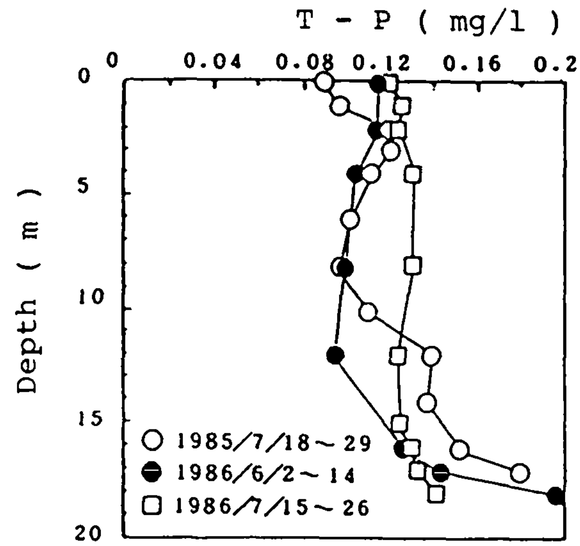

Fig 6 Vertical distribution of total phosphorus

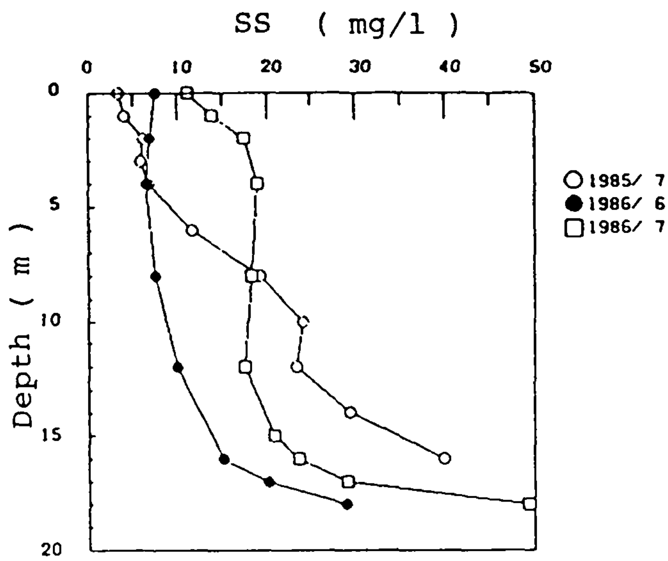

Fig 7 Vertical distribution of suspended materials (mean value of each observed period)

Vertical profiles of PO_4-P shown in Fig. 9 demonsdtrated different pattern between before and after circulation period. The concentration of PO_4-P decreases about 0.045 mg/l to about 0.004 mg/l below 2 m depth. But decreases of T-P does not recognized. This is different result to the effect of hypolimnetic aeration reported by Bengtsson[2]. Behavior of T-P changes according to circulation shown in Fig. 10. Two days after (20 June) and ten days after (28 June) from start of circulation, water column T-P decreases 0.15 mg/l to 0.13 mg/l and 0.13 mg/l to 0.09 mg/l in bottom layers, respectively.

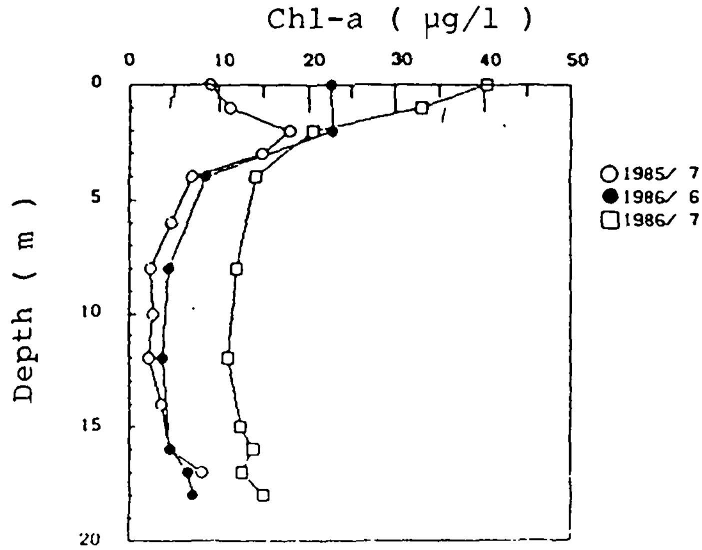

Fig 8 Vertical disribution of Chl-a (mean value of each observed preiod)

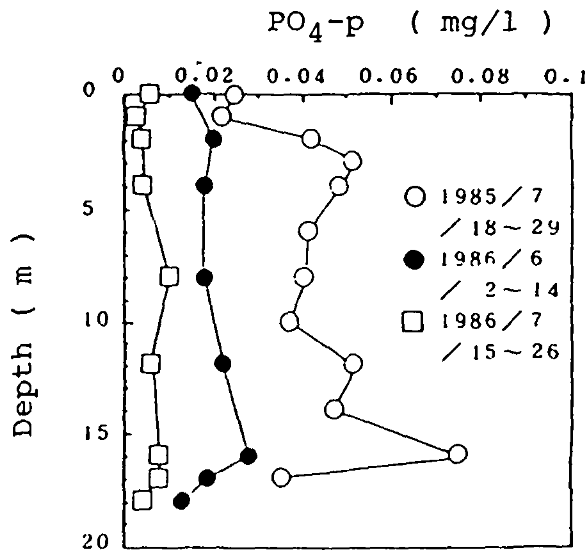

Fig 9 Vertical distribution of PO_4-P (mean value of each observed period)

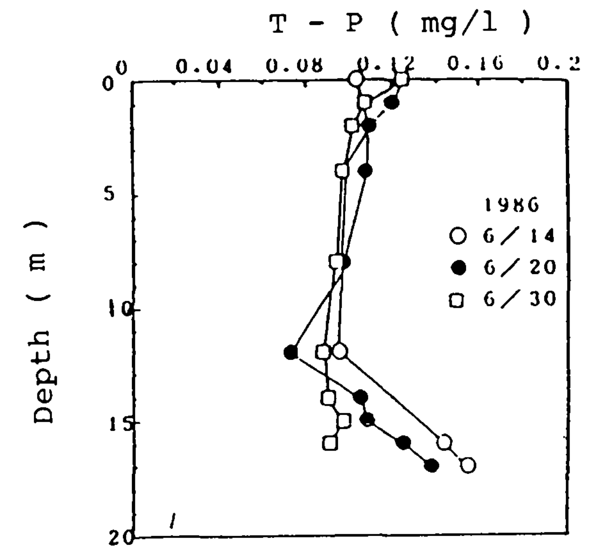

Fig 10 Vertical distribution of T - P, june 1986

Fig. 11 shows NO_3-N vertical profiles before and after circulation period. Vertical profiles of NO_3-N is similar to that of PO_4-P on 14 June(before circulation), but on 20 June and 28 June (after circualtion), vertical profiles are almost uniform on every depth of water expect surface layer. The changes of SS is not observed some striking difference between before and after circulation period. But PO_4-P decreases clearly in near the bottom layer shown in Fig. 12. About this time, if the adsorption of PO_4-P on bottom sediment is not scarcely occured, it will be supposed similar vertical profiles between PO_4-P and NO_3-N. Then the vertical distribution of PO_4-P may be almost uniform profiles. It will be supposed that the average concentration of PO_4-P is about 0.03 mg/l. The decrease of PO_4-P in the bottom layer shown in Fig.12 demonstrated PO_4-P adsorption (sedimentation of ferrous bonding) occured about 0.03 mg/l to about 0.002 mg/l. According to this assumption, the decrease of T-P (since just before circulation to after circulation period) in the bottom layer is considerated mainly depending upon PO_4-P adsorption to the bottom sediment. One month later since start of the circulation, SS vertical distribution is gradiently increased shown in Fig. 13, and the T-P values greater than before circulation period already shown in Fig. 6. Contrary to that period, the difference of SS is scarcely recognised shown in Fig. 14. That is indicated the possibility of appearences increasing T-P in the water column according to artificial circulation caused by re-suspention of sedimented materials.

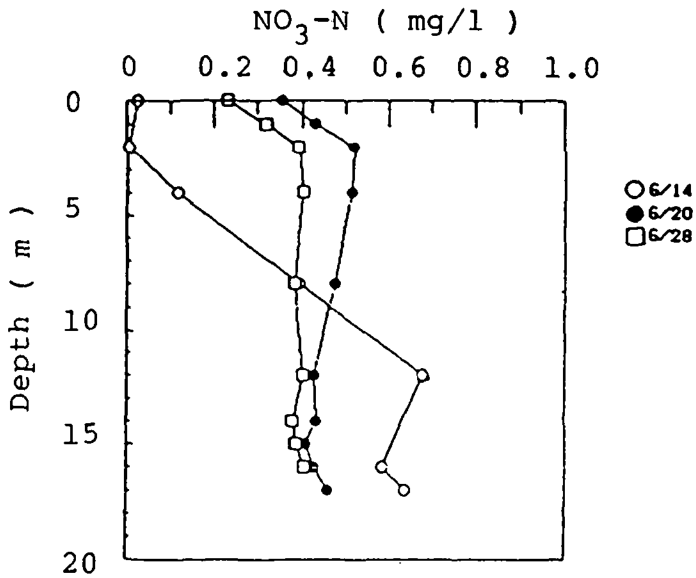

Fig 11 Vertical distribution of NO_3-N, june 1986

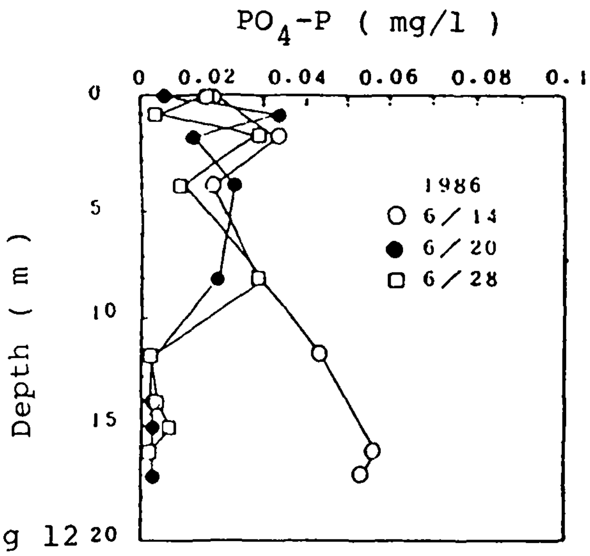

Fig 12
Vertical distribution of PO_4- P june 1986

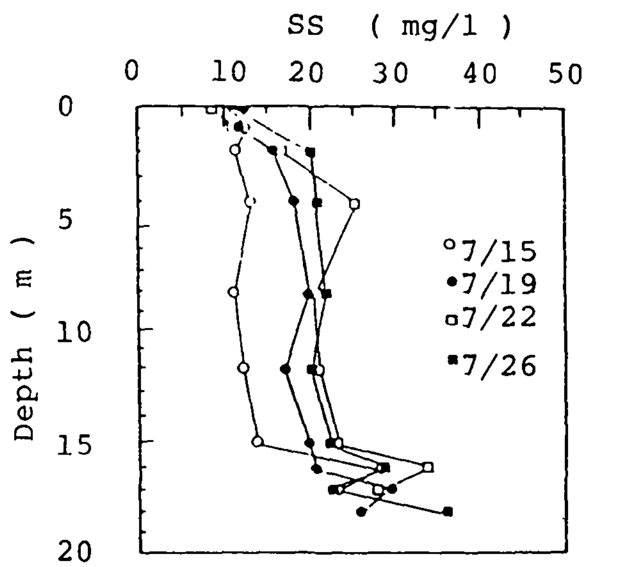

Fig 13 Vertical distribution of
suspended solid July 1986

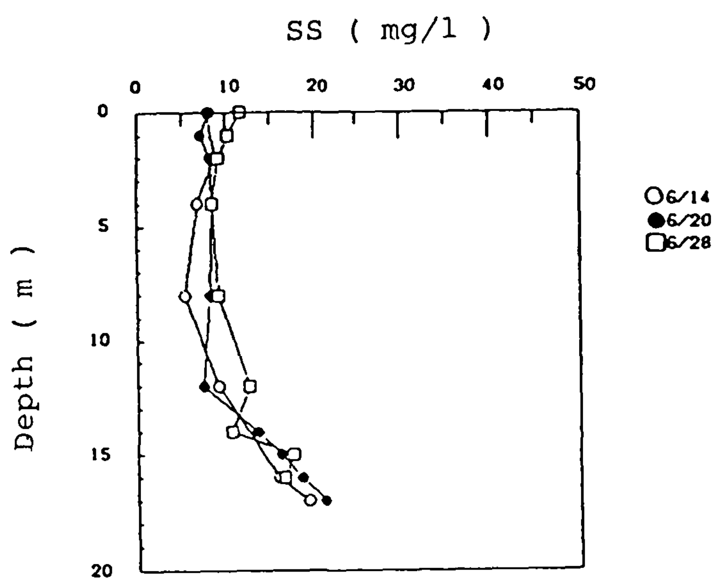

Fig 14 Vertical distribution of
suspended solid June 1986

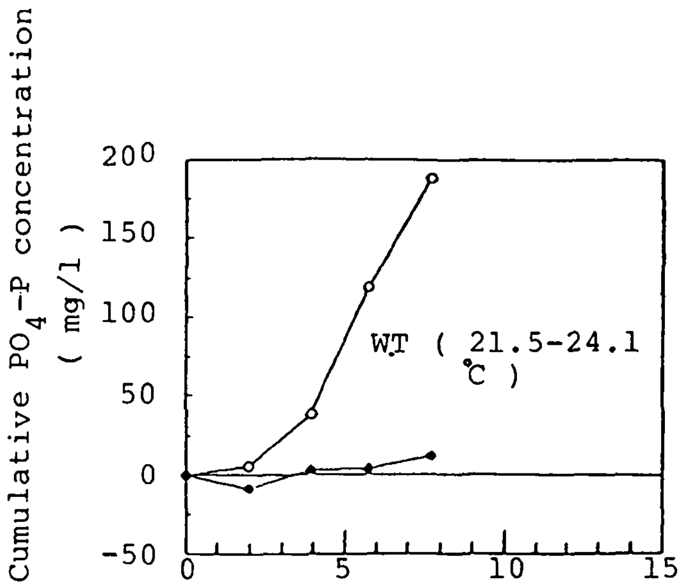

Fig 15 Changes of PO_4- P concentration with core experiment

To understand decrease of PO_4-P concentration coincide with artificial circulation, it is necessary to know the changes of PO_4-P release rate through the bottom sediments. Several experiment are carried out in field and in laboratory with core method. As an example, Fig. 15 shows cumulative PO_4-P concentration transition with time elapsed in the summer in aerated and in oxygen deficit condition. According to some experiment, PO_4-P release rate is about over 10 mg/m^2 per day in the oxygen deficit condition, but is scarcely recognized in aerated condition. On the other hand dissolved oxygen concentration in the bottom layer is less than 0.5 mg/l (July 1985) and over 6.1 mg/l (July 1986). Then, in order to discuss the roughly estimation, assuming that the release rate of PO_4-P through the bottom sediment is about 10 mg/m^2 per day in July 1985 and about zero in july 1986. On this supposition, PO_4-P flux through the bottom sediment is 0.63 kg/day less in Masuma reservoir in July 1985 than that in July 1986. Based on the PO_4-P observed values already shown in Fig. 9, the average PO_4-P in the water column is supposed to 0.04 mg/l in 1985 and 0.004 mg/l in 1986. Then we can calculate the difference of average PO_4-P between in July 1985 and in July 1986. If the difference of PO_4-P is mainly depend on the changes of release rate from the bottom sediment, we estimate the changes of PO_4-P concentration in water column is based on next equation.

$$P = (C_{1986} - C_{1985})\cdot V$$

$$P' = (R_{1986} - R_{1985})\cdot A\cdot t$$

whrer P, P': the difference of water column PO_4-P concentration (mg/l)

C_{1985}, C_{1986} : average concentration of PO_4-P in 1985 and in 1986, respectively (mg/l)

V : volume of the lake (m^3)

R_{1985}, R_{1986} : PO_4-P release rate from the bottom sediments in 1985 and in 1986, respectively ($mg/m^2/day$)

A : bottom area of the lake (m^2)

t : time (day)

According to this equation, PO_4-P decrease about 0.60 kg/day in Masuma reservoir in July 1986 to compare with in July 1985. This calculated value is almost equal to the observed value. Although this is roughly estimation, it is recognized that the decrease of PO_4-P after circulation mainly depends on decrease of PO_4-P release rate from the bottom sediment.

4. Conclusion

To assess the effect of artificial lake circulation techniques, field survey and experiment were done in Masuma reservoir before and after circulation period. Conclusions were listed bellow :

1) It has be demonstrated that remarkable decrease of PO_4-P in the reservoir is about 0.6 kg/day less than before circulation.
2) The field survey and laboratory experiment showed that decrease of PO_4-P is mainly caused by adsorption of the bottom sediments.
3) According to artificial circulation, T-P is not decreased though PO_4-P is decreased. That indicates a possibility of appearence increasing T-P in water body. This tendency is considerated to depend on fine SS rolling up from bottom sediment caused by lake circulation.

5. References

1) M. Symons et al ; " Artificial Destratification in Reservoir ", A Committee Reports, J.A.W.W.A.,1971,2
2) L. Bergtsson, G. Gelin ; " Artificial Aeration and Sunction Dredging Method for Controlling Water Quality ", Proceeding of a Symposium, The Effect of Storage on Water Quality, 1975, pp.313 - 341

THE DEVELOPMENT OF POLYETHYLENE WARM WATER PIPES FOR MODERATE TEMPERATURES.

by :

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STUDSVIK ENERGITEKNIK AB

STUDSVIK/EX-87/38F

1987-06-01

NESTE-4531/4650

Neste Polyeten AB

ABSTRACT

This project is a direct continuation of a previous study aimed at developing and evaluating a new grade of polyethylene from Neste Polyeten AB. The pipe material is intended for applications mainly with warm water at temperatures between 30 and 60°C. In all more than 270 pipes have been tested during the project at 105, 95, 80, 70, 60, 40 and 20°C. There are 35 specimens still being tested; the longest test still running has lasted 75 000 hours (8.6 years). The results to date are very good. Based on the present results a life of more than 50 years is estimated at a dimensioning stress of 5 MPa at 45°C.

LIST OF CONTENTS

- * DGDS-0909 has excellent environmental stress cracking resistance. (ESCR).

- * DGDS-0909 has very good resistance to chemicals.

What is DGDS-0909 and how can its advantages be used for potable water?

DGDS-0909 is a black, improved medium density polyethylene (MDPE) compound (Fig. 5). The extrusion conditions and behaviour are like a normal MDPE grade, but the resistance against surface oxidation under extrusion is outstanding. DGDS-0909 is weldable to all other normal polyethylene pipe materials.

Higher allowable design stress at elevated temperatures gives higher hydraulic capacity for a -0909-pipe of given outer diameter as a thinner wall can be accepted than for standard polyethylene. The other way around, - with a given diameter and wallthickness -, higher hydraulic capacity is obtained as higher pressure can be used (Fig. 6).

This advantage can be illustrated by giving two examples where DGDS-0909 is compared to a standard high density polyethylene (Fig. 7-8).

DGDS-0909 has up to now been used in several industrial projects where the advantages of high design stress/thin pipe walls at elevated temperatures as well as the excellent resistance to stress cracking and chemicals have been utilized. Some of these project are (Fig. 9):

- Industrial pipes (up to Ø 1200 mm)
- Ground heating
- Floor heating
- Greenhouse heating
- Pipe systems in chemical storage facilities
- Energy storage.

Next projects are (Fig. 10):

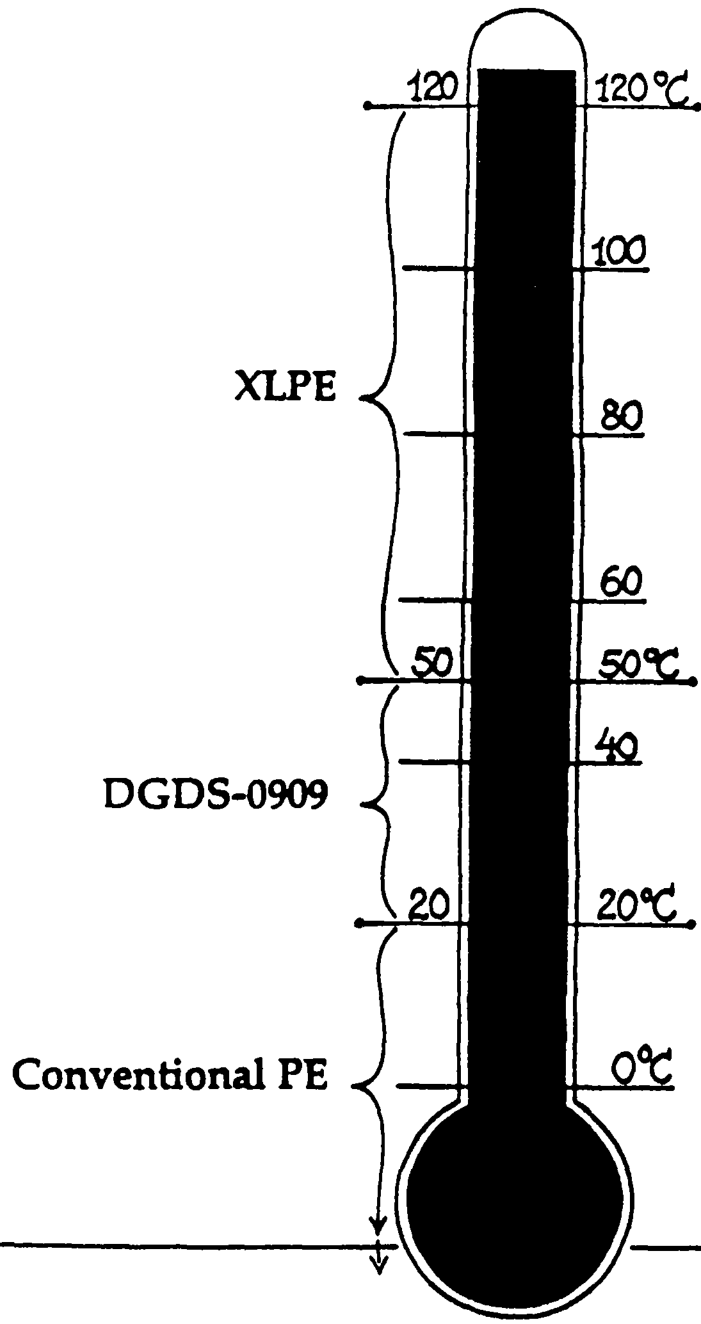
- Fresh water supply in Middle East desert
- Pipe systems in chemical industries
- Solar heat collector
- Combined cooling and heating of ground.

Therefore we take this opportunity to address to the Water -87 conference the following message: Polyethylene, used for potable water, was previously restricted to the design temperature of 20 °C. This restriction can now be overcome by using the -0909-type polyethylene, which will certainly be of great assistance for all people involved in the planning and installation of pipe systems for potable water.

It is also important to note that DGDS-0909 fulfills the requirements for polyethylene in contact with potable water published e.g. in Belgium, Switzerland and West Germany.

The given examples are just a few to illustrate different ways of using the benefits given by -0909. Our development work will continue as the development of DGDS 0909 is just another step, but a very significant one, in Neste's continuous efforts to develop improved materials for the pipe industry.

WORKING TEMPERATURES FOR DIFFERENT MATERIALS



PRESSURE DE-RATING FOR PE-PIPES
ISO/DP 4427

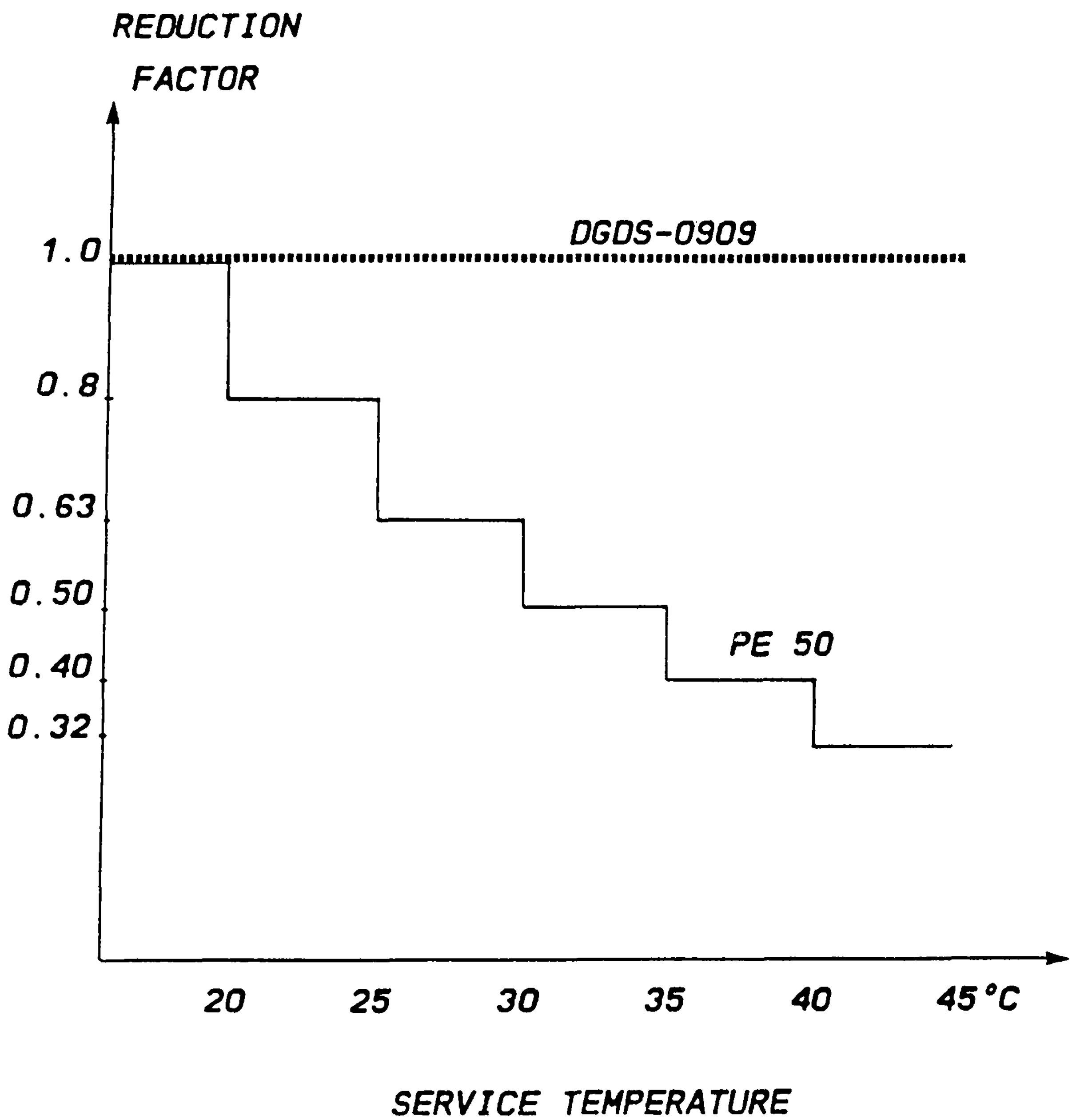


FIGURE 5

PROPERTIES OF DGDS-0909

PROPERTY	TYPICAL VALUE	TEST METHOD
MELT FLOW INDEX, 5 KG	0.6 G/10 MIN.	ISO 1133, COND 18
DENSITY, NOMINAL	934 KG/M^3	ISO 1872, ANNEX A
REFERENCE	941 KG/M^3	ISO 1872, ANNEX B
CARBON BLACK CONT.	> 2 %	ASTM D 1603
MELTING POINT	124 °C	DSC
THERMAL STABILITY, (OIT)	> 40 MIN	ISOTHERMAL IN OXYGEN AT 210 °C
TENSILE STRENGTH AT YIELD	17 MPA	ISO/DIS 6259
ULTIMATE ELONGATION	> 600 %	ISO/DIS 6259
ESCR F_{50}	> 1000 H	ASTM D1693 COND A
CREEP MODULUS, E0 (20 °C)	600 MPA	
(50 °C)	250 MPA	

ALLOWED WORKING PRESSURE IN BAR FOR PIPE SIZE PN 10

WORKING TEMPERATURE DEGREES CELSIUS	WORKING PRESSURE BAR	
	HD OR MDPE (PE 50)	DGDS 0909
< 20	10	10
(20) - 25	8	10
(25) - 30	6.3	10
(30) - 35	5	10
(35) - 40	4	10
(40) - 45	3.2	10

EXAMPLE OF HDPE VERSUS DGDS-0909

GIVEN DATA

BORE: MINIMUM	60 MM
WORKING PRESSURE	8 BAR
WORKING TEMPERATURE	30-35 DEGR C
EXTRUDER OUTPUT	200 KG/H

	HD OR MD (PE50)	DGDS-0909
REDUCTION FACTOR FOR HIGH TEMP	0.5	1
CLOSEST SIZE DESIGNATION OF PIPE	PN 16	PN 10
INNERDIAMETER OF PIPE MM	65.4	61.4
OUTER DIAMETER OF PIPE MM	90	75
WEIGHT OF PIPE KG/KM	3050	1490
EFFECTIVE EXTRUSION TIME H/KM	15.25	7.45
RELATIVE MATERIAL CONSUMPTION	100%	49%
RELATIVE EXTRUSION RATE	100%	205%

EXAMPLE OF HDPE VERSUS DGDS-0909

GIVEN DATA

BORE: MINIMUM	110 MM
WORKING PRESSURE	4 BAR
WORKING TEMPERATURE	40 - 45 DEGR C
EXTRUDER OUTPUT	200 KG/H

	HD OR MD (PE50)	DGDS-0909
REDUCTION FACTOR FOR HIGH TEMP	0.32	1
CLOSEST SIZE DESIGNATION OF PIPE	PN 16	PN 4
INNERDIAMETER OF PIPE MM	116.2	110.8
OUTER DIAMETER OF PIPE MM	160	125
WEIGHT OF PIPE KG/KM	9590	2700
EFFECTIVE EXTRUSION TIME H/KM	48	13.5
RELATIVE MATERIAL CONSUMPTION	100%	28%
RELATIVE EXTRUSION RATE	100%	356%

FIGURE 9

DGDS-0909 PROJECT EXAMPLES

1. INDUSTRIAL PIPES:

   - COOLING WATER OUTLET FROM A NAPHTA CRACKER
     (Ø 1000 MM; PN 3.2 MPA; WORKING TEMPERATURE 50 °C)

   - WASTE WATER TUBE FROM A PULP INDUSTRY
     (Ø 1200 MM; PN 3.2 MPA; 4000 M LONG;
     WORKING TEMPERATURE 30 °C; PEAK TEMPERATURE 45-50 °C)

2. GROUND HEATING:

   - HEATING OF FOOTBALL GROUNDS (FOR EXAMPLE PART OF A LOW TEMPERATURE DISTRICT HEATING SYSTEM)

   - HEATING OF PAVEMENTS AND STREETS (MELT-AWAY)

3. FLOOR HEATING:

   - LOW TEMPERATURE SYSTEMS (UP TO 50-60 °C)

4. GREENHOUSE HEATING:

   - GROWING OF VEGETABLES (PEAK TEMPERATURE 70 °C)

5. CHEMICAL STORAGE:

   - DEPOSITION OF CHEMICALS (VERY GOOD PROPERTIES AFTER SEVERAL YEARS IN USE)

6. ENERGY STORAGE:

   - STORAGE OF ENERGY IN GROUND ("SUNSTORE" METHOD)

FIGURE 10

DGDS-0909 NEW PROJECTS

1. FRESH WATER SUPPLY

   - SUBTROPICAL AND TROPICAL AREAS
     WATER TEMPERATURES UP TO 35-40 DEGREE °C

2. CHEMICAL INDUSTRIES

   - PULP INDUSTRIES; HEAVY CHEMICAL INDUSTRIES
     (TRANSPORTATION OF CHLORINATED HYDROCARBONS ETC)

3. SOLAR HEAT COLLECTOR

   - HEATING OF SWIMMING POOLS

4. COMBINED COOLING AND HEATING OF GROUND

   - ICEHOCKEY RINKS IN WINTER / FOOTBALL GROUNDS IN
     SUMMER

COAGULATION CHARACTERISTICS OF POWDERED ACTIVATED CARBON SUSPENSIONS AND ITS EFFECTS IN THE EUTROPHIC WATER RESOURCES

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1. INTRODUCTION

According to the eutrophication of water resources, water treatment plants take an emergency treatment with addition of powdered activated carbon in order to remove taste and musty odor. Using such water resources, coagulation hindrance have sometimes been occurred by algal extracellular organic matter (EOM).

The purpose of this study is to investigate the coagulation characteristics of powdered activated carbon by jar test. Some coagulation factors, i.e., coagulant type (aluminium sulfate and poly aluminium chloride; PAC), particle initial concentration, pH, zeta potential and floc density, are discussed for illustrating coagulation characteristics of powdered activated carbon in comparison with kaolinite.

Furthermore, EOM of Chlorella sp., which is incubated by using modified M-11 culture medium, is separated by gel-chromatography (Sephadex G-25) in order to evaluate the coagulation hindrance. Then , effect on the coagulation of EOM was discussed in the case of addition of powdered activated carbon.

2. MATERIALS AND METHODS

Samples of powdered activated carbon used in this study were two types. One was powdered activated carbon used in the water treatment plant near Sendai. Other was powdered activated carbon producted by different activation temperature during manufacture process.

Characteristics of these powdered activated carbon is shown in Table 1.

On the other hand, kaolinite was employed in order to compare with powdered activated carbon. As powdered activated carbon had very wide particle size distribution, pre-treatment of suspension(70l) with 3 hours sedimentation was carried out and supernatant zone of suspension (20l) was used for experiments.

Table 1 Characteristics of Powdered Activated Carbon

Sample No.	Activation Temperature (°C)	Adsorption Potential of Methylene blue (mg/g)	Adsorption Potential of Iodine (mg/g)
1	900	140	990
2	1000	175	1060
3	1100	230	1148
4	Standard	200	-

* No.1,2,3 from the same manufacture
* No.4 used in a water treatment plant

Table 2 Modified M-11 Culture Medium

Component	(mg/l)
$NaNO_3$	100
K_2HPO_4	10
$MgSO_4$ $7H_2O$	75
$CaCl_2$ $2H_2O$	40
Na_2CO_3	20
Fe-citrate	6

Then, pH, total alkalinity and SS of this supernatant sample was 9.6-10.0, 100-120 mg/l, 450-660 mg/l, respectively. But in the case of kaolinite, pretreatment was not carried out. Average particle size of powdered activated carbon and kaolinite were 2.5μm, 2.0μm, respectively (Coulter Counter Method).

A series of jar test was performed with a constant coagulant dosage and varied pH method. Sample volume of jar test was 1 liter. The total alkalinity(50 mg/l) with $NaHCO_3$ and 0.1N HCl or NaOH were added to the suspension before jar test predicting the pH after coagulation.

A jar test procedure consisted of rapid mixing(5min, 100rpm), slow mixing(15min, 40rpm) and quiescent sedimentation (10min). After the sedimentation, a 200ml supernatant sample was carefully taken and pH, total alkalinity, turbidity were measured. Also the zeta potential of particles or floc was measured with particle micro-electrophoresis apparatus (RANK BROTHERS Mark II).

All chemical solution and suspension were prepared with distilled water. Coagulants used in this study were aluminium sulfate(Alum: $Al_2(SO_4)_3$ $16H_2O$) and poly chloride aluminium(PAC).

Fig.1 shows the equipment of floc sedimentation for analysis of floc effective density. The volume of mixing sample is one liter and is same size and shape of one liter beaker in jar test. In this experiment, rapid and slow mixing procedure is the same in jar test. By keeping slow mixing, floc was settled in the sedimentation tube and the settling velocity and

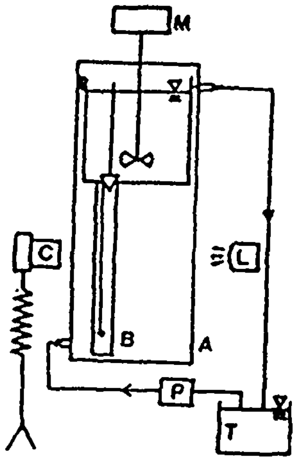


Fig.1 Diagram of floc effective density apparatus

size of floc were measured with stereo-microscope and camera.
All experiments were carried out in the constant temperature room (20+2° C).

Algae used in this study was Chlorella sp. which was isolated from the Kamafusa reservoir near Sendai. Chlorella sp. was incubated with modified M-11 culture medium without EDTA. Incubation condition are as follows: incubation temperature was 25° C, illumination was 2500 lux and mixing was performed by a magnetic stirrer. In order to evaluate algae growth, SS, chlorophyll-a and TOC were measured.

In gel-chromatography, glass tube (I.D.= 2.6cm, height = 90 cm) and sephadex G-25 were employed. A culture medium of each incubation stage was filtrated by 0.45 μm membrane filter. Sample volume, which was concentrated 25 times by a freezing concentration method, was 10 ml and flow rate was 75 ml/hr. Elution was carried out with distilled water up to 60 fractions (600 ml elution volume). From the results of TOC and E260 of each fractions, EOM was separated into organic compounds differing in molecular size and shape.

A mixed elution sample, which was mixed by contineous two fractions , was made in order to investigate a coagulation hindrance of EOM to suspension. A kaolinite suspension of 20mg/l was made by using this mixed elution sample. Zeta potential of this kaolinite suspension was measured by the method described above.

3. RESULTS AND DISCUSSIONS

3.1 ZETA POTENTIAL OF POWDERED ACTIVATED CARBON

An effect of activation temperature on zeta potential of powdered activated carbon is shown in Fig.2. Zeta potential of the highest activation temperature is higher than that of other low activation temperature, and shows positive value in pH range lower than 5.5.

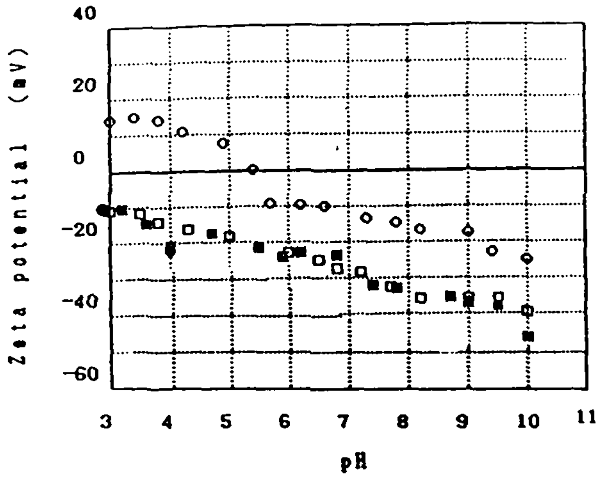


Fig.2 pH vs. zeta potential (activation temperature ○=1100°C, □=1000°C, ■=900°C)

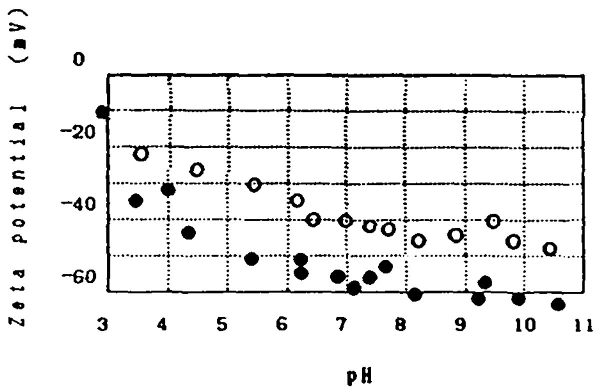


Fig.3 Zeta potential vs. pH (●=powdered activated carbon, ○=kaolinite)

Also, zeta potential of powdered activated carbon varies on the manufacturing process, such as, water washing, acid washing and neutralization. From the results of our study , zeta potential decreased by water washing process and more decreased by acid washing and neutralization process.

A reason of this results is the effect of the inorganic salts or the oxide on surface of powdered activated carbon, such as functional surface groups. Phenolic radical and carboxyl radical are confirmed as one of functional surface groups. It is assumed that the reason why zeta potential shows positive value in the low pH range is caused by the reduction of the dissociation of carboxylic acid and phenol. Powdered activated carbon contains not only the crystallite complex but also non-crystallite complex which shows high reaction and is easily oxidized, and these are formed in manufacturing process . These chemical compounds and quantity are varied with activation temperature and its raw materials etc.

Fig.3 shows zeta potential of kaolinite suspension and powdered activated carbon suspension used in water treatment plant. Zeta potential of powdered activated carbon(-50 to -60mV) is lower than that of kaolinite(-30 to -40 mV) in general pH region of water treatment process.

3.2 COAGULATION CHARACTERISTICS OF POWDERED ACTIVATED CARBON

(1) EFFECT OF pH AND COAGULANT TYPE

Fig.4 shows the typical data of zeta potential and residual turbidity percentage of powdered activated carbon used in water treatment plant at each pH in the case of aluminium sulfate(Alum) as coagulant.

The pH range of optimum coagulation was about from 6 to 7 owing to charge neutralization of particles and bridging action of aluminium hydroxide. Re-stabilization about pH 5 is mainly caused by an excess positive charge of particle owing to tetravalent polynuclear species . Coagulation below pH 4 is caused by charge neutralization owing to trivalent aluminium ion.

Fig.5 shows typical coagulation pattern in the case of PAC as coagulant. The coagulation pH zone of PAC became wider than that of Alum.

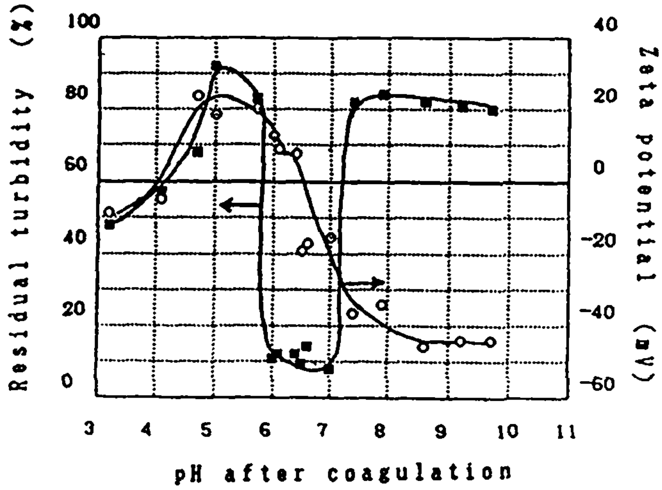


Fig.4 pH vs. residual turbidity and zeta potential (powdered activated carbon C_0=50 mg/l, Alum=40 mg/l)

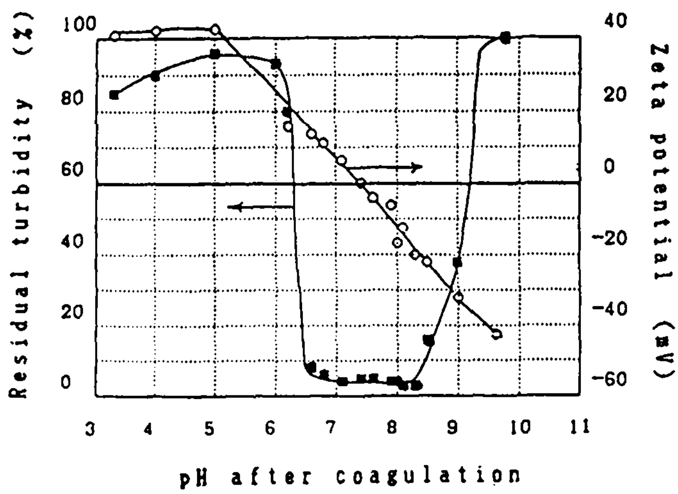


Fig.5 pH vs. residual turbidity and zeta potential (powdered activated carbon C_0=50 mg/l, PAC=40 mg/l as Alum)

(2) COMPARISON OF COAGULATION CHARACTERISTICS BETWEEN POWDERED ACTIVATED CARBON AND KAOLINITE

Fig.6 shows the coagulation patterns of powdered activated carbon and kaolinite suspension of Co=20mg/l in the case of Alum. The coagulation pH zone of powdered activated carbon is lower than that of koalinite in the case of the same initial concentration .

Zeta potential range of optimum coagulation of powdered activated carbon is from -10 to +10 mV and it is almost the same of kaolinite. Although pH of isoelectric point(zeta potential=0)of kaolinite is almost constant with increasing dosage of Alum, that of powdered activated carbon become large from 6 to 7 in the range of this study.

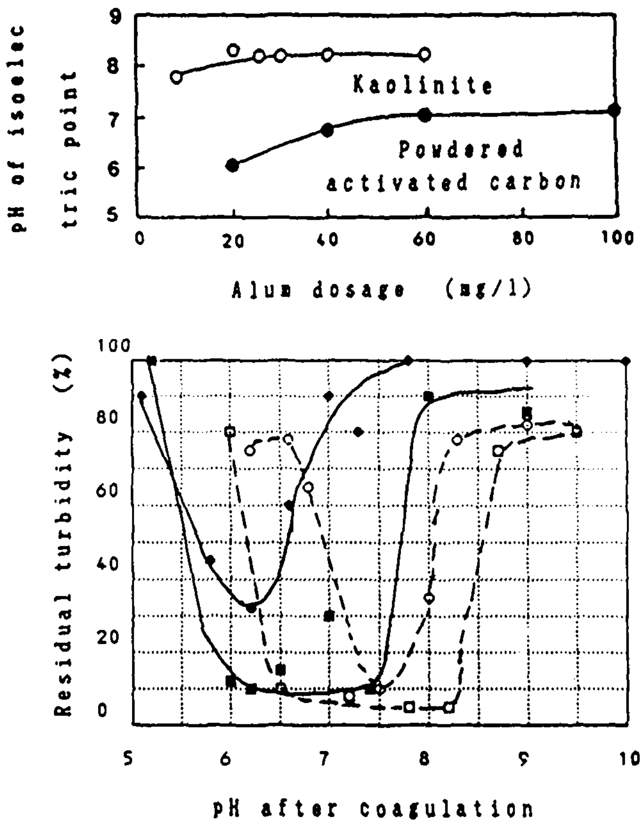


Fig.6 Coagulation charactristic vs. particle type (C_o=20 mg/l)

Alum (mg/l)	20	60
Powdered activated carbon	●	■
Kaolinite	○	□

It is assumed that one of the reason is the difference of Cation Exchange Capacity(CEC) between two samples. The value of CEC of kaolinite is 1.3 meq/100g and that of powdered activated carbon is 62 meq/100g. Gupta reported that when CEC became large, pH of isoelectric point decreased.

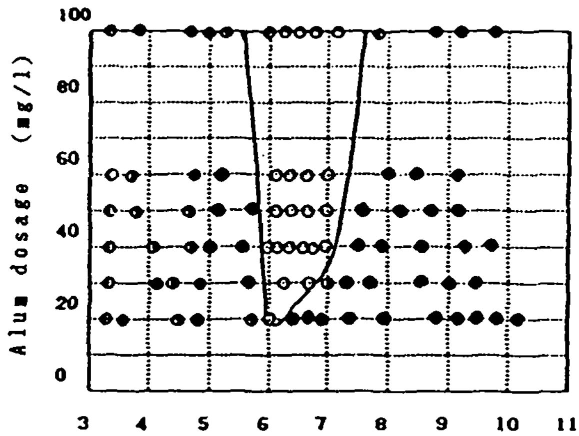
From these results, it is assumed that a surface activity of kaolinite, which has small CEC value, is not affected with the change of pH.

(3) COAGULATION MAP OF POWDERED ACTIVATED CARBON

Fig.7 shows the coagulation map of powdered activated carbon of Co=50mg/l in the case of Alum. The coagulation pH zone, which is defined here as residual tuabidity percentage below 30%, shows a tendency to shift to alkali zone with increasing dosage of coagulant.

Then, the range of zeta potential of residual turbidity percentage below 30% shows from 10 mV to -12 mV in the pH range of general water treatment(pH 5.8-8.6).

As shown in Fig.8, the coagulation pH zone of PAC defined above becomes wider than that of Alum. In each case, the coagulation pH zone have a tendency to shift to alkali zone. Consumption of total alkalinity of PAC is smaller than that of Alum. PAC has a high basicity and forms aquocomplexes ion in water, so PAC has a strong bridging action owing to



pH after coagulation

Fig.7 pH zone of coagulation vs. Alum dosage (powdered activated carbon C_o=50 mg/l)

Residual turbidity

○ 0-30 % ◐ 30-50 % ◑ 50-70 % ● 70-100%

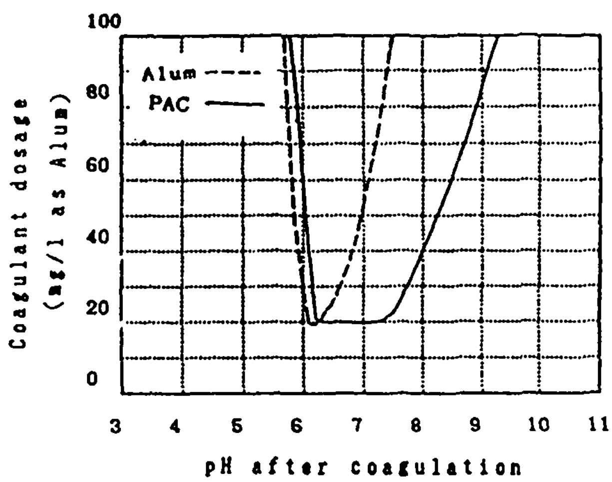


Fig.8 pH zone of coagulation vs. coagulant type (powdered activated carbon C_0= 50 mg/l)

formation of polymer complexes by using OH radical for bridging.

Fig.9 shows the relation between the coagulation pH zone described above of different initial concentration of powdered activated carbon(Co=20-200mg/l) and Alum dosage(20-200mg/l). The coagulation pH zone shows a tendancy to shift to acid zone with increasing initial concentration of powdered activated carbon, and becomes narrow and slightly shifts to acid zone in comparison with inorganic suspension such as kaolinite suspension.

From these results, in the case of removal of powdered activated carbon suspension, it is easy to use PAC as coagulant. Also, it is necessary to care the pH control in using Alum as coagulant.

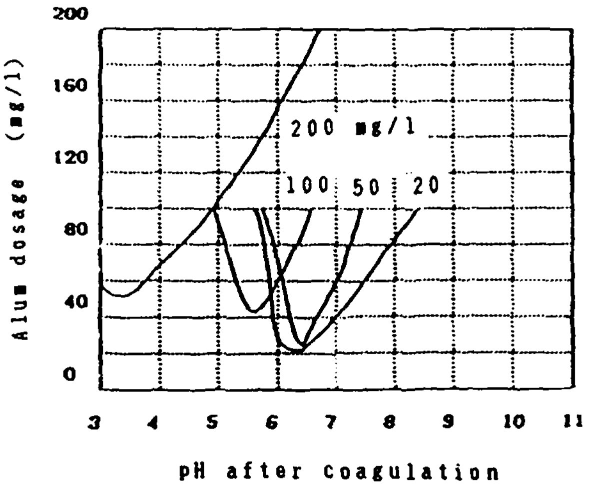


Fig.9 pH zone of coagulation vs. powdered activated carbon concentration
The values in Fig. are powdered activated carbon concetraion

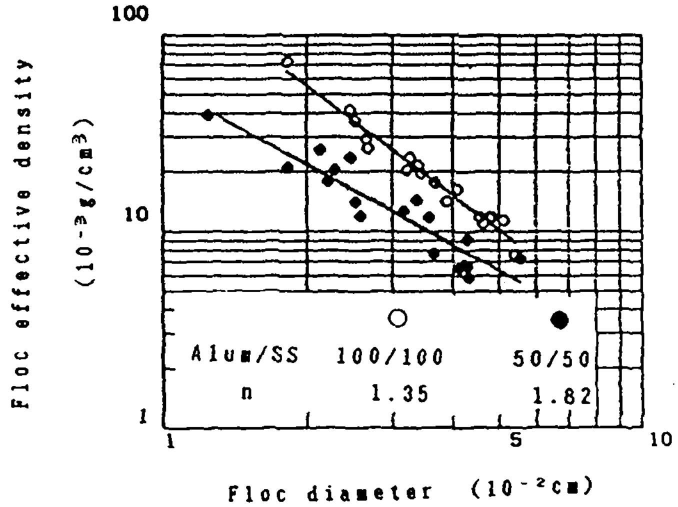


Fig.10 Floc diameter vs. floc effective density (Alum, powdered activated carbon, pH=6.5)

(4) FLOC DENSITY FUNCTION OF POWDERED ACTIVATED CARBON

Floc density function, which was based on stoke's law and proposed by Tambo, was expressed as, $\rho_e = ad^{-n}$. Here , ρ_e and d are floc effective density and floc equivalent diameter, respectively. Also, n and a are *constants depending on coagulation conditions.*

Fig.10 shows the result of floc formed by the same Alum/SS ratio which is defined as the ratio of Alum dosage to powdered activated carbon concentration. It showed that for the same Alum/SS ratio, the floc effective density decreased with increasing dosage of coagulant . This result was similar to some studies.

Moreover, from the results of floc formation under C_0 =50 mg/l and coagulant dosage 50-200 mg/l, the floc formed by PAC made a rapid formation and had larger floc diameter of 400-2000 µm than that of 250-700 µm formed by Alum. Also, the n values of powdered activated carbon were 1.6-1.8(Alum) and 1.3-1.8(PAC). The high n value of powdered activated carbon was near that of activated sludge floc.

3.3 COAGULATION HINDRANCE IN EUTROPHIC WATER RESOURCES

(1) GEL-CHROMATOGRAPH OF EOM

Fig.11 shows the growth curve of Chlorella sp. As shown in Fig.11, we used the culture medium after 24days which was exponential growth phase, and that after 84 days which was death phase. Fig.12 shows the gel-chromatogram of EOM of exponential growth and death phase and the zeta potential of kaolinite in each mixed fraction elutions.

Here, in the case of gel-chromatogram in this study, fraction No.19 is the peak of blue-dextran(molecular weight 2 millions), fraction No.39 is the peak of Vitamin B12(molecular weight 1350).

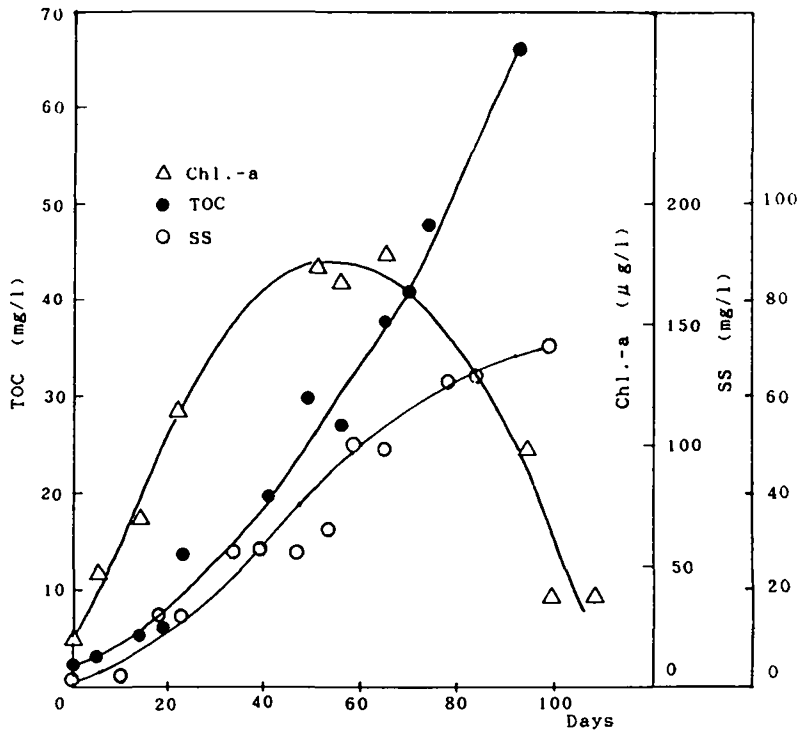


Fig.11 Variation of TOC, SS and Chlorophyll-a during the life stage of chlorella sp.

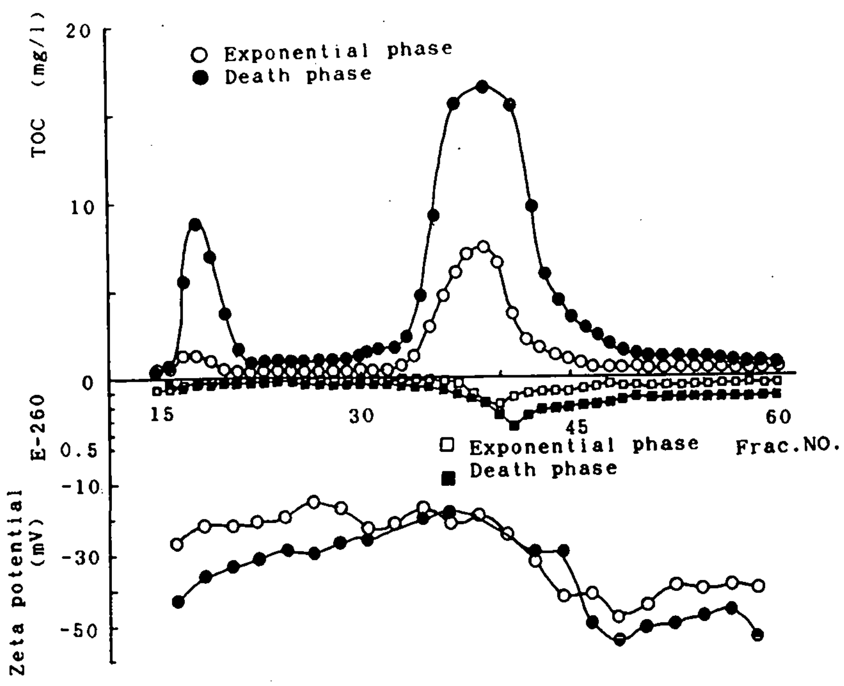


Fig.12 Gel-chromatogram of chlorella sp. at exponential growth phase and death phase and zeta potential of kaolinite in elution sample

(2) EFFECT OF EOM ON COAGULATION

Assuming that the zeta potential at the fraction No.19 is base value, EOM up to about fraction No.40 has a tendency to neutralize the charge of kaolinite, and EOM over fraction No.40 has a tendency to decrease the charge of kaolinite in both phase.

In the range of this study, the zeta potential of kaolinite in death phase showed more negative charge than that of growth phase for each fraction number. Tambo reported that organic materials of low molecular weight below 1500 is difficult to remove by coagulation process. So, in death phase, EOM of low molecular weight increases, it is clear that it is necessary to use much coagulant.

On the other hand, Bernhardt reported that EOM of Dictyosphaerium sp. had the ability of anionic-coagulant aids. EOM of Cholrella sp. used in this study, showed a same ability to react as a polymer described above in the coagulation test used by kaolinite suspension.

From these results, in eutrophic water resources, where powdered activated carbon have to use, there is a positive and negative effect of EOM to suspension such as powdered activated carbon.

The addition of powdered activated carbon for removal of taste and musty odor can also adsorb low molecule of EOM and reduce not only the trihalomethane formation derived by pre-chlorination but also the coagulation hindrance for suspended substances.

4. CONCLUSION

The conclusions of this study are summarized as follows:

1. Activation temperature and pH have a significant effect on zeta potential of powdered activated carbon. High activation temperature of powdered activated carbon has high zeta potential value.

2. Zeta potential of powdered activated carbon used in water treatment plant shows from -50 to -60 mV and it is lower than that (-30 to -40 mV) of kaolinite. Zeta potential of powdered activated carbon varies because of the hydrophobic difference according to activation condition and adsorption or desorption of salts owing to functional surface groups of powdered activated carbon.

3. With an increase in the amount of coagulant (aluminium sulfate), pH of isoelectric point of powdered activated carbon varies from 6.0 to 7.2 in the case of same initial concentration (Co=20 mg/l), and that of kaolinite shows constant value (about 8.2). In the case of low initial concentration of powdered activated carbon (Co =20mg/l), pH region for coagulation is from 6.0 to 8.2, but in the case of high initial concentration (Co=200 mg/l), it is from 5.0 to 6.3. From these results, pH adjustment is a very important operation for coagulation of powdered activated carbon.

4. The critical zeta potential for coagulation of both particles is about from +10 to -12 mV in the case of aluminium sulfate. PAC is more suitable coagulant for removing powdered activated carbon, because of having wider pH zone for coagulation than that of aluminium sulfate.

5. Floc effective density decreases with increasing Alum/SS ratio. PAC makes floc which is large and has rapid settling velocity than aluminium sulfate, but floc effective density is small. The n values of powdered activated carbon floc shows 1.3 to 1.8 and its high n values is about the same value of activated sludge floc.

6. The results of gel-chromatogram of culture medium of Chlorella sp. shows that EOM almost consists of the low molecular weight (M.W.=1500) at exponential growth phase and death phase. Molecular weight lower than 1500 increases the negative charge of zeta potential of kaolinite. On the other hands, this negative charge sometimes behaves like anionic coagulant aids effect and EOM acts like as polymer to accomplish interparticle bridging and improves the coagulation efficiency.

7. The addition of powdered activated carbon for removal of taste and musty odor can also adsorb low molecule of EOM and reduce not only the trihalomethane formation derived by pre-chlorination but also the coagulation hindrance for suspended substances.

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ODORS CONTROL OF CHENG CHING LAKE WATER TREATMENT PLANT IN TAIWAN

by :

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INTRODUCTION

The water from the lake of Cheng Ching has a notorious oder problem, especially in summer since 1976. In recent years, water consumers in Kaohsiung area have kept on complaining of "peculiar odor" of drinking water which is supplied by Cheng Ching Lake water treatment plant. Thus the Graduate Institute of Environmental Engineering, National Cheng Kung University, has conducted a series of survey from July 1981 to June 1983 to find the source of odor in the lake of Cheng Ching. Results from the survey have clearly indicated that the water odor generated from the lake of Cheng Ching was obvious and happened to be seasonal through those two years. The average threshold odor number (TON), an expression of water odor, increased from 12.8 $\pm$ 2.3 in 1982 to 20 $\pm$ 11 in 1983. It is worth noting that the TON of lake water was as high as 56 in July 1982.[1][2] As a result, people in Kaohsiung area could hardly bear the increasing odor from lake water, particularly in musty odor occurring season. Therefore, it is extremely urgent to thoroughly mitigate the odor problem of the water of Cheng Ching Lake.

Silvey[3][4] and Peskator[5] have pointed out that a conventional water purification process could not effectively destroy the odor of raw water except being incorporated with other chemical treatment methods. Thus coagulants including alum, ferric chloride and ferrous sulfate, chemical oxidants including potassium permanganate and sodium hypochlorite, and powdered activated carbon were used in this study to resolve the effective and feasible treatment scheme for removing the odor from lake water. The finding based upon this study would provide, both the authorities of Cheng Ching Lake water treatment plant and some other water purification plants which have the similar odor problem, with a cost-effective strategy for the improvement of water quality.

MATERIALS AND METHODS

Experimental Apparatus

Coagulation Reactor Set-up. Besides the jar test device, a coagulation reactor set-up, shown in Fig.1, that could indicate the rotating speed and torque, was used. The plexiglass reactor with the size of ϕ30cm × L 46cm used in the coagulation study was implemented with six pieces of baffles with the size of 30cm × 30cm.

Rapid Sand Filter Set-up. Rapid sand filter with the size of ϕ26mm× L 500mm was installed together with headloss meter and others, as shown in Fig.2. The filter media used in this study were taken from Cheng Ching Lake water treatment plant. The specification and layout of lab-scale rapid sand filter including media depth, effective size, uniform coefficient and specific gravity are listed in Table 1.

TABLE 1. Media depth, effective size, uniform coefficient and specific gravity of filter media in lab-scale rapid sand filter

Filter media	Depth cm	Effective size mm	Uniform coefficient	Specific gravity
Anthracite	15	0.7	< 1.6	1.45
Sand	11	0.55	< 1.5	2.60
garnet	3	0.2 ± 0.05	< 1.5	2.60
garnet	3	1.85 ± 0.05	< 1.5	4.00

In addition to the above experimental set-up, the water bath, ultra-violet and visible light spectrophotometer were also used in this study.

Experimental Methods

The test water used in this study was taken from Cheng Ching Lake and its water treatment plant. Jar test incorporated with the measurement of odor was mainly used to determine the effectiveness of various chemicals, powdered activated carbon and several water purification processes for the removal of water odor.

Measurement of Odor. The measurement of water odor was according to the U.S. Standard Methods for the Examination of Water and Wastewater.[6]

Selection of Odor Examiner. Various concentrations of the solvent of n-butanol were prepared as the odor standard. Every candidate of odor examiner was tested by using his own nose to detect the odor. In so doing, candidates who failed to well sense the odor would not be selected. After several times of tests, it was found that the female students have a better sensibility of odor than male students. In addition, the non-smoker was more sensitive to odor than the smoker. Finally, five female students and one male student were chosen to carry out the task of the measurement of odor through the entire studies. Meanwhile, at least four persons were appointed to measure the water odor in each test. All the test results were obtained by repeating at least twice of measurement.

Lab-scale Operation and Analyses. In the entire lab-scale studies, Cheng Ching Lake water was served as the raw water sample and finished water collected from the effluent of rapid sand filter of Cheng Ching Lake water treatment plant was served as the clean water sample or the afore-said two different kinds of water samples were mixed with the synthetic water of high-strength odor to proceed various types of unit operation for water purification. Meanwhile, the water quality of treated waters was analyzed.

Chlorination of raw water. Two sets of 250 ml flasks filled with adequate amounts of raw water into which sodium hypochlorite was added and followed by vigorously mixing to allow 30 minutes of contact time. Thus far two sets of samples were immediately removed, one set was using DPD colorimetric method to determine the chlorine residual, the other set was therefore adding equivalent amounts of 0.025 N sodium thiosulfate to destroy the chlorine residual prior to the measurement of odor.

Conventional water purification treatment.
Coagulation-sedimentation. Firstly a series of jar tests were conducted to determine the most effective coagulant, its optimum pH and dosage for the removal of water odor. Then batch coagulation studies were proceeded according to the operating conditions listed in Table 2. In this study, the supernatant which has been treated by rapid mix, slow mix and sedimentation was siphoned into glass storage tank. At this thime, the turbidity and TON of supernatant were analyzed. Besides the supernatant was also used as the test water of lab-scale rapid sand filtration.

TABLE 2. Operating conditions of batch coagulation studies ($G=0.328N^{1.475}sec^{-1}$, Settling time=96min, Temp.=20°C)

	Rotating speed N rpm	Gradient G sec^{-1}	Time min.
Rapid mix	150	530	1
Slow mix	25	38	30

Rapid sand filtration. The supernatant obtained from the coagulation test was pumped into the upper-end of constant-head water tank of lab-scale rapid sand filter by one metering pump. Meanwhile, the other metering pump, installed under the rapid sand filter, was carefully controlled at constant speed of 450 m/day to proceed the filtration run. The filtrate was then sampled at designated time interval and its water quality and head loss were respectively determined and recorded.

Chlorination of clean water. The experimental procedure of the chlorination of clean water was the same as "chlorination of raw water" except that the test water used in this particular study was taken from finished water of rapid sand filter of Cheng Ching Lake water treatment plant.

Potassium permanganate treatment. Several beakers were respectively filled with 500 ml of raw water into which both the optimum dosage of alum determined by coagulation-sedimentation tests and various concentrations of $KMnO_4$ were added. Then the experiment which is similar to the procedure of jar test proceeded. In this study, all test samples were filtered by 0.45 μ filter papers prior to the measurement of TON. In addition, various concentrations of $KMnO_4$ were added into several beakers which were filled with raw water, allowing 30 minutes of slow mix with a rotating speed of 25 rpm. Then samples were taken and filtered by 0.45 μ filter papers. And the optimum dosage of $KMnO_4$ was determined by measuring TON of every filtered sample. Later the effectiveness for the removal of odor by incorporating the treatment of $KMnO_4$ with that of powdered activated carbon was accomplished by the pretreatment of $KMnO_4$ under the optimum dosage, followed by the treatment of alum alone or together with powdered activated carbon.

Powdered activated carbon treatment. Six beakers were respectively filled with 500 ml of raw water into which both the optimum dosage of alum determined by coagulation-sedimentation tests and various amounts of powdered activated carbon were added. Then the experiment which is similar to the procedure of jar test proceeded. In this study, all test samples were filtered by Whatman's No.2 filter papers prior to the measurement of TON. The appropriate amount of powdered activated carbon required for meeting the water quality standard was determined by measuring TON of every filtered sample.

RESULTS AND DISCUSSION

Removal of Water Odor by Lab-scale Water Purification Treatment

Chlorination of Raw Water. When there was a musty odor in the raw water, the initial TON could be reduced to one-half by proper chlorination as shown in Figs.3. If TONs of raw waters was 25, the chlorine dosages required for reducing odor to a treatable degree were 7.14 mg/l. When there was a fishy odor in the raw water, the TON of raw water would decrease with increasing dosage of chlorine as indicated in Fig.4.

Coagulation-Sedimentation Test.

Alum($Al_2(SO_4)_3 \cdot 18H_2O$). The removal efficiency of fishy odor was 33% at the alum dosage of 15 mg/l while the pH values ranged from 5 to 9, as indicated in Fig.5. In Fig.6, the removal efficiency of fishy odor was 50% at the alum dosage between 20 and 35 mg/l; that is, the TON of raw water declined from 12 to 6. However, alum was not effective for the removal of musty odor. Based upon the above finding, it is worth pointing out that fishy odor is rather easier to be removed than musty odor when alum is used as a coagulant.

Ferric chloride ($FeCl_3 \cdot 6H_2O$). Fishy odor could not be removed by varying coagulant dosages of ferric chloride as shown in Fig.7.

Ferrous sulfate ($FeSO_4 \cdot 7H_2O$). Fishy odor could not be removed by varying coagulant dosages of ferrous sulfate as shown in Fig.8. On the contrary, the odor (metal odor) tended to be intensified by adding ferrous sulfate.

In summary, alum was more effective than both ferric chloride and ferrous sulfate for removing water odor. Meanwhile, alum is currently being used as a coagulant in Cheng Ching Lake water treatment plant; so the alum was chosen to proceed the following coagulation tests.

Prechlorination incorporated with coagulation test. When raw water was treated by coagulation following prechlorination, as indicated in Figs.9,10, the input of chlorine in raw water could not only remove the odor from raw water but also enhance the process of coagulation resulting in the improvement of the odor removal. In Fig.10, the TON of raw water declined from 25 to 3 when the chlorine dosage of 7.14 mg/l together with the alum dosage of 35 mg/l were added.

Rapid Sand Filtration Test. No matter the raw water was attributed to fishy odor or musty odor, the TON of filtered water taken from the treatment of rapid sand filtration following coagulation-sedimentation still maintained the same as the supernatant taken from the treatment of coagulation-sedimentation. In other words, the water odor could not be removed by rapid sand filtration.

Clean Water Chlorination. When there was a fishy odor or a musty odor in filtered water of rapid sand filtration, the experimental results from clean water chlorination was the same as those from raw water chlorination, as shown in Figs.11 and 12. Only fishy odor, instead of musty odor, of filtered water could be treated by chlorination to meet the water quality standard.

The results discussed above implis that the following conventional water purification treatment scheme: rapid mix, slow mix, sedimentation, rapid sand filtration and clean water chlorination can reduce the water odor in fishy odor occurring season to meet the water quality standard. The worst thing is the occurrence of musty odor in raw water, then treatment nethods other than conventional water purification process must be implemented together to reduce the musty odor to meet the water quality standard.

Removal of Musty Odor by $KMnO_4$

No matter $KMnO_4$ was added into raw water alone, or added into coagulation tank together with alum during rapid mix, as indicated in Fig. 21, this chemical oxidant was not very effective for the removal of musty odor to meet the water quality standard.

Removal of Musty Odor by Powdered Activated Carbon

In this study, both alum and powdered activated carbon (particle size 0.149~0.088mm) manufactured by Witcarb were added into coagulation tank during rapid mix. In the musty odor occurring season, when the alum dosage of 20 mg/l was added, the amounts of, powdered activated carbon required to be supplemented for reducing the TON of 25, 35, 50 and 70 to 3 were 70, 120, 150 and 200 mg/l, respectively, as shown in Fig.14. Furthermore, Fig.14 can be regraphed as Fig.15 by the replacement of abscissa and ordinate. In so doing, the following equation could be derived from Fig.15:

$$PAC(mg/l) = 11.74 + 2.739\ TON$$

Accordingly, the amount of powdered activated carbon required to reduce the musty odor of water to an acceptable degree could be approximately estimated.

According to all the experimental results obtained from the entire study, powdered activated carbon treatment was the most effective method for the removal of water odor. More than 90% of musty odor could be removed by the powdered activated carbon treatment, however, the required amount of powdered activated carbon would be very large and costly. Therefore, the best strategy for saving the use of powdered activated corbon is using the more economical methods, such as $KMnO_4$, high dosage of prechlorination, to first reduce the water odor to a certain degree and then followed by powdered activated carbon treatment, as shown in Figs.16 and 17.

CONCLUSIONS

Based upon the experimental results obtained from this study, the following conclusion can be made:

The water odor generated by the organics was not effectively removed by rapid sand filtration alone, however, in the fishy odor occurring season, the water odor could be declined to meet the water quality standard by the following conventional water purification treatment scheme: rapid mix, slow mix, sedimentation, rapid sand filtration and clean water chlorination. On the other hand, in the musty odor occurring season, the raw water with TON less than 25 could be effectively treated by high dosage of prechlorination together with alum coagulation resulting in meeting the water quality standard.

For instance, the TON of raw water could be declined from 25 to 3 when the chlorine dosage of 7.14 mg/L together with the alum dosage of 35 mg/L were added. But when a musty odor with a TON was as high as 50, the following three methods can be used to treat the water odor to meet the water quality standard: First, pretreated with a $KMnO_4$ dosage of 2 mg/L and followed by a conventional water purification process with an alum dosage of 20 mg/L and a powdered activated carbon dosage of 50 mg/L. Second, a conventional water purification process uses an alum dosage of 20 mg/L together with a powdered activated carbon dosage of 150 mg/L. Third, prechlorinated by maintaining 10.6 mg/L of available chlorine and followed by a conventional water purification process with an alum dosage of 50 mg/L and a powdered activated carbon dosage of 6 mg/L.

Although powdered activated carbon treatment is the most effective method for the removal of water odor, the required amount of powdered activated carbon will be very large and costly. Therefore, it can only be used in the emergency case of treatment of water odor. The effect of various chemicals and treatment schemes on the removal of water odor is tabulated below:

The relative effectives of various chemicals for the removal of water odor.

Chemical	Alum	$FeCl_3 \cdot 6H_2O$	$FeSO_4 \cdot 7H_2O$	NaClO	$KMnO_4$
Fishy odor	+	-	- -	+	+
Musty odor	-	-	- -	+ -	+

The relative effectiveness of various treatment schemes for the removal of water odor.

Treatment scheme	Cl_2 + Alum	Cl_2 + Alum, PAC	Alum + PAC	Alum + $KMnO_4$	$KMnO_4$ + Alum, PAC
TON 0 25	+ +	+ +	+ +	+	+ +
TON 50	+	+ +	+ +	+	+ +

++ : water odor can be reduced to a TON of 3.
+ : water odor can be decreased but not below a TON of 3.
+- : water odor can be decreased or intensified.
- : water odor can not be removed.
-- : water odor can not be removed, instead, can be intensified.

ACKNOWLEDGEMENT

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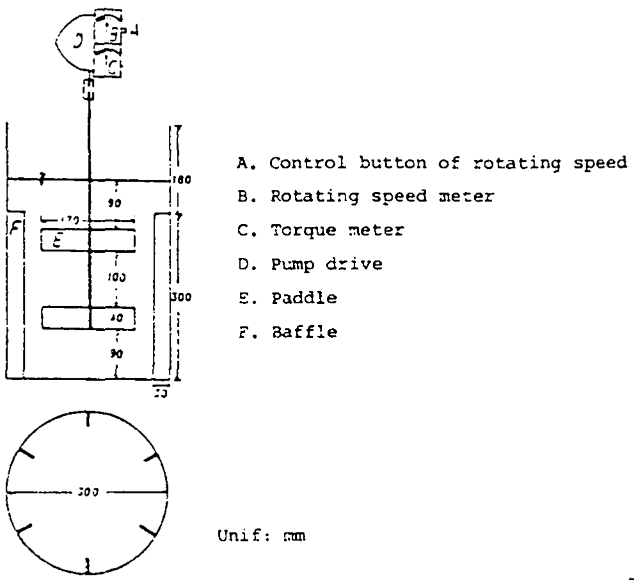

Fig.1 Coagulation reactor set-up.

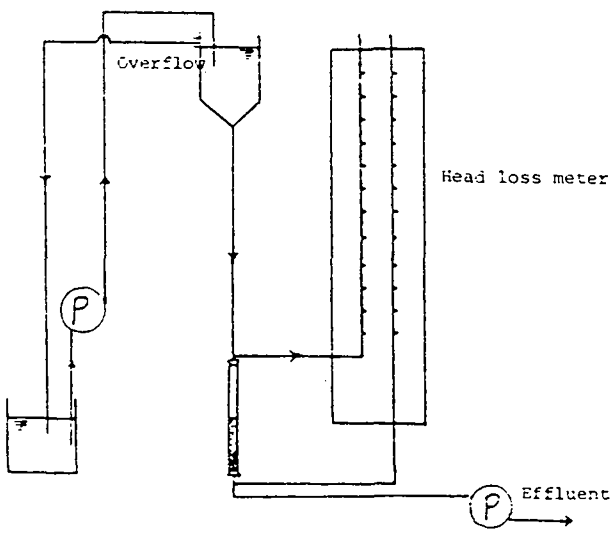

Fig.2 Rapid sand filter set-up.

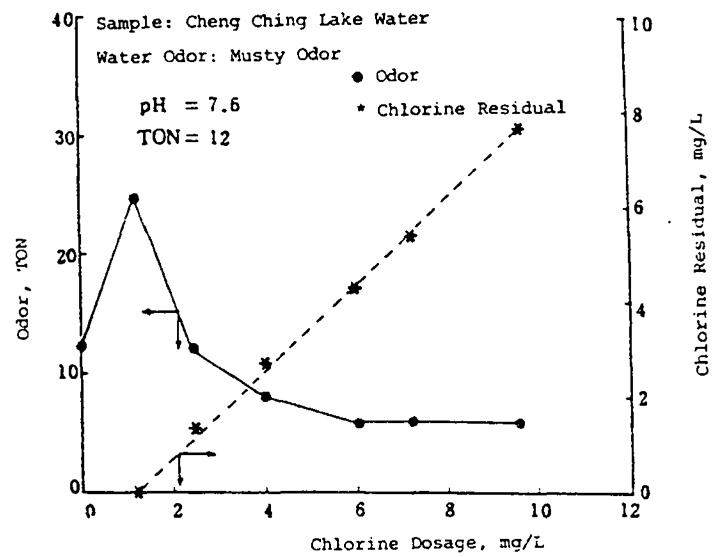

Fig.3 Relationship between raw water chlorination and the removal of musty odor.

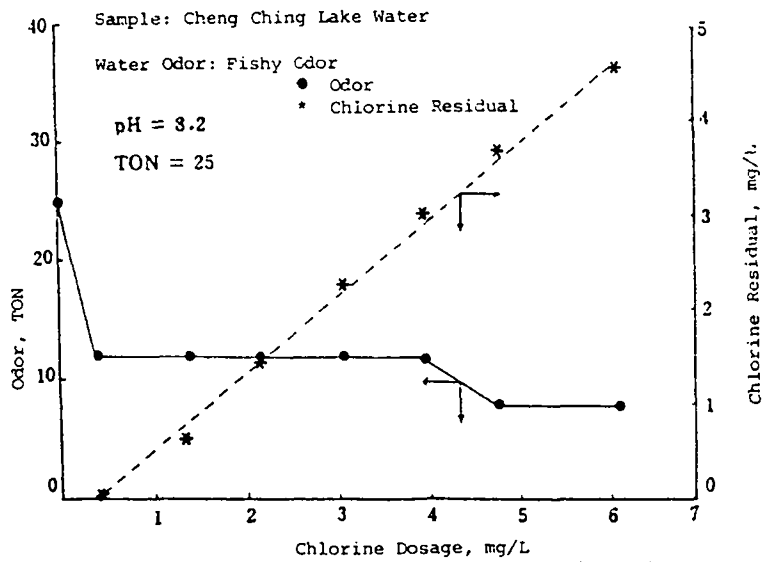

Fig.4 Relationship between raw water chlorination and the removal of fishy odor.

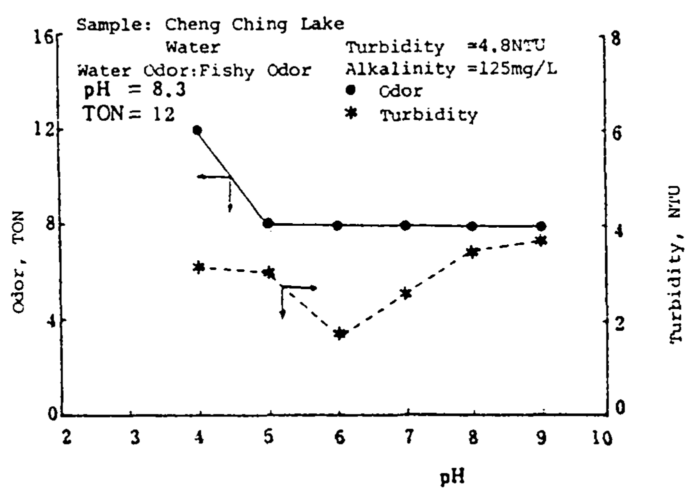

Fig.5 Relationship between pH and the removal of turbidity, fishy odor, $(Al_2(SO_4)_3 \cdot 18H_2)$=15mg/L)

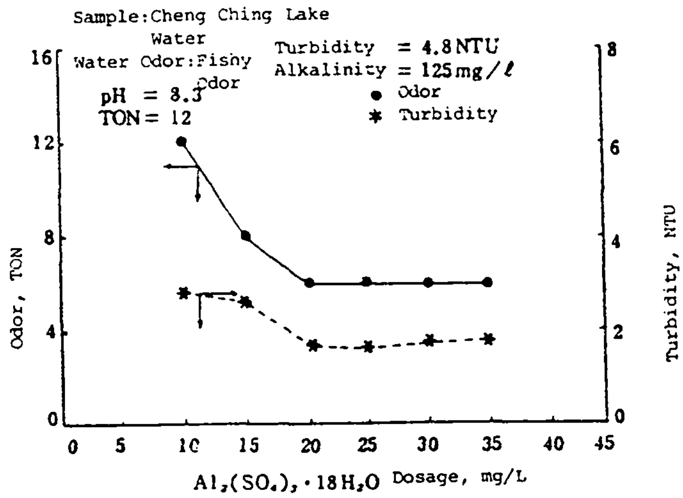

Fig.6 Relationship between alum dosage and the removal of turbidity, fishy odor.

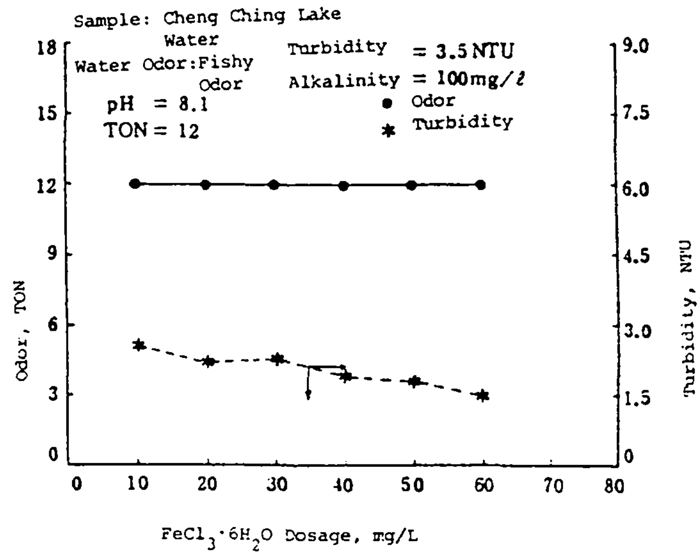

Fig.7 Relationship between ferric chloride dosage and the removal of turbidity, fishy odor.

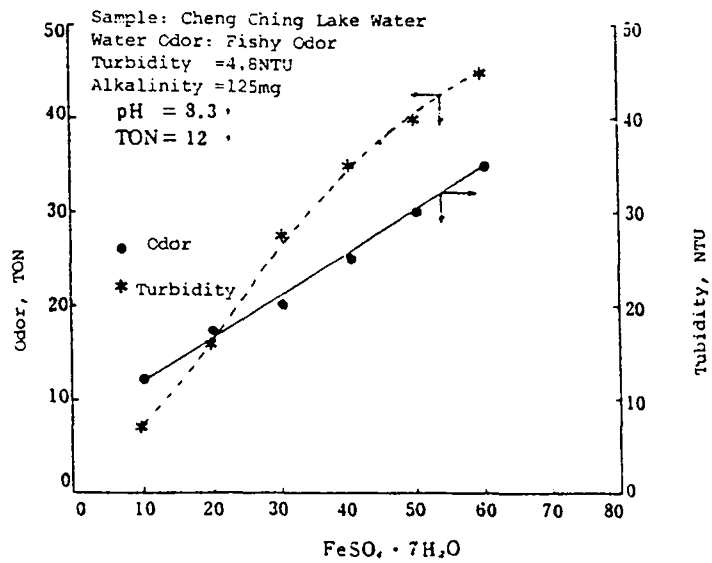

Fig.8 Relationship between ferrous sulfate dosage and the removal of turbidity, fishy odor.

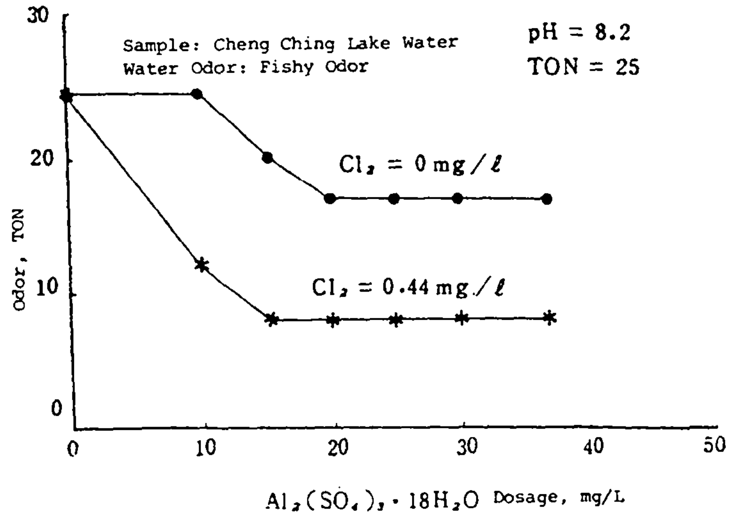

Fig.9 Effect of raw water chlorination on alum dosage required and the removal of fishy odor.

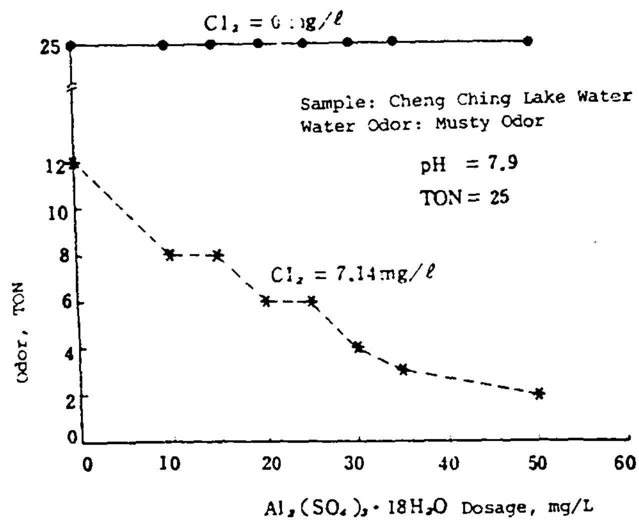

Fig.10 Effect of raw water chlorination on alum dosage required and the removal of musty odor.

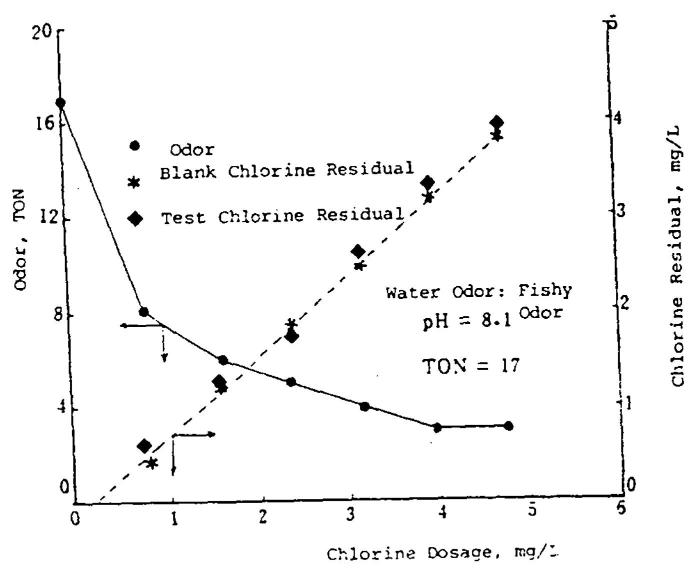

Fig.11 Relationship between clean water chlorination and the removal of fishy odor.

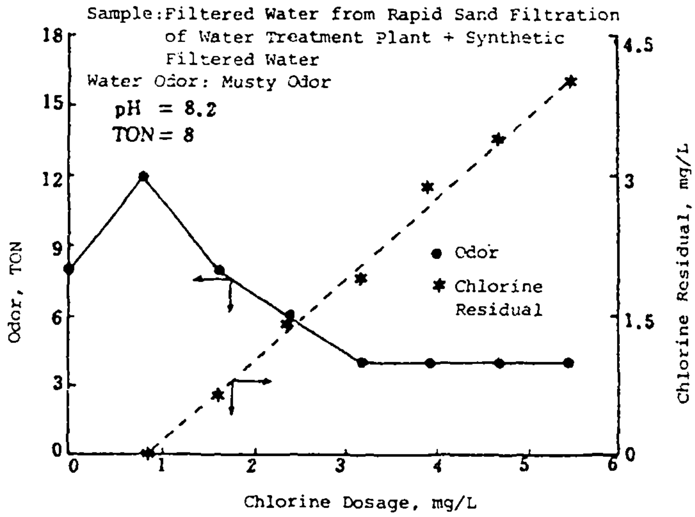

Fig.12 Relationship between clean water chlorination and the removal of musty odor.

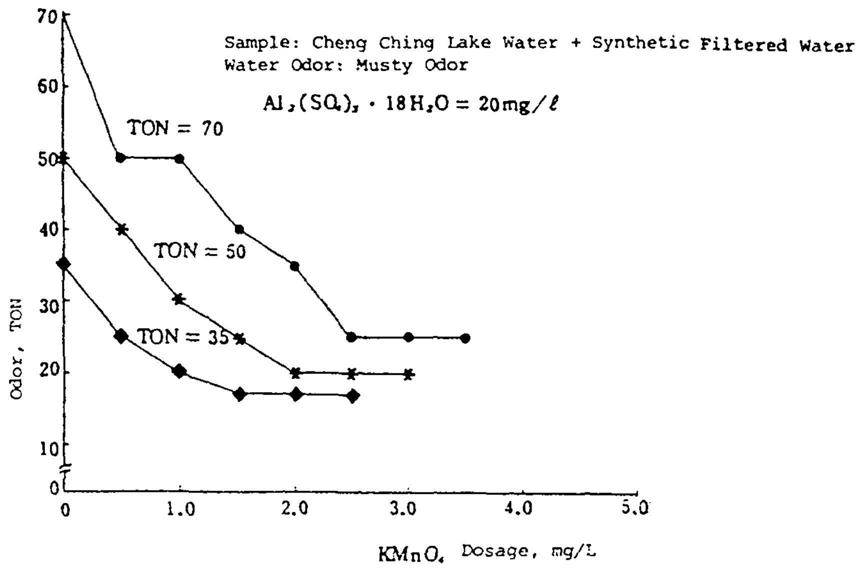

Fig.13 Comparison of the removal of various musty odor by $KMnO_4$.

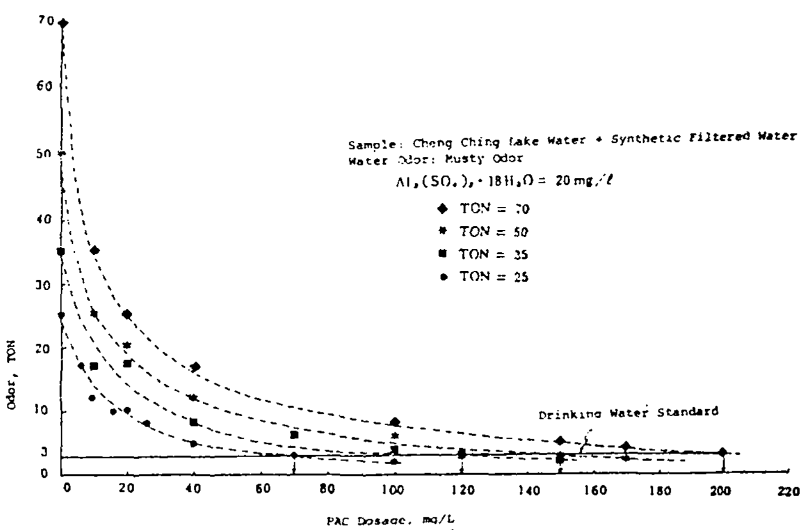

Fig.14 Comparison of the removal of various musty odor by powered activated carbon.

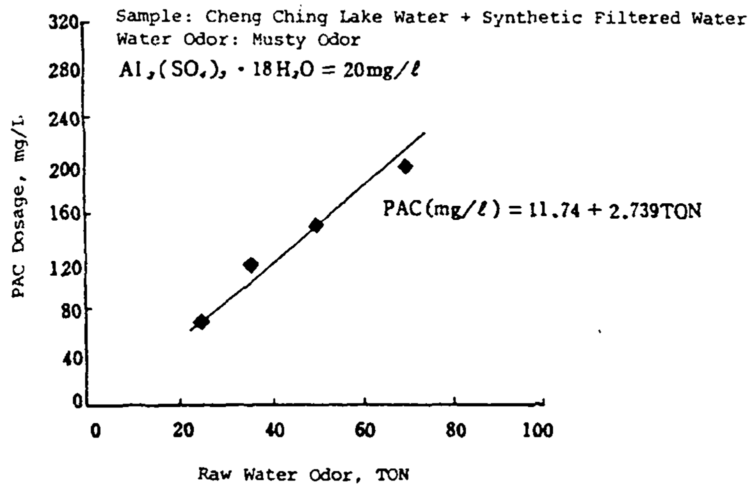

Fig.15 Relationship between powdered activated carbon and musty odor of raw water for reducing TON to 3.

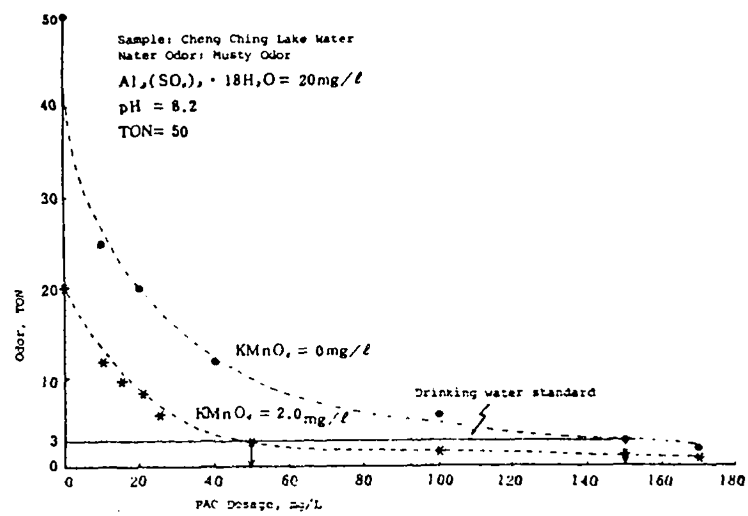

Fig.16 Effect of pretreatment of potassium permanganate on powdered activated carbon required and the removal of musty odor.

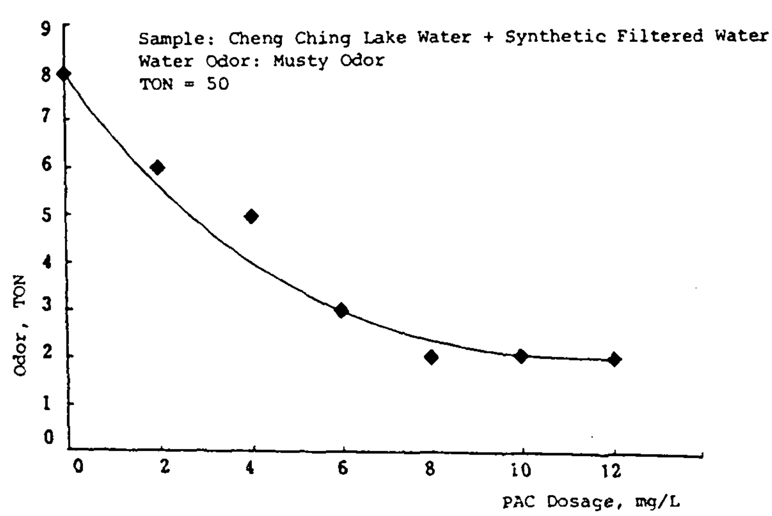

Fig.17 Relationship between powdered activated carbon and the removal of musty odor. (Cl_2=10.6mg/L. $Al_2(SO_4)_3$ $18H_2O$=50 mg/L)

IMPROVEMENT OF DEWATERING ON SAND BEDS AND ITS EFFICIENCY

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1. INTRODUCTION

It is desirable that dewatering of water treatment plant sludges is carried out by non-chemical conditioning and less energy. The method of dewatering on sand beds is the most economical process owing to using natural energy, i.e., gravity dewatering and evaporation drying. But the disadvantages of this process are that it needs a large treatment area and its efficiency is dominated by climates.

In order to decrease treatment area and treatment period, high speed sand drying beds was developed. However, the efficiency of this process has not been clear yet.

In this study, we estimated the gravity dewatering rate in conventional sand beds process and high speed sand beds process.

2. GRAVITY DEWATERING EQUATION

(1) RUTH'S CAKE FILTRATION THEORY

Under constant pressure filtration, the filtration experimental data, plotted as (t/V) versus V will yield a straight line and which is expressed as:

$$t/V = (1/K_R)V \qquad (1)$$

where t = time (sec)
V = filtrate volume (m^3)
$1/K_R$ = slope from (t/V) versus V plot (m^6/sec)

Assuming that the cake resistance is in proportion to the cake solid mass per unit filtrate volume , Ruth defined specific resistance as follows:

$$\alpha = \frac{2PA^2(1-mS_0)}{K_R \mu \rho S_0} \quad (2)$$

where α = specific resistance (m/kg)
P = filtration pressure (Pa)
A = filtration area (m^2)
μ = viscosity of filtrate (Pa•sec)
ρ = filtrate density (kg/m^3)
S_0 = initial solid content (-)
m = ratio of wet cake mass to dry cake mass (-)

The relationship between specific resistance and head was studied and found to be empirically described by the following equation.

$$\alpha = \alpha_0 (h/h_0)^n \quad (3)$$

where h = filtration head (m)
α = specific resistance (m/kg)
α_0 = specific resistance at head=h_0 (m/kg)
n = compressibility coefficient (m)

From Buchner funnel test, we obtain the values of specific resistance and compressibility coefficient of sludge.

(2) GRAVITY DEWATERING EQUATION[1]

Adrian derived a mathematical model for the gravity dewatering rate of sludge by using the specific resistance concept.

$$-\frac{dh}{dt} = \frac{g \cdot h_0^{n} \cdot (1-mS_0)}{\mu \cdot \alpha_0 \cdot h^{(n-1)} S_0 (H_0 - h)} \quad (4)$$

where Ho = initial sludge head (m)
g = gravity acceleration (m/sec^2)

Substituting the value of m obtained from Buchner funnel test into equation (4), Adrian predicted the dewatering time. Also a media factor was used to make a close agreement between observed and calculated values. Considering the limit of Ruth's filtration theory, the value of m used for calculation is redefined by us to evaluate experimental results. A modified m, which is defined as m_f, will describe later.

Assuming that m_f is not a function of time and head, equation (4) could be integrated as follows:

$$t = 0 \; ; \; h = H_0$$
$$t = t \; ; \; h = h \qquad (5)$$

$$t = \frac{\mu \cdot \alpha_0 \cdot S_0}{g \cdot h_0{}^n (1 - m_f \cdot S_0)} \left[\frac{1}{n+1} h^{(n+1)} - \frac{H_0}{n} h^n + \frac{H_0{}^{(n+1)}}{n(n+1)} \right] \qquad (6)$$

The parameters dominate the gravity dewatering rate are divided into three groups.

1) Treatment Conditions
   S_0 = initial solid content
   H_0 = initial sludge head
2) Dewatering Characteristics of Sludge
   α_0 = specific resistance
   n = compressibility coefficient
   m_f = ratio of wet cake mass to dry cake mass at the end of filtration period
3) Temperature
   μ = viscosity

It is important to determine the parameters, such as α_0, n and m_f for estimating the gravity dewatering rate.

3. MATERIALS AND METHODS

3-1. MATERIALS

Alum sludges were taken from water treatment plants near Sendai. Sludge A and Sludge B were used in conventional sand drying beds experiment and high speed sand drying beds experiment, respectively. The results of Buchner funnel test of these sludges are shown in Table 1.

Table 1 Buchner Funnel Test Results

	sludge A	sludge B
α_0(at head 1m) (m/kg)	1.16×10^{12}	1.23×10^{12}
n (-)	0.753	0.786

3-2. CONVENTIONAL SAND DRYING BEDS

Fig.1 shows the experimental apparatus of conventional sand drying beds. The acrylic column has 12 cm I.D. and 80 cm height. The supporting filter media is consisted of 5 cm depth of sand and its uniformity coefficient and effective size were 1.0 and 0.78 mm, respectively.

Filtrate volume, height of sludge surface and sludge temperature were measured. The solid content profiles in the sludge during gravity dewatering were measured by slicing the cake to each thin layer.

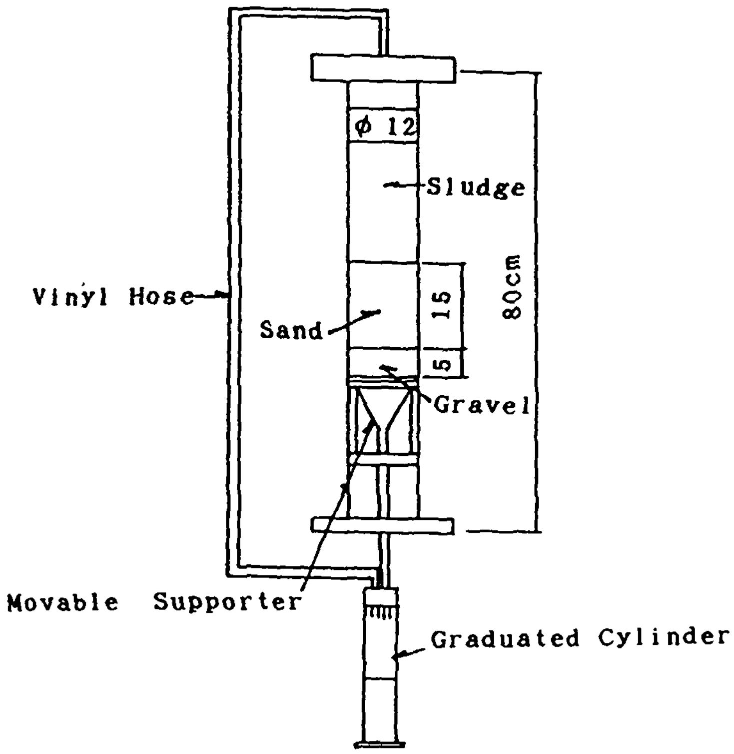


Fig. 1 Experimental Apparatus of Conventional Sand Drying Beds

3-3. HIGH SPEED SAND DRYING BEDS

Fig.2 shows the experimental apparatus of high speed sand drying beds. The column has 12 cm I.D. and 100 cm height. In order to prevent disturbance of sand beds, filter cloth was used as the supporting filter media. In this study, three types of mixing method such as aeration (type A), mechanical stirring (type B) and aeration combined with mechanical stirring (type C), were employed to investigate the effect of mixing method on the gravity dewatering rate. At the same time, conventional process was carried out to compare with those results of high speed process. The shape of mixing devices (paddle and diffuser) is shown in Table 2. Mixing devices are set at 0.5 cm above the media. Operation conditions are listed in Table 2. Mixing was carried out by two methods such as continuous mixing and non-continuous mixing.

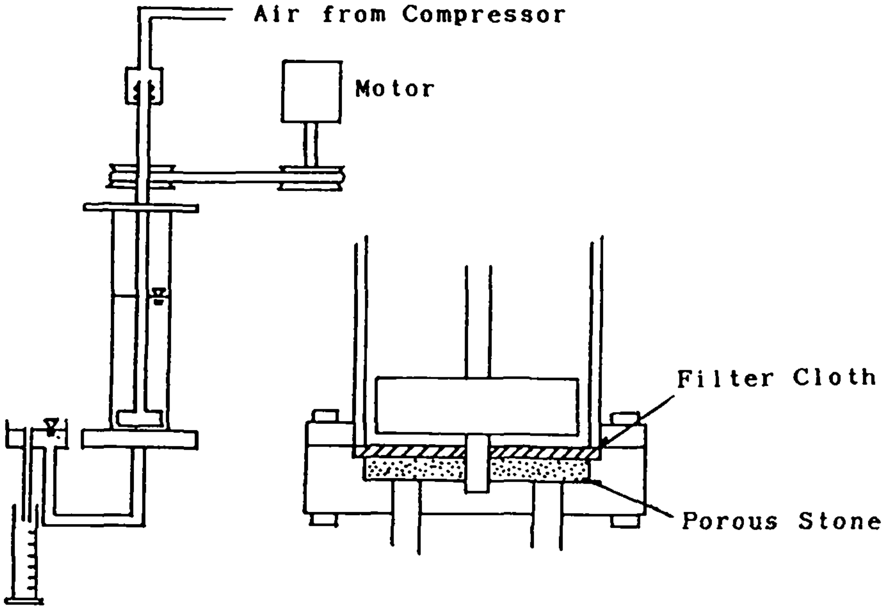
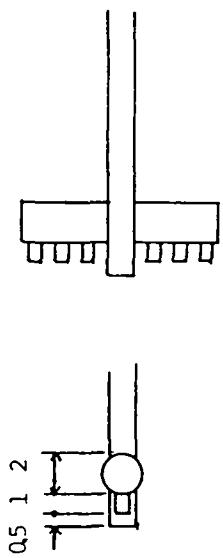
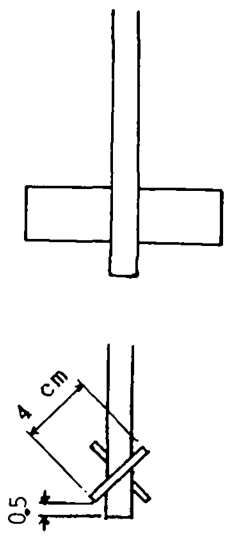
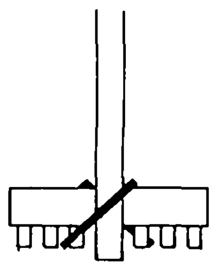


Fig. 2 Experimental Apparatus of High Speed Sand Drying Beds

Table 2 Experimental Conditions of High Speed Sand Drying Beds

	TYPE A	TYPE B	TYPE C
mixing method	aeration	mechanical stirring	aeration and mechanical stirring
air flow (l/min)	2.5	——	2.5
stirring (rpm)	——	1.9	1.9
shape of paddle and diffuser			

4. RESULTS AND DISCUSSIONS

4-1. CONVENTIONAL SAND DRYING BEDS

(1) DEFINITION OF TRANSITION POINT

Fig.3 shows the height of sludge surface during gravity dewatering and Fig.4 is obtained by rearranging the data of Fig.3 into t/V' vs. V' plot, where dimension of time is changed to hour and V' means filtrate volume per unit area. As shown in Fig.4, the transition point is clearly defined and gravity dewatering process is able to divide into two stages. During the first stage, before transition point, the relationship between t/V' and V' shows almost linear. Whereas, during the second stage, after transition point, the linear relationship is not satisfied. Therefore, it seems that the mechanism of solid-liquid separation varies at the transition point.

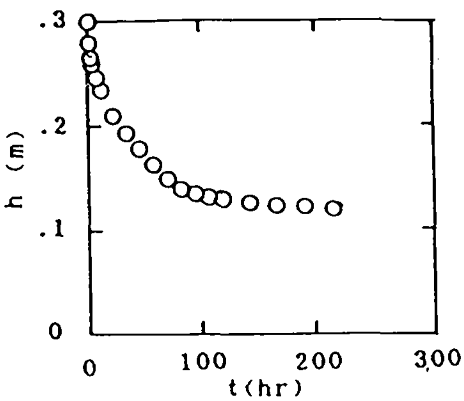


Fig. 3 h vs. t

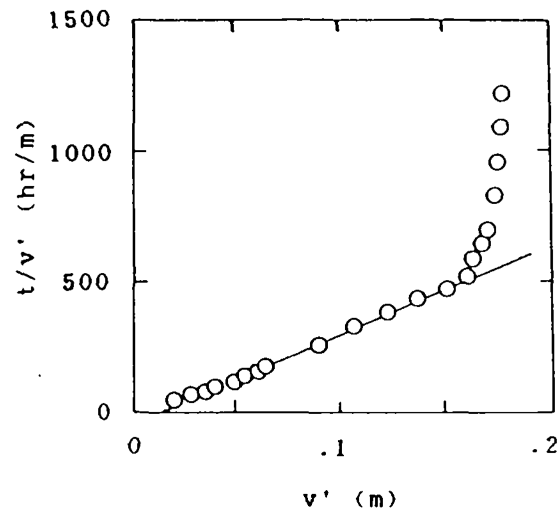


Fig. 4 t/V' vs. V'

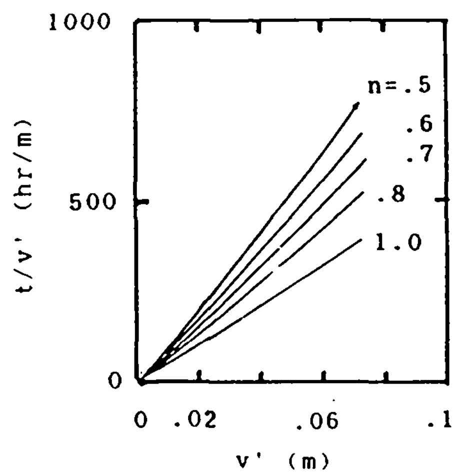


Fig. 5 t/V' vs. V'

$\alpha_0=1.65\times10^{12}$(m/kg)
$\mu=0.0012$(Pa·sec)
$S_0=0.049$(-)
m=15.4(-)
$H_0=0.3$(m)

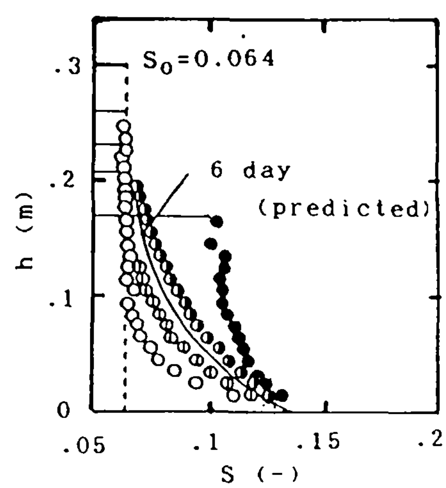


Fig. 6 Solid Content Profiles

○ : 1 day
◐ : 3
◑ : 7
● : 14

From the calculation results of equation (6) shown in Fig.5, the relationship between t/V' and V' is almost linear when coefficient of compressibility is high, and equation (6) could only express dewatering curve during the first stage.

The solid content profiles in other experiment are shown in Fig.6. During gravity dewatering, the concentrated cake layer is built up above filter media, and the gravity dewatering rate is limited by this layer. In this experiment, the transition point was obtained at 168 hrs. It is found that the time at the transition point is nearly equal to the time when solid content of sludge surface begins to increase by gravity dewatering.

(2) AGREEMENT BETWEEN CALCULATED AND EXPERIMENTAL RESULTS

The value of m_f used for calculation is a reciprocal of average solid content of sludge at the transition point.

Calculated and experimental results of gravity dewatering process are shown in Fig.7 and 8. In this study, calculated results shows a good agreement with experimental results in spite of changing initial head (Fig.7) and initial concentration of sludge (Fig.8). Adrian attempted to adjust calculated results to experimental results by using media factor which is the empirical factor of

media resistance. But the cause of this difference between calculated and experimental results is the determining method of m. Using m_f defined by authors, equation (6) is able to express the process of gravity dewatering during the first stage. As shown in Fig.7, the two dewatering curves, before 1 day of gravity dewatering are similar without the effect of changing initial sludge head. From these results , it could be considered that the cake resistance per unit filtrate volume dose not change with initial height but increase with the increase in initial solid content of sludge.

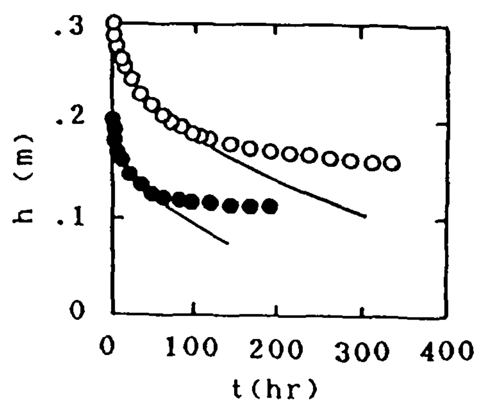


Fig. 7 h vs. t (S_0=0.098)
○ ; H_0=0.3(m)
● ; H_0=0.2(m)
– ; calculation

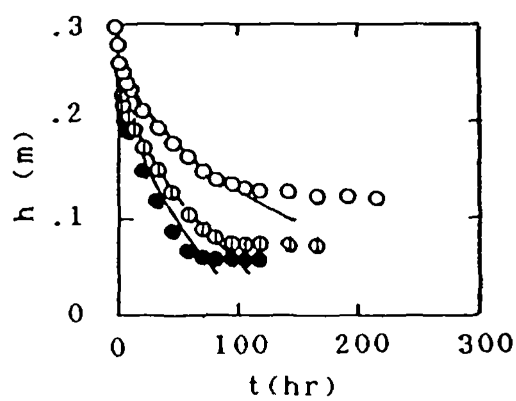


Fig. 8 h vs. t (H_0=0.3m)
○ ; S_0=0.079
◐ ; S_0=0.050
● ; S_0=0.039
– ; calculation

4-2. HIGH SPEED SAND DRYING BEDS

(1) EFFECT OF MIXING ON DEWATERING RATE

Dewatering curves of these processes with continuous mixing are shown in

Fig.9. Experimental results have no difference between type A and type B. As to mixing method, aeration shows an excellent effect on mixing in this experimental equipment. In type B, because of a weakly mixing, the dewatering rate is slower and more supernatant is observed during dewatering, but the sludge surface decline curves exist no significant difference among those three types. If supernatant is drained properly, the dewatering ability in type B is the same as that in type A and type C.

Furthermore, the sludge surfaces for all three types have the same height when operation period is over 5 days, and the filtrate volume of there processes are twice as large as that of conventional process. When operation period is designed at 5 days, it can obtain the same dewatering efficiency by using any one of types.

Comparing conventional process with high speed process, the results show that dewatering rate could be improved greatly and larger filtrate volume is obtained by high speed process.

(2) INTERMITTENT MIXING PROCESS

In view of economics, intermittent mixing method is considered as an effective operation method. Intermittent mixing experiment is operated at 3 hrs intervals including 15 min mixing and 165 min non-mixing, and its results are shown in Fig.10 . For type A and type C, sludge dewatering curves existed no difference. The experimental result in type B shows that in the beginning, dewatering curve is similar to those of other high speed processes , but in the end of experiment dewatering curve are similar to conventional process.

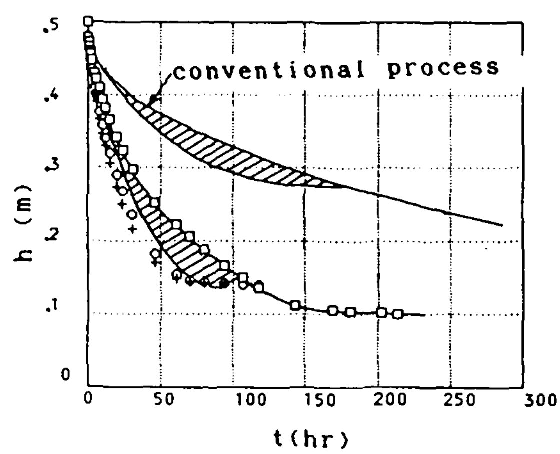


Fig. 9 h vs. t
(continuous mixing)
○ ; type A
□ ; type B
+ ; type C
hatched area ; supernatant

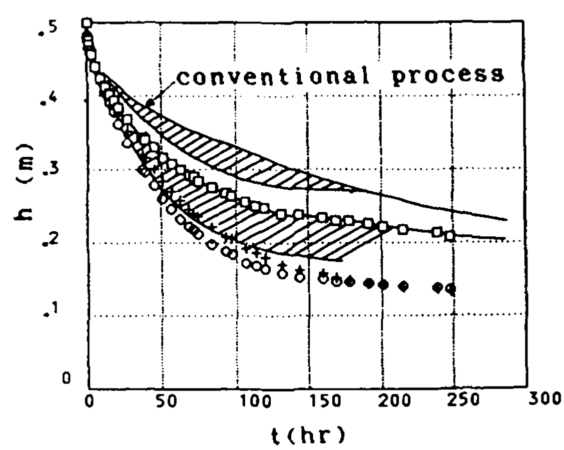


Fig. 10 h vs. t
(intermittent mixing)
○ ; type A
□ ; type B
+ ; type C
hatched area ; supernatant

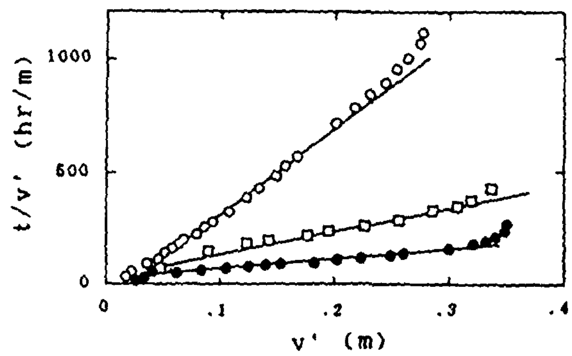


Fig. 11 t/V' vs. V' (type A)
○ ; non-mixing
□ ; intermittent mixing
● ; continuous mixing

This is because of weaker mixing in type B and it is unable to destruct high concentrated sludge cake layers.

Comparison results of dewatering curves among continuous mixing with aeration, intermittent mixing with aeration and conventional process are given in Fig.11. The time for sludge surface declining from 0.5 m to 0.3 m (V' increase from 0 m to 0.2 m) in continuous process and intermittent process are 1/3 and 1/6 of that time of conventional process, respectively. In considering operation conditions, such as operation cost, operation period and so on, mixing method should be decided suitably. In Fig.11, both continuous process and intermittent process have the same transition point near V'=0.3(m), and that of conventional process is at V'=0.2(m).

(3) SIMULATION OF INTERMITTENT MIXING PROCESS

In order to investigate the effect of intermittent mixing interval on the dewatering rate, the following calculation was used.

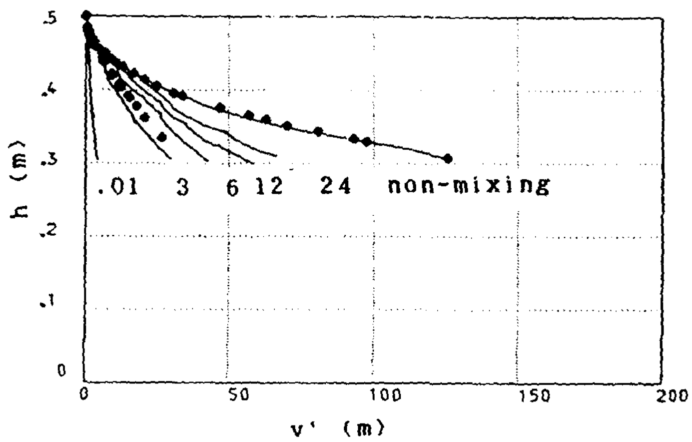


Fig.12 h vs. t
— ; calculation
● ; experiment

The height of sludge surface (H_a) at time (t_a) is predicted by using equation (6). At time of ta, assuming complete mixing is carried out and average solid content of sludge (S_a) is expressed as:

$$S_a = S_o\left(\frac{H_o}{H_a}\right) \qquad (7)$$

where S_a = average solid content of sludge at time t_a (-)
H_a = height of sludge surface at time t_a (m)

Then, substituting H_o and S_o for H_a and S_a into equation (6),the relationship between the dewatering rate and time interval in intermittent mixing process could be obtained. In this calculation, parameters of sludge B were used and its results showed in Fig.12. α_0 is assumed as a constant in spite of changing initial solid content of sludge. When intermittent mixing intervals is very short (for example 0.01), the simulated result dose not agree with experimental result, so the gravity dewatering model is not suitable for evaluating continuous mixing process. The reason is that sludge cake layer can not destructed completely. Whereas it can be used to estimate dewatering rate when intermittent mixing interval is larger than 3 hrs.

5. CONCLUSION

The results in this paper are summarized as follows:

(1) The gravity dewatering rate of conventional process is estimated by Adrian's equation which is modified by authors.

(2) High concentrated cake layer is built up above media surface, and this layer has a bad effect on the rate of gravity dewatering.

(3) The high speed sand drying beds is very efficiency for the increase of filtrate volume and dewatering rate.

(4) Continuous mixing process is very efficiency, and intermittent mixing process also could obtain a good result when mixing interval and mixing method are decided properly.

REFERENCE

(1) Adrian D.D. "Sludge Dewatering and Drying on Sand Beds" EPA-600/2-78-141 (1978)

APPLICATION OF FILTRATION LAWS IN CROSS-FLOW MICROFILTRATION

by :

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1. Introduction:

The three major membrane processes used in water and wastewater treatment are electrodialysis, reverse osmosis and crossflow filtration (ultrafiltration and microfiltration). Electrodialysis is a proven process for desalting brackish water. Reverse Osmosis is also used extensively in desalting applications for brackish water. It has an added advantage of being able to remove many organic compounds in addition to the ionic species. The crossflow filtration techniques like Ultrafiltration and Microfiltration are useful in removing macromolecules, colloids and suspended solids.

Unlike in the standard filtration techniques, in crossflow filtration, since the direction of the feed flow is tangential to the filter surface, accumulation of the filtered solids on the filtered medium can be minimized by the shearing action of the flow (Figure 1). Crossflow filtration thus affords, at least in principle, the possibility of a quasi-steady operation with a nearly constant flux when the driving pressure differential is held constant. Unfortunately, this theoretical possibility has still not been achieved in practice.

There is an important difference between crossflow microfiltration and ultrafiltration with respect to the sizes of particles removed. The separation range of microfiltration is from 0.02 to 10 μm (Figure 2). Since the particle sizes to be separated in microfiltration and ultrafiltration are different, the physics of the separation process are also different. Furthermore, microfiltration changes none of the chemical properties of the solution whereas, in ultrafiltration, separation of the dissolved species modifies the chemical potential and creates a gradient which tends to make the separated water diffuse back in the reverse direction.

At present, Crossflow microfiltration is used in different domains of solid-liquid separation including: water treatment, medical and pharmaceutical industry, chemical processing, biotechnical applications, slurry treatment, food & beverage processing, film and electronics industry and in water injection systems for secondary oil recovery, even though the applications of microfiltration are still not completely utilized. In some of these applications, the crossflow microfiltration would benefit the environment, at considerable cost savings, since recycling of water and/or recovery of valuable products would be possible.

Not much work has been done on the crossflow microfiltration especially during the filtration process. Only the particle deposition at the critical condition has been investigated in previous works. This study investigates the influence of membrane pore size, particle size, particle concentration, crossflow velocity and applied pressure on the performance efficiency of crossflow filter.

This study was however limited to an artificial feed of Kaolin clay and latex suspension in order to study the filtration performances under controlled conditions. The experimental unit used was of batch type mode, where the membrane model geometry is flat.

2. The Blocking Mechanisms of Membrane:

HERMANS AND BREDEE (1936) classified the filtration mechanisms into four different types based on the rate of change of resistance, r, with the volume of filtrate, v (*i.e.* $\phi = dr/dv$). The relationship between ϕ (the rate of blocking) and r (the resistance) is a characteristic of the filter mechanism. The four different mechanisms are the following:

2.1 Cake filtration principle:

This involves the formation of a porous layer on the surface of the membrane, thus leaving the resistance of the membrane itself unaltered.

At a given time, the hydraulic resistance R_t, is the sum of membrane resistance (R_m) and the deposit resistance (R_d).

i.e. $R_t = R_m + R_d$ (1)

where $R_d = \frac{rwv}{A}$

A = Area of membrane
r = Specific filtration resistance per unit weight of cake solids
v = Volume of permeate in a given time (or filtrate)
w = Weight of dry cake solids per unit volume of filtrate

$$w = \frac{\rho_1 \cdot S}{(1 - mS)}$$

ρ_1 = density of feed
m = Liquid content of the sludge
and S = the fraction of solid in suspension

Thus R_t can be written in the following way

(2)

$$R_t = R_m + \frac{rwv}{A}$$

From Darcy's law, one has ,

$$\frac{dV}{dt} = \frac{\Delta P \,.\, A}{\mu \,.\, R_t} \qquad (3)$$

or

$$\frac{dV}{dt} = \frac{\Delta P \,.\, A}{\mu (R_m + \frac{rwv}{A})}$$

where μ = Viscosity of feed

Assuming constant pressure over time,

$$\int_o^t dt = \int_o^v \left(\frac{\mu wrv}{\Delta PA^2} + \frac{R_m \mu}{\Delta PA}\right) dv$$

i.e.

$$\frac{t}{v} = \frac{\mu wrv}{2\Delta PA^2.} + \frac{R_m \mu}{\Delta PA} \qquad (4)$$

The above equation can also be written as,

$$\frac{t}{v} = \frac{K_c \,.\, V}{2} + \frac{1}{Q_o} \qquad (5)$$

where $K_c = \dfrac{\mu w.r}{\Delta P.A^2} = \dfrac{\mu r \ \rho_1 .S}{\Delta P.A^2 (1 - mS)}$

and $Q_o = \dfrac{\Delta P.A}{\mu R_m}$

2.2 <u>Intermediate blocking</u>

The probability of a pore being obstructed is a function of area available for flow; thus, at the time t + dt, the active surface area of membrane is

$$A_{t+dt} = A_t - \sigma \ (Q_f)_t . \ dt \ \frac{A_t}{A_o} \qquad (6)$$

where A_t = Active surface area membrane at time t

σ = Fraction coefficient of blocking

Q_f = Volumetric flow rate at time t

By introducing Darcy's law in the above equation,

$$dA = -\sigma \frac{\Delta P}{\mu R \ A_o} \ A^2 dt \qquad (7)$$

Integrating the above equation;

$$Q_f = \frac{Q_o}{1 + \frac{\sigma \ \Delta P}{\mu R} \ . \ t} \qquad (8)$$

The above equation can also be expressed in the following form

$$\frac{1}{Q_f} = \frac{\sigma \Delta P}{Q_o \mu R} t + \frac{1}{Q_o} \qquad (9)$$

from Darcy's Equation, one has

$$\frac{\Delta P}{\mu R} = V_f = \frac{Q_o}{A_o}$$

Substituting the above relationship in equation (9)

$$\frac{1}{Q_f} = K_1 t + \frac{1}{Q_o} \qquad (10)$$

where $K_1 = \sigma / A_o$

For filtration at constant pressure, one has,

$$\frac{d}{dv} \left(\frac{1}{Q_f}\right) = \frac{d^2 t}{dv^2} \qquad (11)$$

Substituting equation (10) in equation (11)

$$\frac{d^2 t}{dv^2} = K_1 \frac{dt}{dv} \qquad (12)$$

2.3 Standard Blocking:

If the pore volume decreases proportionally with the filtrate volume, the following equation can be obtained. Here it is assumed that the pores have a cylindrical capillary geometry.

$$N (- 2 \pi r dr\, L_p) = C_v dV \qquad (13)$$

where N = No. of pores
r = pore radius
L_p = Length of pore
and, C_v^p = Volume of particles deposited/filter volume

Poiseuille's Equation for cylindrical capillary can be written as,

$$Q_o = \frac{dv}{dt} = N \, \Delta P \, \frac{\pi r^4}{8 L_p} \qquad (14)$$

From equation (13) and (14), one can obtain the following equation,

$$Q_f = Q_o \left(1 - \frac{K_s v}{2}\right)^2 \qquad (15)$$

where $K_s = \dfrac{2 C_v}{L_p A_o}$

From equation (13), (14) and (15) one can obtain,

$$\frac{t}{v} = \frac{K_s t}{2} + \frac{1}{Q_o} \qquad (16)$$

Substituting Equation (15) in equation (11)

$$\frac{d^2t}{dv^2} = K_s^{/} \left(\frac{dt}{dv}\right)^{3/2} \qquad (17)$$

where $K_s^{/} = K_s \, Q_o^{1/2}$

2.4 Complete blocking:

From the Darcy's Equation at time t,

$$Q_f = \frac{\Delta P \, . \, A_t}{\mu R} \qquad (18)$$

where $A_t = A_o - \sigma V$

σV is the pore fraction blocked and it is a function of particle diameter and particle concentration as given below

$$\sigma V = \left(\frac{V^{*} \rho_m \, . S}{\rho_s}\right) \left(\frac{6}{\pi d^3}\right) \left(\frac{\pi d^2}{4\psi}\right) \qquad (19)$$

where
V_{*} = Volume filtered
V^{*} = Suspension volume
ρ_m = mixture density
ρ_s = solid density
S = fraction of solids in suspension
d = particle diameter
and ψ = shape factor of particle

Also, $Q_f = Q_o - \dfrac{\Delta P \, . \, \sigma V}{\mu R}$

i.e

$$Q_f = Q_o - K_b \, V \qquad (20)$$

Substituting equation (20) in equation (11), one obtains,

$$\frac{d^2t}{dv^2} = K_b \, . \left(\frac{dt}{dv}\right)^2 \qquad (21)$$

2.5 Summary of Filtration Principles:

The above mentioned four different mechanisms of membrane blockage can be described by the classical equation of filtration (Equation 22).

In this equation the coefficients K and n varies for the different mechanisms of filtration as summarized in Table 1.

$$\frac{d^2t}{dv^2} = K \left(\frac{dt}{dv}\right)^n \qquad (22)$$

3. Experimental Investigation

3.1 Experimental Set-up

The schematic diagram of the experimental set-up is shown in Figure 3a. The feed was pumped under pressure from the base of the stock tank into the membrane filter. The details of membrane filter is shown in Figure 3b. A small portion of the feed was filtered out as filtrate while the major portion of the feed was recycled back to the stock tank. The by-pass system was necessary for controlling the operating condition at different pressure and crossflow velocity values.

3.2 Suspension

In order to control particle size range and concentrations, Kaolin clay and latex have been used in the preparation of the artificial suspension. Different size ranges of kaolin clay and latex have been used. The different sizes of kaolin clay was obtained by allowing the suspension to settle for different settling times viz: no settling, 2.5h settling and 6h settling. The mean sizes of the kaolin clay were 3.0, 3.6 and 5.0 μ respectively.

3.3 Membrane

The membranes used in the experiment are : Assoatiment membrane cellulose nitrate with pore sizes of 0.3 μm, 0.45 μm, 0.65 μm, 1.2 μm, 3 μm, 5 μm and 8 μm. The diameter and thickness of these membranes are 4.7 cm and 150 μm respectively.

3.4 Operation

The suspension in the stock tank was kept under certain applied pressure, and was pumped at a known flow rate to the filter. The temporal variation of filtrate flow and effluent quality was measured until the membrane became clogged. The experiment was conducted under different operating conditions (by varying crossflow velocity, pressure applied, membrane pore size, particle size and concentration).

4. Application of the Filtration Equations to the Experimental Results Obtained

Data from the filtration runs conducted using suspensions of different particle sizes on membranes with different pore size, at different operating conditions were analyzed (Figures 4, 5 and 6). The curves were plotted t/v vs t and t/v vs V in order to investigate the filtration mechanisms. A sample curve plotted for the entire filter run and a curve plotted in an enlarged scale for the initial period of filtration run are presented in Figure 7. The straight line portions of these curves fully define the regions of both standard blocking and cake filtration, in accordance with equations (16) and (5) respectively.

In general, the data exhibit an initial region of filtration during which neither standard blocking nor cake filtration apply. Attempts to apply the complete blocking equation (Table 1) to the initial period of filtration run failed in almost all cases. During this initial period, the effluent turbidity was high especially when the membranes with larger pore size was used. Behaviour during this initial period of filtration may be due to a rapid change in the degree of particle retention. The proposed filtration equations (Table 1) assume that the volume or number of particles retained per unit volume filtered remains constant. This is far from reality for the initial period of filtration where permeate turbidity decreases rapidly.

The curves plotted showed that the filtration cycle in general passes through a number of different mechanisms instead of one particular filtration mechanism. In each case, the region developed after the initial period of the cycle, can satisfactorily be represented by the mechanism of standard blocking, and the final region by the cake filtration. There is a transition zone between the region of standard blocking and the region of cake filtration. Attempts to apply the equation of intermediate blocking to this zone was not successful. This region of filtration was of short duration (Table 2) in most cases and appears to be a true transition not amenable to any single relationship. From the figures plotted between t/v and v, and t/v and t, one could note the presence of two regions of filtration with an abrupt change in the slope occuring from the first to the second zone. This transition resulted in a decrease of slope or a decrease in effective cake resistance.

5. Conclusions

From the experimental results, it can be concluded that the filtration cycle generally passes through a number of mechanisms; initial region, standard blocking region, transition region and cake filtration. Among the four different blocking mechanisms of membrane, as described by HERMANS and BREDEE, only standard blocking and cake filtration can be applied to membrane filtration and that too for a particular time period of the filtration cycle. For the initial and transition zone, none of the above mechanisms can be applied.

The duration of standard blocking was found to be short. This duration was found to be a function of the membrane characteristics, suspended particle characteristics and the operating parameters. At the beginning of this region, effluent turbidity decreased and then remained constant for the remainder of the filtration cycle.

The complete blocking mechanism and intermediate blocking mechanism of filtration law have not been observed in the present study.

Table 1:

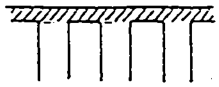
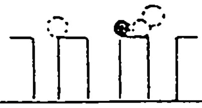
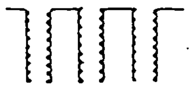
Filtration principle		n		Linear equation
Cake filtration		o	$K = K_c = \frac{\mu \gamma \cdot \dot{\rho}_L \cdot s}{\Delta p A^2 (1-ms)}$	$\frac{t}{V} = \frac{K_c V}{2} + \frac{1}{Q_o}$
Intermediate blocking		1	$K = K_i = \frac{6}{A_o}$	$\frac{1}{Q} = K_i t + \frac{1}{Q_o}$
Standard blocking		3/2	$K = K'_s = \frac{2C_v}{L_p A} Q_o^{\frac{1}{2}}$	$\frac{t}{V} = \frac{K_s t}{2} + \frac{1}{Q_o}$
Complete blocking		2	$K = K_b = V_{fo}\ 6$	$Q = Q_o - K_b V$

Table 2: Blocking Mechanism for Standard Blocking and Cake Filtration

Particle Size (μm)	Pore Size (μm)	Period of Standard Blocking Occur (min)	Time of Cake Filtration Occur (min)
0.27	0.3	0.25 - 2.7 min	1st 3.0 min 2nd 47.0 min
0.27	0.65	2.2 - 6.0 min	9.7 min
0.27	1.2	2.8 - 6.0 min	26.5 min
0.27	3.0	3.1 - 5.5 min	1st 7.5 min 2nd 114.0 min
0.27	5.0	1.5 - 4.0 min	1st 6.0 min 2nd 166.0 min
0.27	8.0	0.20 - 1.2 min	1st 3.0 min 2nd 121.0 min
0.99	0.3	0.25 - 1.8 min	1st 6.5 min 2nd 72.0 min
3.5	0.3	1.5 - 4.0 min	14.0 min
5.0	0.3	3.7 - 8.5 min	31.0 min
3.0	1.2	1.5 - 4.5 min	41.0 min
floc d_f = 26 μm	1.2	1.6 - 3.3 min	10.0 min
Wastewater TS=1.1g/l	1.2	2.0 - 4.6 min	15.0 min

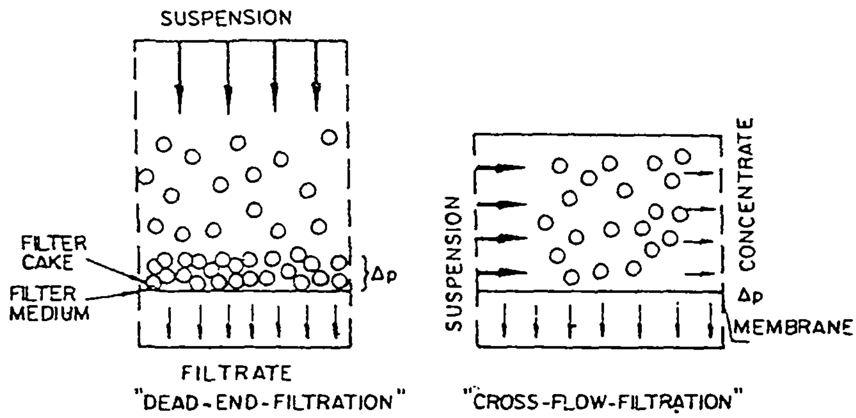


Figure 1 Comparison of filtration principles

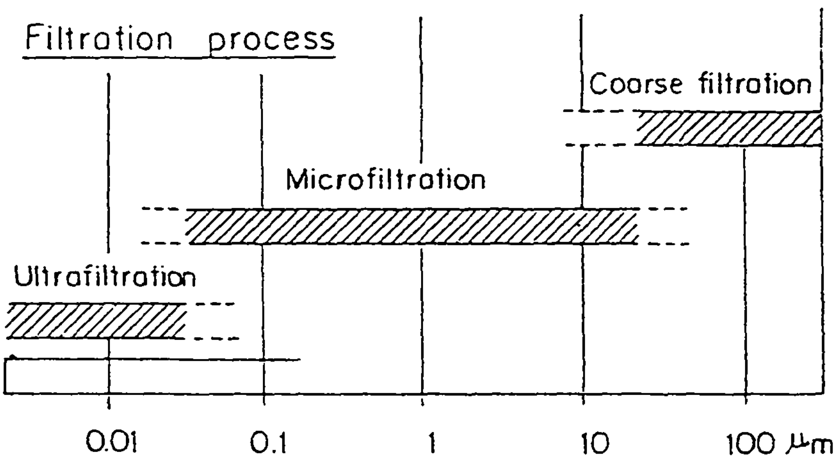


Figure 2 Separation range of microfiltration

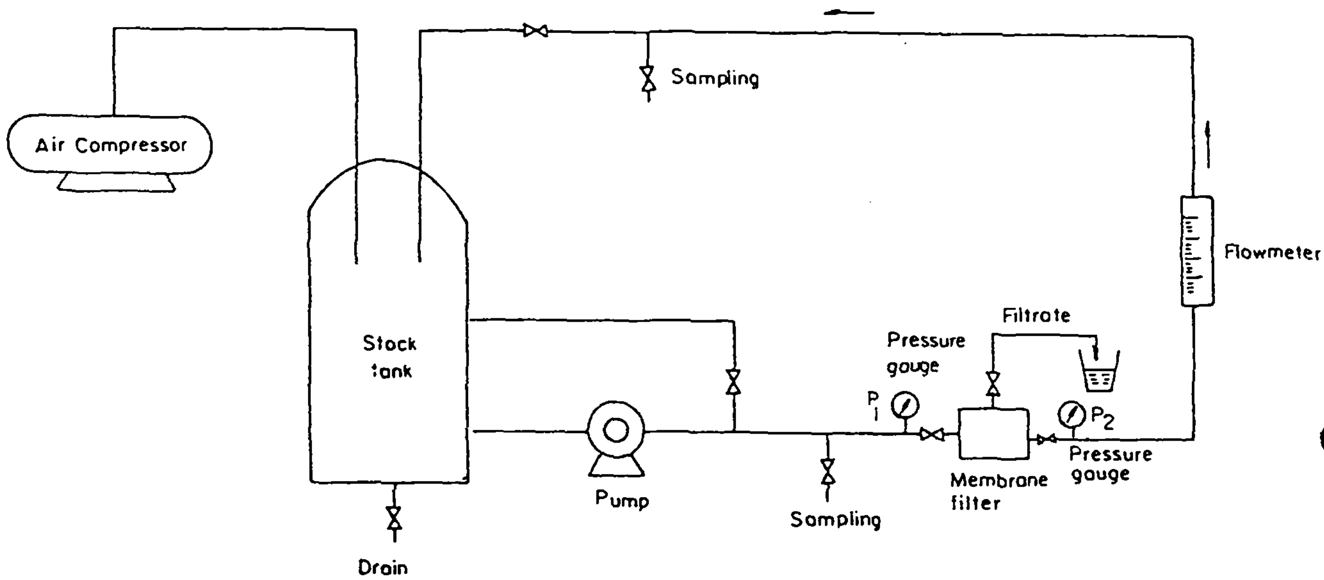


Figure 3(a) Experimental setup for crossflow microfilter performance

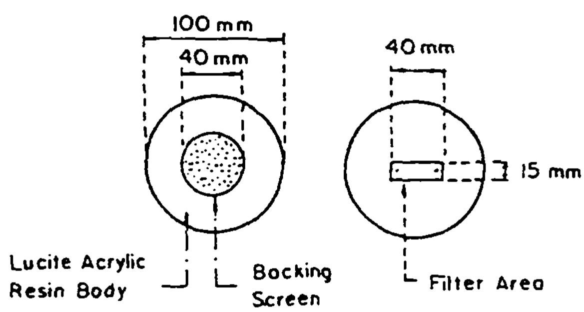


Figure 3(b) Details of membrane filter

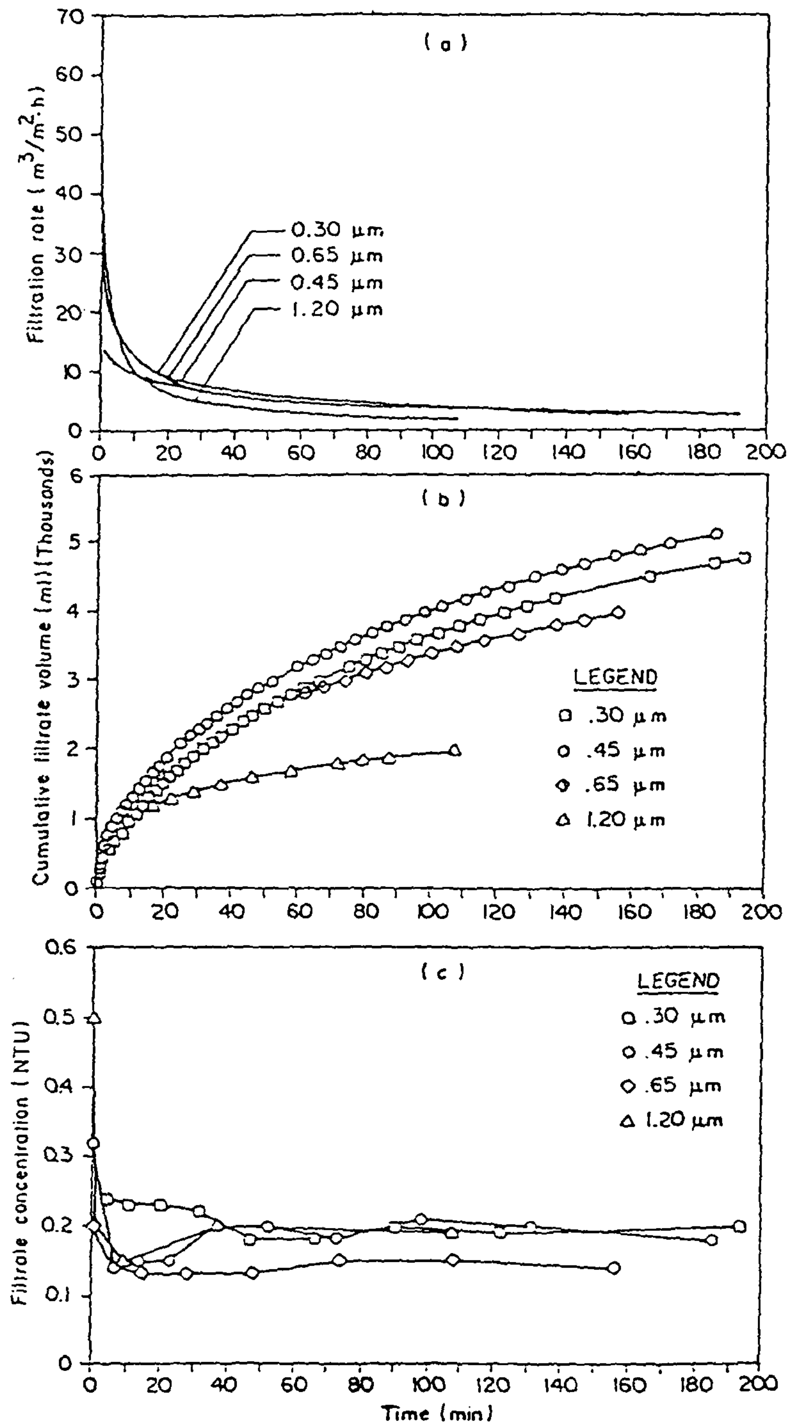


FIGURE 4 : Effect of Membrane Pore Size on (a) Filtration Rate (b) Cumulative Filtrate Volume (c) Filtrate Concentration (d_p = 3.6 um , C_0 = 2.5 mg/L, V = 2.5 m/s , p_1 = 7 psi , p_2 = 2 psi , Kaolin Clay Suspension)

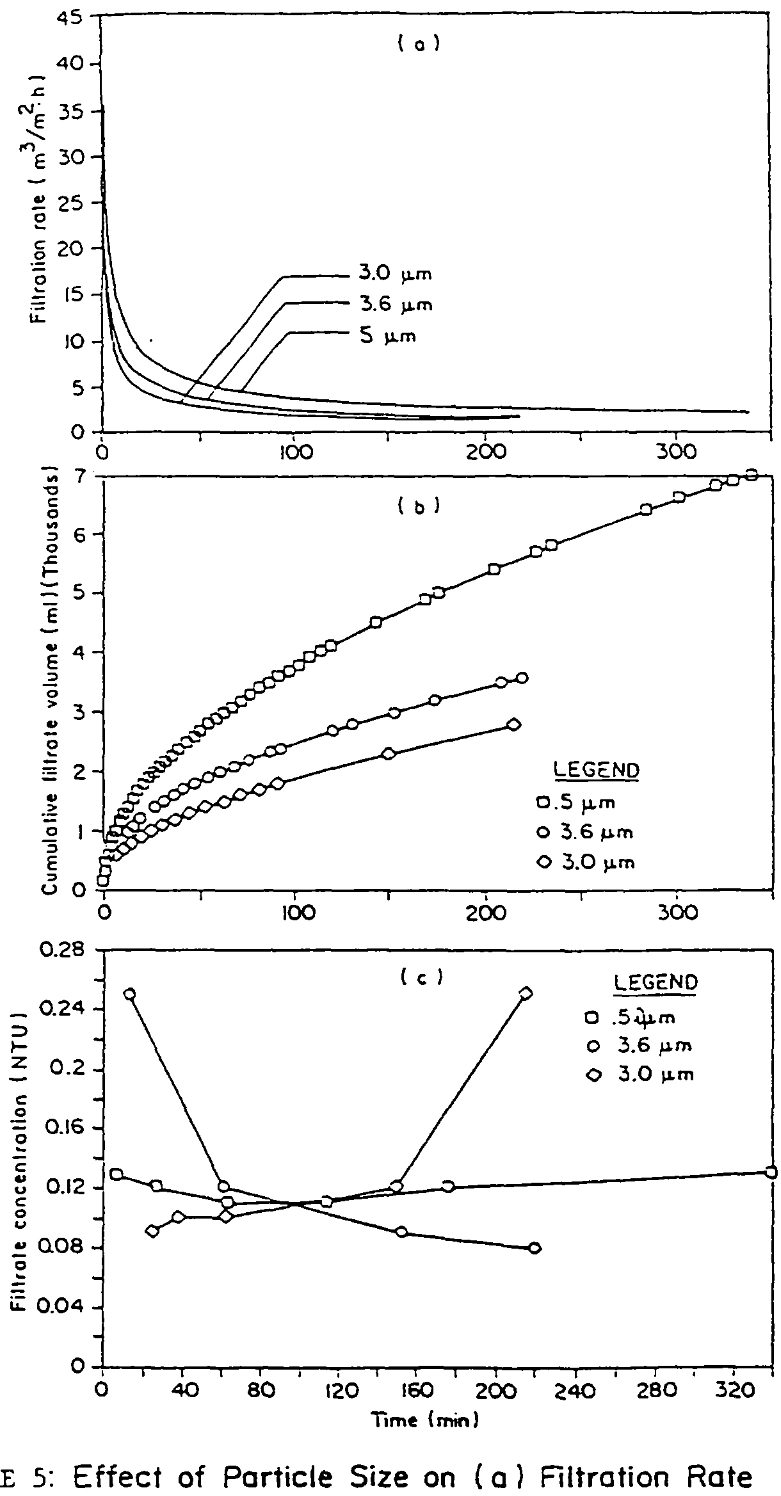


FIGURE 5: Effect of Particle Size on (a) Filtration Rate (b) Cumulative Volume (c) Filtrate Concentration (d_{p_0} = 0.3 u m, C_0 = 100 mg/L, V = 5.37 m/s, p_1 = 24 psi, p_2 = 2 psi, Kaolin Clay Suspension)

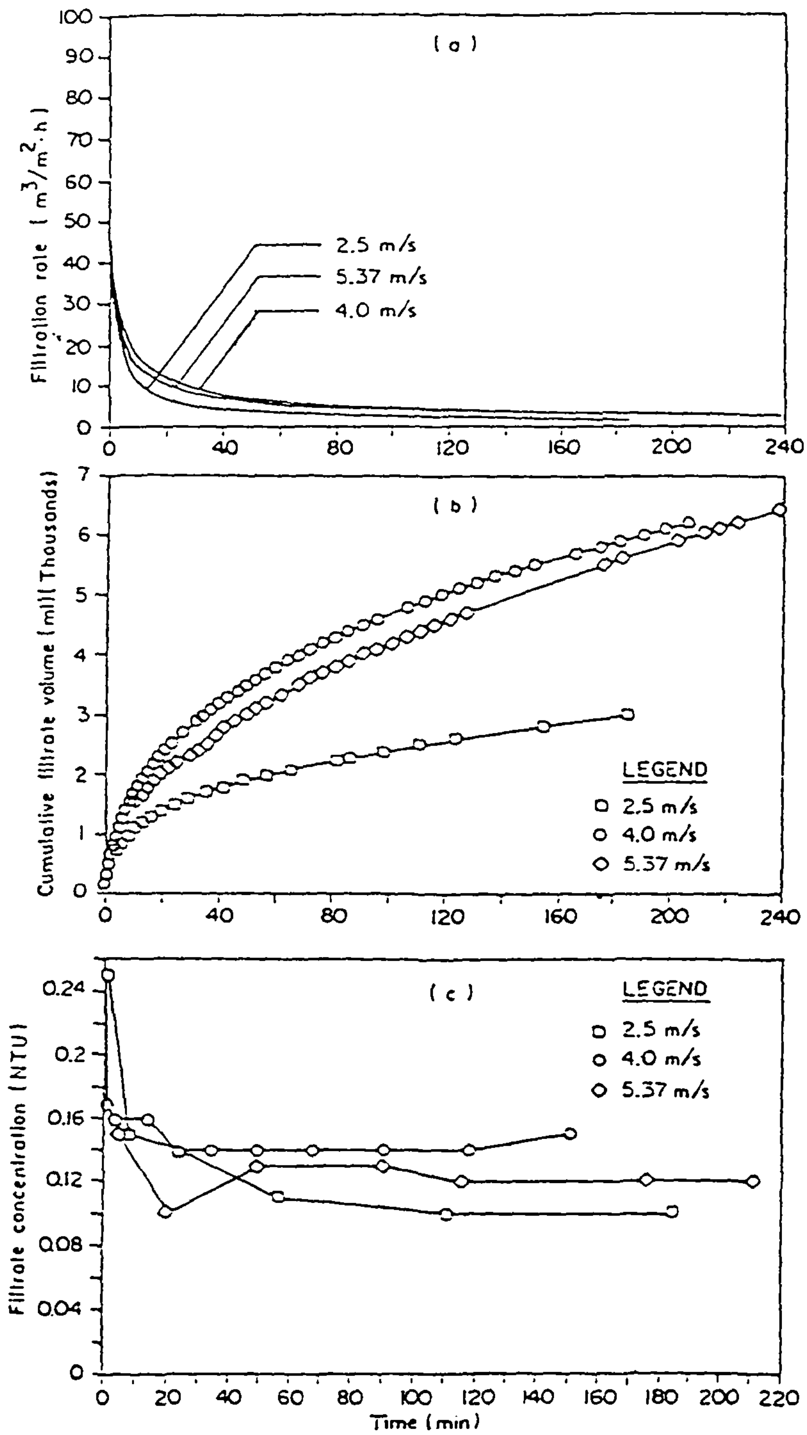


FIGURE 6 : Effect of crossflow velocity on (a) filtration rate (b) cumulative filtrate volume (c) filtrate concentration (d_{po}=1.2um, C_o=25 mg/L, d_p=3 um, P_1^o=24psi, kaolin clay suspension)

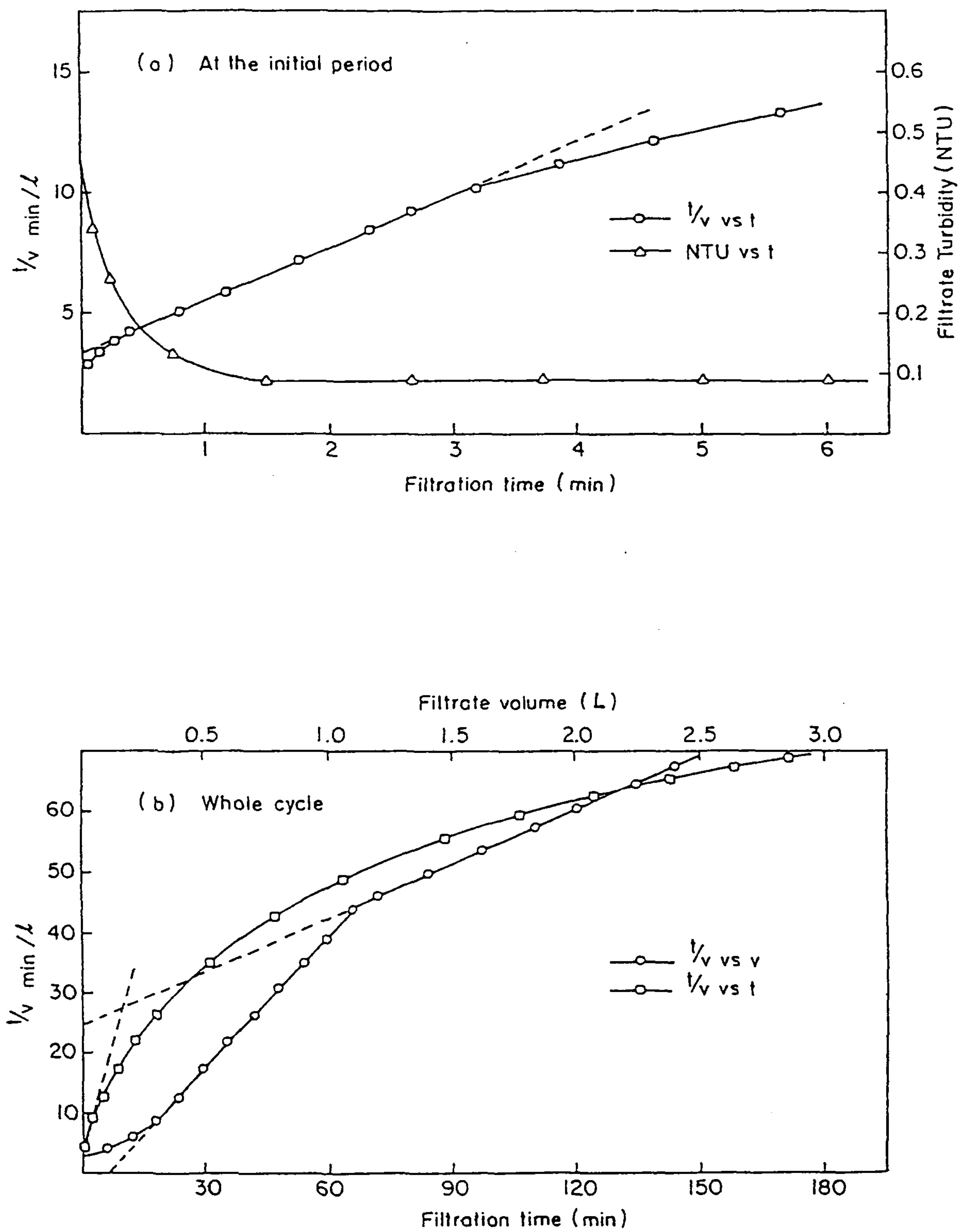


FIGURE 7 : Filtration Performance Curves (d_m = 0.3 μm , d_p = 0.27 μm , v_s = 5.37 m/s , C_0 = 5 mg/l , Δp = 12.5 psi)

Limnological Studies of Lakes and Reservoirs for Waterworks in Thailand

by :

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Abstract

This paper is described about the limnological research taken place in Thailand for water works during two years from August 1983 to July 1985. In this project, 20 reservoirs and 3 natural lakes located all over Thailand were chosen as the subject of research.

In three natural lakes (Phayao, Nong Han and Song Khla Lake), the flora and fauna were very abundant and the dominant organisms were some species of planktonic blue green algae. It has been suggested that they are ranking as eutrophicated lakes. Furthermore, Microcystis aeruginosa of blue green alga was detected the large number of colonies in these lakes and the algal water bloom was frequently formed at dry seasons. Sometimes, a phenomenon of floc carry-over had been occured in sedimentation basin according to the bloom and the formation of mud ball in the sand filter bed of water treatment plant.

These twenty reservoirs will be classified into two types of small scale and large scale reservoirs, respectively. In the small scale reservoirs, the depth was shallow and the amounts of planktonic algae were very abundant and they were ranking as eutrophicated reservoirs. On the other hand, the large reservoirs have more than a billion cubic meters of capacity. Allow-

ing the detention period of inflow water from rivers was very long and the suspended matters were able to precipitate gradually in these reservoirs. The planktonic biota was not so much and the mass was counted low over all. If thesebig scale reservoirs are utilized as the resources of water supply, the good water quality will be obtained and the water treatment will be very easy and ecomonical.

1. Introduction

In Thailand, there are many limnological reports on lakes and reservoirs however the biological basic data are not so much. These basic data are important for planning and maintenance of water treatment plant on water supply.

National Economic and Social Development Board, Kingdom of Thailand (1982) commissioned to Asian Institute of Technology (AIT) to investigate about rehabilitation and development of Bung Boraped and Nong Han Lake. This report is described about plankton of those lakes and resources of water works. Mizuno (1970) investigated about plankton of three lakes and one reservoir in Thailand as a part of section FP (FreshWater Productivity) of IBP (International Biological Programme).

This reserching project was started for the purpose of obtaining limnolo gical data for water supply, especially the biological data on lakes and reservoirs in the whole of Thailand. This report was a part of researching projects supported by Japan International Cooperation Agency (JICA) as the technical co-operation to Chiang Mai University.

2. Materials and Methods

Twenty reservoirs including three lakes (Phayao, Nong Han and Song Khla Lake) and two ponds in the whole country were chosen for our study. The localities of researching points are shown in Fig. 1.

Kitahara's water sampler was used for collecting water at each vertical points and the samples were done to analyze some chemical items and quantitative determination of plankton. The qualitative samples of plankton were collected by plankton net (Rigosha NXX 25).

Some characteristics of water quality (pH, D.O, and Conductivity) were directly measured in the field, and the other were measured in the laboratory. The items of water quality were determinated according to Standard Method of Drinking Water Examination. Especially, total nitrogen and phosphorus were done by the document of Japanese Environmental Agency.

3. Results and Discussion

Natural Lakes ;All three lakes are very shallow and the average of water depth are about two meters. As a result of such shallow depth,several problems were occurred as follow. The sediments from the high turbid river were not able to settle to the bottom of lakes. Furthermore, the sediments at the bottoms of these lakes were easily disturbed by the windand tides. Consequently, these lakes are presented high turbidity and maintains a yellowish brown color. The planktonic population was very abundant,especially blue green algae (Cyanophyceae) and green algae (Chlorophyceae) were detected as dominant species. Those lakes will be ranking as eutrophicated aquatic area.

Fig.2 shows the sampling station and Table 1 the planktonic population in Song Khla Lake located in southern part of Thailand. The lake is directly connected to Gulf of Thailand and the most area become to brakish water in dry season. However, the oceanic plankton were not observed even No.9 station owing to water flood after heavy rain in this researching time. In this lake, the dominant species are almost the blue green algae (Anabaena sp., Lyngbya sp., Spirulina sp. and Phormidium tenue etc.). It is considered that the unique phenomenon such as accumulating in No.7 station of middle area is occurred by flood.

Table 2 shows the planktonic biota on Phayao located in northern Thai and Nong Han Lake in northeastern Thai. Two lakes were detected Microcystis aeruginosa (blue green alga) as the dominant species. For water bloom of this species in Phayao Lake, the trouble of carry-over in sediment basin and formation of mud ball in rapid sand filter basin have occurred through process of water treatment plant, respectively. So that, the velocity of filtration is decreased by clogging the sand layer in water treatment plant.

Reservoir: Table 3 shows the planktonic biota in the four large scale reservoirs in northern Thailand and one reservoir located on Phuket Island in southern Thailand. Bhumipol Dam is one of the biggest reservoirs in Thailand and the capacity can reach about 3.6 billion cubic meters. The population of plankton at this dam was very abundant and Ceratium hirundinella, Peridinium sp. and Anabaena sp. were observed as dominant species. It is considered that the cause of population is due to waste water from the municipalities in Chiang Mai and Lamphun area.

On the other hand, these three reservoirs weren't remarkablly polluted as those in the big municipality and industrial area in catchment basin. The planktonic population was not abundant. Peridinium sp.(Dinophyceae) and Anabaena sp. were detected as dominant species.

In the case of the big reservoirs, the detention period is long enough so that the numerous suspended solids could settle to the bottom. In fact, these big reservoirs had low turbidity. However, the total nitrogen and phosphorus were detected more than the indicated values of eutrophication (T-N 0.2 mg/l, T-P 0.02 mg/l) as shown in Table 4.

Table 5 shows the planktonic biota of reservoir in northeastern area. Kra Narn Reservoir using as the water sources of slow sand filter system for purifying is a small scale reservoir. The biomass was comparatively abundant, however the purifiedwater was very good quality and the turbidity was less than 2 degrees. The planktonic population of other two reservoirs weren't so much and they were ranked to the level of oligo- and meso-trophicated reservoir.

At Lam Ta Khong Dam located in the middle eastern area near Nakhon Ratchasima (Korat), a feasibility study for constructing water treatment plant on 1985 had been taken place. Table 6 shows the planktonic population and Table 7 the chemical data in Lam Ta Khong Dam. The most dominant species was Phormidium tenue of blue green algae and it was same species the caused musty odor troubles in the world. The organism was observed 6,900 n/ml, however the musty odor was not noticed in Lam Ta Khong Dam. Synedra acus of diatom was detected 500 n/ml, and the mass was not enough to cause the filter clogging. In the bottom layer, the turbidity and total phosphorus values were high. On the other hand, the surface and middle layer were low, respectively. In general, if the annual average of turbidity is less than 10 degrees in water resources for water supply, it will be possible to introduce the slow sand filter system for treatment plant. Fortunately, the turbidity in the present research of Lam Ta Khong Dam was less than 10 degrees. So it is considered that the level of turbidities level is low enough to introduce the slow sand filter system as water treatment plant. In Thailand, this system has already been introduced 34 facilities at the small scale and rural waterworks.

Acknowledgement

Authors were possible to obtained considerable cooperation from many staffs of PWA (Provincial Water Works Authority), EGAT (Energy and Gas Authority of Thailand), Department of Irrigation, National Environmental Baord and Department of Environmental Engineering (Chiang Mai University) for this research project. We are deeply indebted to all of them for their considerable asistances.

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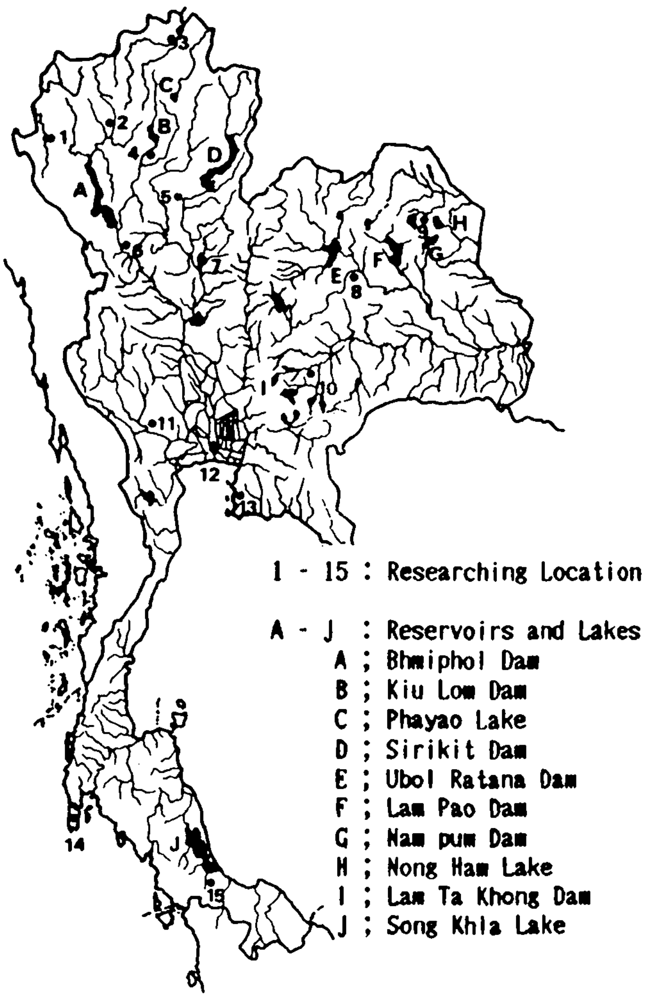

Fig.1 Researching Localities of Lakes and Reservoir
(August, 1983 - July, 1985)

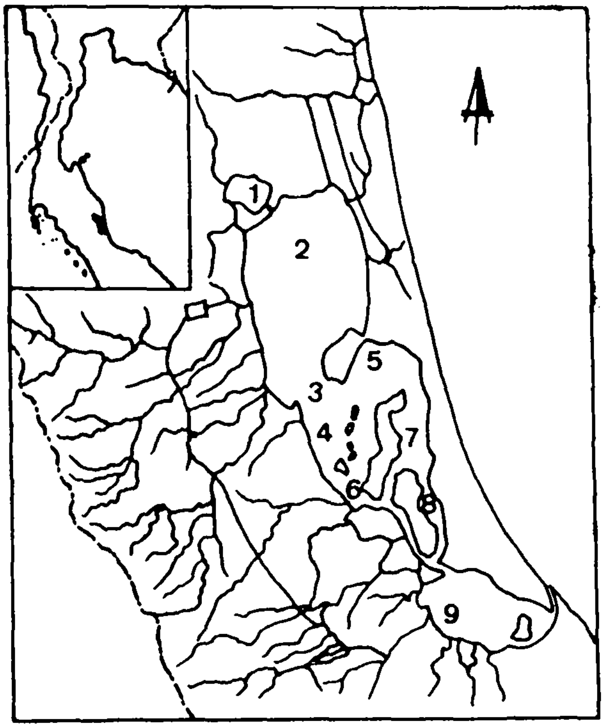

Fig. 2 Sampling Station of Song Khla Lake on Southern Thailand (14－21, January, 1985)

Table 1 Planktonic Population of Song Khla Lake (14－21 Jan. 1985)

N/ml

Station	1	2	3	4	5	6	7	8	9
Flora									
Cyanophyceae									
Anabaena sp.		450	180	580	4,400	780	24,000	500	1,900
Lyngbya sp.		2,600	500	2,100	1,300	1,200	40,000	1,300	450
Merismopedia glauca							2,500		
Microcystis flos-aquae							1,500		25
Phormidium tenue		50	50	50	4,800	150	35,000	1,500	380
Spirulina sp.		150	180	330	1,400	180	40,000	500	130
Euglenophyceae									
Trachelomonas sp.	50			25			100		
Dinophyceae									
Peridinium sp.	25						150		
Chrysophyceae									
Mallomonas sp.			50						
Bacillariophyceae									
Navicula pupula		25		25		25	50		
Nitzschia spp.	50	100				25	100		
Synedra sp.		25	25	50		50			25
Chlorophyceae									
Ankistrodesmus falcatus						25			300
Coelastrum reticulatum			25				50		
Pediastrum simplex		25					50		
Scenedesmus ecornis							150		

Table 2 Planktonic Population of Phayao and Nong Han Lake

Name of Lake	Phayao 3 May '84	Nong Han 1 March '85
Flora		
Cyanohyceae		
Anabaena spp.	+	+
Aphamixomenon sp.	+	
Lyngya spp.	++	
Microcystis aeruginosa	+++	+++
Chrysophyceae		
Ochromonas sp.	++	
Euglenophyceae		
Trachelomonas sp.	+	
Bacillariophyceae		
Achnanthes sp.	+++	
Melosira granulata	+	
Chlorophyceae		
Ankistrodesmus falcatus	+	
Micrasterias faliacea	+	+
Pediastrum simplex	r	
Staurastrum freemanii var. *nudiceps*	+	
Streptonema sp.		++
Fauna		
Rotatoria		
Brachionus falcatus	+	
B. forficula		+
Keratella vulga	r	
Polyarthra trigla	+	
Copepoda		
Cyclops sp.	+	
Nauplius	+	+

+++ : very abundant, ++ : abundant, + : common, r : rare

Table.3 Plankton of Reservoirs on Northern Area and Phuket Island (1985)

Reservoir(Date)	1/30	3/20	4/30	4/29	3/17
	Bhumipol	Mae Paum	Sirikit	Kiu Lom	Kuwan Ba
Flora					
Cyanophyceae					
Anabaena sp.	++		+	++	
Lyngbya sp.	+			rr	
Microcystis aeruginosa	+		rr		
Dinophyceae					
Ceratium hirundinella	+++				
Peridinium sp.	++	r	+	+++	++
Xanthophyceae					
Botryococcus braunii				rr	+
Chrysophyceae					
Dinobryon bavaricum	+				+
D. sertularia	+				r
Chlorophyceae					
Staurastrum spp.			+		+
Fauna					
Protozoa					
Difflugia sp.			+	++	rr
Rotatoria					
Keratella cochlearis		++	rr		
Polyarthra trigla		r		+	+
Copepoda					
Cyclops sp.	++			r	
Nauplius	++				

+++ : very abundant , ++ : abundant , + : common , r : rare , rr : very rare

Table.4 Water Quality of Three Reservoirs on Northern Thailand (1985)

Sampling Station	Mae paum(9m)			Srikit(56m)			Kiu Lom(12m)		
Date	20 Mar. '85			30 Apr. '85			29 Apr. '85		
	sur.	mid.	bot.	sur.	mid.	bot.	sur.	mid.	bot.
W.T. (℃)	27.5	25.9	24.3	31.9	27.4	27.1	30.0	26.7	25.2
pH	6.9	6.6	6.6	8.3	7.9	7.8	8.3	7.6	7.9
Turbidity	1.4	1.6	4.8	3.0	2.8	5.0	2.2	3.5	9.0
Hardness (mg/l)	54	54	80	98	102	104	128	134	134
D.O. (mg/l)	7.3	5.1	2.1	9.4	4.9	2.5	9.0	5.2	2.4
Alkalinity (mg/l)	28	22	32	48	52	56	72	82	82
T O C (mg/l)				3.2	3.3	4.0	7.4	7.9	9.2
T-P (mg/l)	0.028	0.025	0.048	0.028	0.040	0.043	0.033	0.060	0.22
T-N (mg/l)	0.63	0.71	1.3	0.43	0.53	0.78	0.94	0.82	1.7

Table 5 Planktonic Population of Reservoirs on Northeastern Area
(1 March, 1985)

sample station	Ubol Ratana Dam	Kra Narn slow sand	Lam Pao Dam	Nam Pung Dam
Flora				
Cyanophyceae				
Anabaena sp.	++	++		
Microcystis aeruginosa	++		++	+
Oscillatoria spp.	+	r	r	
Dinophyceae				
Peridinium sp.	r	+++	r	rr
Chrysophyceae				
Dinobryon serutularia	r	++	r	
Xanthophyceae				
Botryococcus braunii	+	+	rr	+
Chlorophyceae				
Desmidium beileyi				++
D. swartzii				+++
Dictyospherium pulchellum			++	
Micrasterias faliacea				+
Staurastrum freemanii				
var. nudiceps			++	+
S. subscolopacinum				++
Fauna				
Rotatoria				
Hexarthra mira		+		+
Keratella cochlearis		+	rr	r
Polyarthra trigla	r	r		+
Copepoda				
Nauplius		+	rr	r

+++ : very abundant, ++ : abundant, + : common, r : rare, rr : very rare

Table.6 Plankton of Lam Ta Khong Dam (11th May '85)
(N/ml)

Sampling Station	Station 1			Station 2		
	1 m	9 m	18 m	1 m	10 m	19 m
Cyanophyceae						
Anabaena sp.	150	25		50	25	
Oscillatoria sp.	100	25		250	150	50
Lyngbya sp.	150	200				
Phormidium sp.	6900	4300	10	4800	1600	400
Dinophyceae						
Ceratium hirundinella	25			75		
Bacillariophyceae						
Synedra acus	500	200	150	250	500	50
Chlorophyceae						
Ankistrodesmus sp.	150					
Chlamydomonas sp.	50	50		50		

Table 7 Water Quality of Lam Ta Khong Dam (11th May '85)

Sampling Station	station 1			station 2		
	1m	9m	18m	1m	10m	19m
pH	6.9	6.6	6.3	6.8	6.8	6.6
Total Solid (mg/l)	201	199	228	195		222
Alkalinity (mg/l)	122	120	150	121	121	155
Chloride (mg/l)	26.7	21.1	20.2	22.0	21.3	20.4
Total Phosphorus(mg/l)	0.028	0.028	0.13	0.018		0.18
C O D (mg/l)	13.5	11.5	9.2	8.3	6.1	11.5
Calcium (mg/l)	67.5	68.8	72.5	67.5	68.8	87.5
Turbidity	5	6	16	8	6	14

METASTABLE STATE OPERATION FOR SEPARATION
– Fluidized Bed Pellet Separator –

by :

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1. Introduction

Most of water treatment systems address to remove impurities as solid state final products. The conventional water purification systems are usually composed of several steps of processes to remove suspensions such as coagulation, flocculation, sedimentation, and filtration with complicated slugde treatment processes. If we can have much simpler and efficient processes for the separation based upon very much new concept, future composition of water treatment will be changed drastically.

As one of such new category treatment processes, the authors like to propose a process of "Metastable state operation" for the removal of clay suspensions.

2. Concept of Metastable State Process

A supersaturated solution for a labile concentration forms a precipitate spontaneously. A metastable solution may form no precipitation over a relatively long period. It needs an "Aging" time to reach an equilibrium state.

However, if a large amount of the same kind of solid phase is introduced into a metastable state, precipitation of solute upon the introduced solid surface occurs very quickly and dense solid aggregates generate very often.

This kind of treatment is already devised for hard water softening in Netherlands[1]. This kind of process has much wider range of applications, if we handle "Metastable state" with much broader sense of understanding.

Here, the metastable state products are considered to be those which have already an elementary structure of the final aggregate, but do not have enough size and/or concentration to make the aggregate instantly by themselves. We like to call the metastable state products simply as the "elementary particles" in the following discussion. Therefore, if high concentration solids which have the same activity to the metastable state compound, i.e. the elementary particle, are introduced into the metastable system, very quick association of the elementary particle with the active solids surface will occur in accordance with the mode of one by one attachment of the elementary particle onto the solids. Random collisions among the elementary particles to make flocs introduce large void volume into the produced aggregates. However, this mode of one by one attachment of the elementary particles onto the introduced solid particles scarcely causes bulky agglomerates. Therefore, the resulted aggregates would be very dense pellets arranging the elementary particles regularly around active core materials.

The kind of process can be used for the removal of clay and biological cell suspension separations, phosphate removal and so on as well as hard water softening which has already been used in Netherlands[1].

In this paper, the authors like to handle the case of clay suspensions. In the case, primary floc particles which are generated by the addition of coagulant to a suspension are considered to be the elementary particles. The collision of the elementary particle with grown pellets brings about metastable states separation as will be discussed in the following sections.

3. Experimental Apparatus and Method[2]

Figure 1 shows the experimental apparatus to develop a fluidized pellet separation process of clay suspensions in Hokkaido University.

For the removal of clay suspensions, "the metastable state operation" is carried out by using a fluidized bed as the following procedures; 1. The least amount of metal coagulant such as aluminum salts is added at neutral pH to neutralize surface potential of clay so as to make direct collisions of clay particles possible. In the flash mixer the elementary particles i.e. micro flocs, generate. 2. At the bottom inlet of the fluidized bed, weak anionic organic polymer (Accofloc A-110PWG) is added to give strong binding forces to the micro flocs. The micro flocs which attached the organic polymers behave as the elementary particle in the progress of the process. 3. The elementary particle is introduced into the fluidized pellet bed and attaches onto the pellets one by one. In the first stage, a fluidized bed of pseud-pellets is made prior to the introduction of the elementary particles by way of the conventional suspended solids contact method for flocculation by using polymer flocculant. The fluidized bed operation is started from low rate upflow condition and increases their flow rate gradually in keeping pace with maturing of pellet flocs. Finally, when it reaches to the upflow rate of 30 cm/min after 30 minutes operation, constant rate operation is carried out. 4. So as to make a concentric size increase of the mother pellet flocs with regular attachment of the elementary particles, a suitable intensity of the paddle agitation is given to break down irregularly grown part of the pellets. By the operation the structure of grown pellet becomes very much tough and spherical. Therefore, simple drawn out of the pellets from the fluidized bed overflow to a sludge bed enables to dewater the pellet sludge very easily and quickly. 5. The above mentioned experimental procedures are repeated with different combination of operation conditions with respect to aluminum and polymer dosages, raw water concentration, rate of agitation, and shapes and pitches of

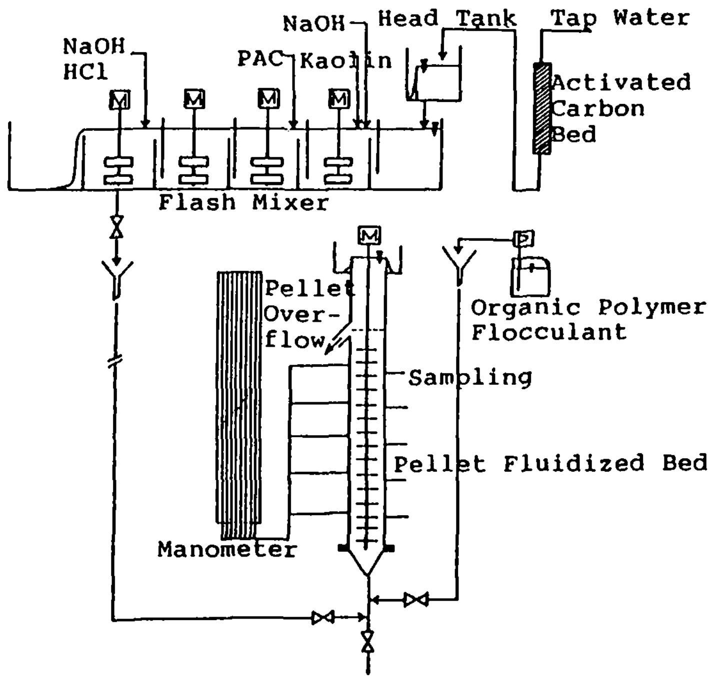


Figure 1 Schematic Diagram of Experimental Apparatus

agitation paddles. 6. Measurements are carried out with the concentration of influent and effluent, variation of pressure drop through the fluid bed, and natures of generated pellet such as pellet diameter distribution and density both of which control the settling velocity.

4. Result of Experiments

Figure 2 shows the inlet and outlet suspension concentrations. These experiments are carried out to develop a suitable process to use in the high turbidity regions such as China main land[3)] and South-East Asia. As shown in this figure, high concentration raw water is treated effectively with a very high overflow rate of 30 cm/min (5 minutes detention time) and very clear overflow.

Pressure drop throughout the bed is measured with time for 6 hrs in keeping pace with the growth of pellet diameter in the

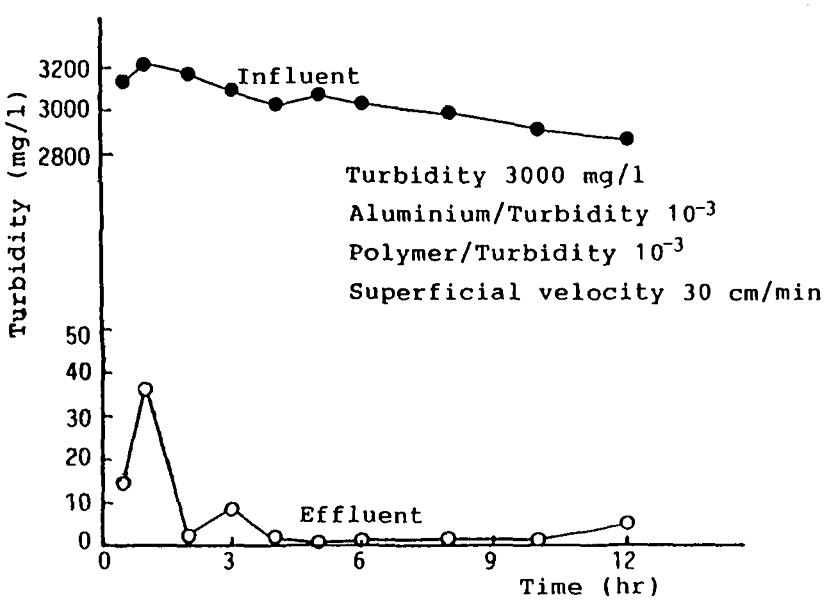


Figure 2 Veriation of Turbidity with Time

bed. It reaches steady state after about 6 hrs operation period (Figure 3). The total head loss is as small as 15 cm-H_2O. For both of the transitional and the steady state conditions, measurements of longitudinal pellet diameter distribution with various time of duration are performed as shown in Figure 4. After 6 hrs, vertical pellet diameter distribution is not changed. It means that the growth of pellet is balanced with breakdown and discharge of pellets.

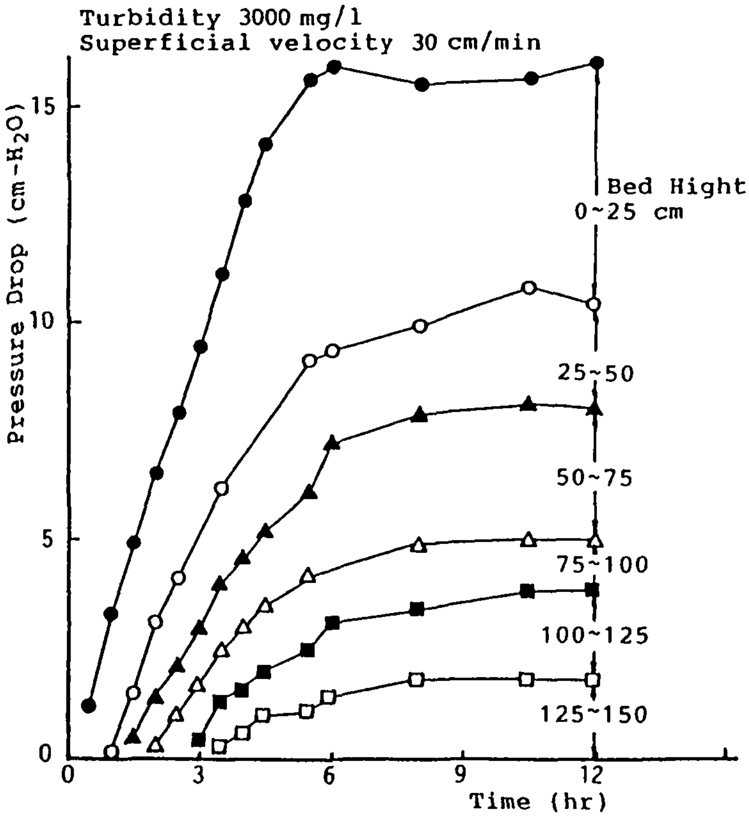


Figure 3 Veriation of Pressure Drop with Time

Figure 5 shows the relationship between pellet diameter and effective pellet density. This plot shows that pellet density is almost constant with very narrow diameter distribution range in comparison with conventional floc particles. For the comparison, Tambo and Watanabe's floc density function[4] is also plotted in the figure. The comparison of the nature for both floc and pellet shows that effective density of pellet is nearly one order higher than the ordinary floc density of the size. The generated large size and high density spherical pellet is shown in Photograph 1.

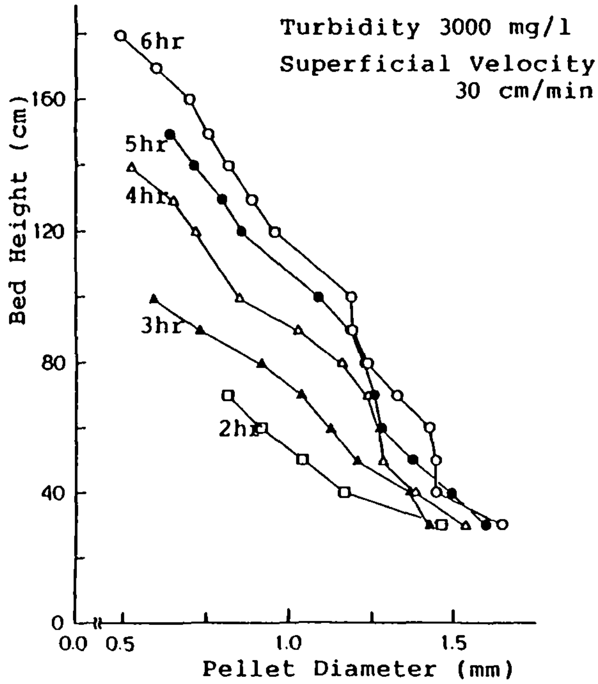


Figure 4 Veriation of Pellet Diameter Distribution in Bed with Time

From experiments of the various conditions, the following characteristic results are revealed; 1. Pellet density and size are effected by the rate of agitation and pitch of paddles. The higher rate of agitation generates smaller diameter but higher density pellets. Large pitch paddle arrangement with the same energy dissipation rate generates smaller pellets by the reason of more uneven distribution of agitation intensity which may yield much stronger breakage force. 2. In the case of a little lower turbidity such as 200 mg/l, it is necessary to increase polymer dosage ratio on the base of inflow turbidity. It is to say that for 3000 mg/l raw water, optimum polymer turbidity ratio is the order of 10^{-3} but for 200 mg/l turbidity the ratio should be increased as high as 10^{-2}. The aluminum turbidity ratio is the same for both cases. However, if

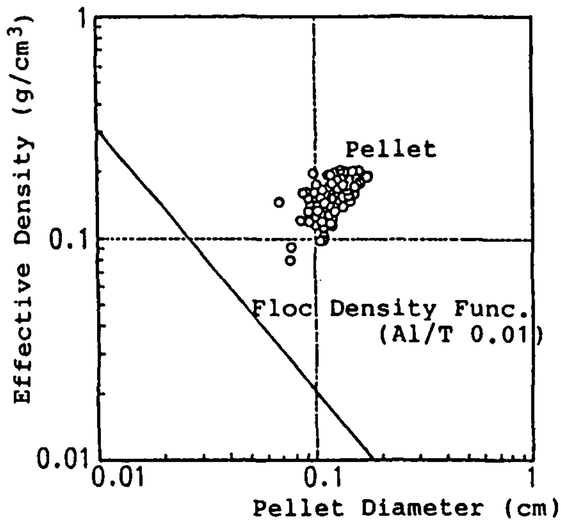
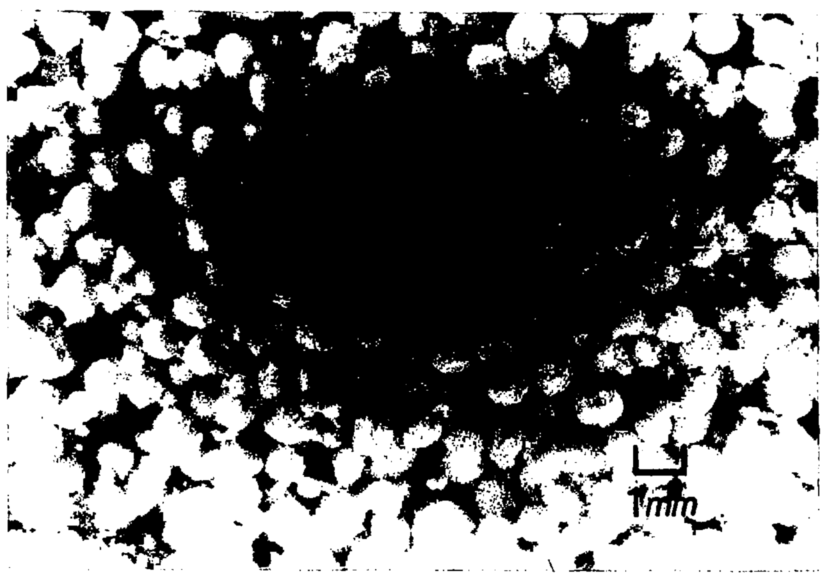


Figure 5 Pellet Density and Ordinary Floc Density



Photograph 1

man calculates the polymer ratio on the base of fluidized bed concentration, there is no difference for both cases. It means that the added polymer are used to keep pellet conditions in the fluidized bed.

As it has been mentioned, the steady state of fluidize bed is kept on the balance of growth and breakdown of pellets. To evaluate the relationship quantitatively, an experiment of fluidized bed operation without influent turbidity was carried out as shown in Figure 6. It shows that the breakdown of pellet continuously occurs in the bed and smaller pellets are generated. Decreasing mean pellet size by the breakage decreases the pressure drop. However, bed height are not greatly changed by the higher expansion of the smaller size pellets in the bed. Even under the operation of non inflow turbidity, a high effluent concentration is observed continuously for long time. These phenomena can be explained by the reason that there are two types of breakdown of pellet particles. One is generation of smaller size pellets by the division of lager pellets. Resulted smaller pellets consist fluidized bed again. Another mode of the breakdown is abrasion of pellets which causes increase of outflow turbidity by the introduction of minute fractures. Under the steady state conditions, the former category divisions keep up

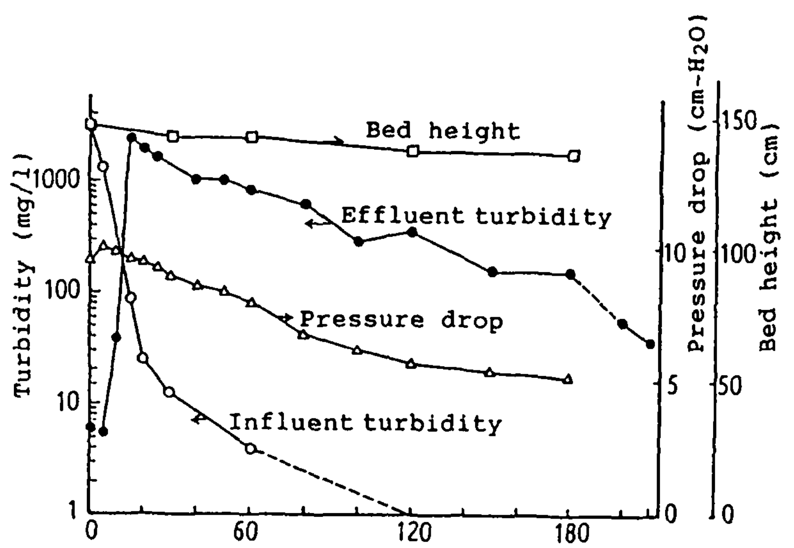


Figure 6 Behavior of Pellet Fluidized Bed without Influent Load

the number of pellet particles in the fluidized bed with compensating the number of loosed pellet in sludge in due course of the operation. The latter breakdown contributes the finished water turbidity.

The above mentioned phenomena are highly effected by the point of

Table 1 Effect of Polymer Dosage Point

Dosage Point	Effluent Turbidity (mg/l)	Effective Density (g/cm^3)
Bottom of Fluidized Bed	<10	0.15
Bottom Mixer	25	0.11
Flash Mixer	25	0.08
Flash Mixer with Flocculator	Pellet is not produced	

polymer introduction. Table 1 shows the conditions of operation to generate high density pellets and good effluent turbidity. The shortest duration between addition of polymers to micro flocs to generate the elementary particles and adhesion of the elementary particles onto the fluidized pellet are requested. No preliminary mixing of polymer with micro flocs are recommended. Flocculator after the addition of polymer cannot generate any acceptable good pellet bed.

5. Conclusion

By the proposed fluidized pellet separation method based upon the idea of metastable state separation a superb effective separation was obtained. By a series of experiments for high turbidity suspensions, raging from hundreds to thousands mg/l concentration, it is proved that in a few minutes detention time without any additional difficulties of sludge treatment suspension is treated with good effluent.

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GRAPHIC REPRESENTATION OF PIPE NETWORKS ANALYSIS

by :

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1. Introduction

This paper proposes a new idea of graphic analysis and its calculation method for pipe networks. There are two purposes for the analysis of pipe networks. The first is to decide the location and caliber of trasmission and distribution pipes, the scale of pumping stations and distribution reservoirs, when the waterworks facilities are planned and designed. The second is to find the method how to control the existing or planning waterworks facilities, that is, to gain the control information for transmission and distribution facilities. This study deals with the analysis of pipe netwoks and its graphic expression considering the second purpose.

In case of present pipe networks analysis, its results are shown numerically. However, as the actual consumptions are varying hourly, it is necessary to know the state of pipe networks at each time for its control. Nowadays it is reqired the new pipe netwoks analysis method which can calculate the varying conditions of pipe networks, and express its output graphically. Also it is better to use microcomputers instead of large computers, because microcomputers are becoming readily available to many engineers.

Therefore, we propose the method of pipe networks analysis considering hourly fluctuation of flow, and the method of graphic expression by using a microcomputer whose storage is 640K bytes.

2. Method of Pipe Networks Analysis

Since the method of analyzing the flows in pipe networks was developed by Hardy Cross[1], the numerical methods have been performed by large computers. There are two methods for pipe networks analysis. The one is the flow correction method which is calculated unknown flow in each pipe, the other is the energy head correction method which is calculated unknown energy head at each node. In this section, we propose the latter method which has two basic equations, that is, 1) energy equations and 2) flow continuity equations.[2),3)]

1) Energy equations

The head loss of pipe between node i and j is represented the difference of energy head at each node.

$$H_{ij} = E_i - E_j \qquad \cdots\cdots (1)$$

where H_{ij} ; head loss of pipe between node i and j

E_i ; energy head at node i

E_j ; energy head at node j.

Suppose Q_{ij} is the flow rate in pipe between node i and j. The relation of Q_{ij} and H_{ij} is shown in Eq. (2) considering the direction of flow.

$$Q_{ij} = R_{ij} | H_{ij} |^{a-1} H_{ij} \qquad \cdots\cdots (2)$$

Substituting Eq. (2) into Eq. (1) yields Eq. (3).

$$Q_{ij} = R_{ij} | E_i - E_j |^{a-1} (E_i - E_j) \qquad \cdots\cdots (3)$$

In case of using Hazen-Williams formula,

$$R_{ij} = 0.27853\, C\, D_{ij}^{2.63} L_{ij}^{-0.54} \qquad \cdots\cdots (4)$$

$$a = 0.54 \qquad \cdots\cdots (5)$$

where C ; Hazen-Williams friction coefficients

D_{ij} ; inside diameter of pipe between node i and j

L_{ij} ; length of pipe between node i and j

2) Flow continuity equations

The flow continuity equation at node i is represented by Eq. (6).

$$\Sigma\, Q_{ij} + q_i = 0 \qquad \cdots\cdots (6)$$

where q_i = consumption in node i

As the result, we can gain simultaneous equations by substituting Eq. (3) into Eq. (6). The number of simultaneous equations is (N - M), where N means the number of nodes and M means the number of inflow nodes (for example distribution reservoirs) to the pipe netwoks. As these simultaneous equations are non-linear, these can be approximated by using the Newton-Raphson's method. Then we can solve the simultaneous linear equations. These process is shown in Fig.1.

3. Hourly Fluctuation of Consumption Considering Regional Characteristics

In case of present pipe networks analysis, the hydraulic pressure and velocity of flow in each pipe and pump are only calculated after supposing the outflow (i.e. water consumption) of each node at two assumed cases, which are the most critical conditions; one is the maximum hourly flow in a planned maximum daily consumption and the other is the planned maximum flow included fire fighting water.[4] However, as the actual consumption is varying hourly, it is necessary to know the state of flow in pipe networks at each time for the control of waterworks facilities. Therefore it is required to estimate the hourly fluctuation of consumption. This consumption is not only influenced by the regional characteristics, but also the feature in each district (i.e. node).

These caracteristics of consumption will be measured by a flow meter. But this measurement needs lots of cost and time. For these reasons it is better to express the fluctuation of consumption with some patterns. For example, these patterns can be shown in Fig. 2. There are mainly 3 patterns, that is, the domestic use pattern in residential district, the business and commercial use pattern, and the industrial use pattern. According to above patterns, the hourly fluctuation of consumption at each node can be roughly applied. In next section, this idea is applied to the computer simulation considering hourly consumption.

4. Graphic Expression of Calculation Results

Nowadays, the calculation results of pipe networks analysis are shown numerically. However these results don't appeal to us rapidly for the critical conditions as follows; the node whose hydraulic pressure is high or too low, the pipelines which have a risk of cavitation because of high velocity, in addition, the pipelines which have the water quality problems (especially residual chlorine and dead water) because of too low velocity.

Therefore it is required to express these results graphically. We propose one idea of graphic expression by using a microcomputer whose storage is 640K bytes, and also considering hourly fluctuation of flow.

1) Colorful expression of critical conditions

As we mentioned above, the critical conditions of pipe networks are the hydraulic pressure i.e. effective head at each node and the flow velocity in each pipeline. Now we determined the colour of each node and pipeline as follows.

a) Color of node

Red color : effective head is more than 7.5 kg/cm^2.

Yellow color : effective head is between 4.0 kg/cm^2 and 7.5 kg/cm^2.

Green color : effective head is between 1.5 kg/cm^2 and 4.0 kg/cm^2.

Blue color : effective head is between 0.0 kg/cm^2 and 1.5 kg/cm^2.

White color : effective head is less than 0.0 kg/cm^2.

b) Color of pipeline

Red color : flow velocity is more than 6 m/s.

Orange color : flow velocity is between 4 m/s and 6 m/s.

Yellow color : flow velocity is between 2 m/s and 4 m/s.

Green color : flow velocity is between 0.3 m/s and 2 m/s.

Blue color : flow velocity is less than 0.3 m/s.

2) Method of graphic representation

The method of graphic representation using a microcomputer consists of next 5 steps in Fig. 3.

Step 1 : Input the pipe networks system

Step 2 : Estimation of hourly consumption at each node.

Step 3 : Calculation of energy head at each node and flow velocity in each pipeline.(by using the Newton-Raphson's method)

Step 4 : Graphic expression of calculation results.

Step 5 : Repeat the procedure (Step 2 to 4) until the hourly fluctuation of consumption is calculated.(for example 24 hours in a day)

Fig.4 is one of calculation results of our model case and its graphic expression. This model consists of 19 nodes, 24 pipelines, and 6 loops and besides it has one service reservoir and one pumping station. This graphic expression is shown at every hour, so we can catch the critical conditions of pipe networks system. In addition, the flow in each pipe line is not static, it looks as if it is moving toward the direction of pipe flow on the graphic display.

Lastly, above pipe networks analysis and graphic expression program written in BASIC language is shown in Appendix. This program can express 30 nodes and 20 loops on the maximum, in case of using a graphic display which has 640*400 dots area.

5. Conclusion

This paper proposed the graphic expression method of pipe networks analysis considering hourly fluctuation of flow. With this computer graphic simulation, it is possible to distinguish colorfully the critical conditions as follows; the nodes which have the risk because of high hydraulic pressure or too low, the pipelines which have the risk of cavitation because of high velocity, and the pipelines which have the water quality problems because of too low velocity. In addition, above computer simulation can be calculated by evry hour. So we can operate the pumps and valves for the pipe networks system under this simulation results. We consider that this proposed method will be able to offer the useful information rapidly in case of transmission and distrisution facilites control planning.

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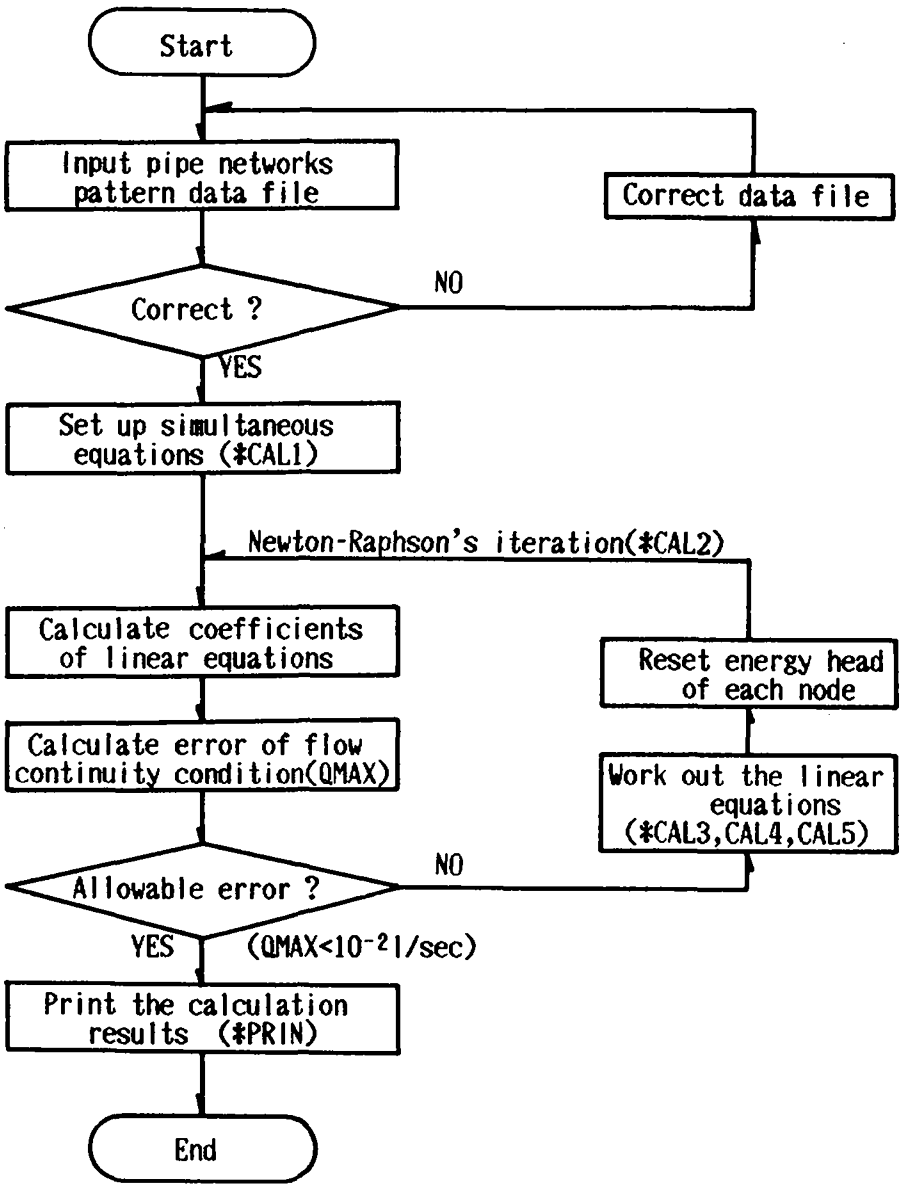
[Variables for Pipe Networkes Analysis]

NN	; number of node
JJ	; number of pipe
MM	; number of inflow
NP	; number of pump
IRES	; node No. of inflow
ICON	; node No. of fixed energy head
IPUMP	; node No. of pump
JS	; inflow and outflow node No.
KS	; pipe No. linked with each node
JM	; maximum number of pipe linked with some node (<=10)
NEQU	; number of equations (<=20)
LENG	; length of each pipe [m]
DIA	; diameter of each pipe [mm]
C	; Hazen-Williams friction coefficients
P	; consumption [l/sec]
E	; energy head of each node [m]
GL	; ground level of each node [m]
HP	; pump head [m]
SLA	; coefficient of each pipe in Hazen-Williams formula
A	; exponent of Hazen Williams formula
FLMAX	; allowable error of flow continuity [l/sec]
DEL	; energy head correction of iteration

[Variables for Graphic Representation]

NOF	; node No. of fire fighting water
FP	; fire fighting water flow rate [l/sec]
NTIME	; repeat number of simulation
PR	; hourly fluction coefficient
LXY	; location for graphic representation
V	; flow velocity of each pipe[m/sec]
VPIP	; flow velocity for color class
ENOD	; effective head for color class
CNO	; code No. of 16 color
CBK	; palette No. of back ground color
CPIP	; palette No. of pipe color class
CNOD	; palette No. of node color class
PC	; palette No. of each node
PSTEP	; number of arrow in a pipeline
DLX,DLY	; dot size of a pipe networks
CX,CY	; location of ellipse center (dot)
RX,RY	; radius of ellipse (dot)
DD	; width of pipeline (dot)

Fig.1 Process of pipe networks analysis



NOTE : * means subroutine

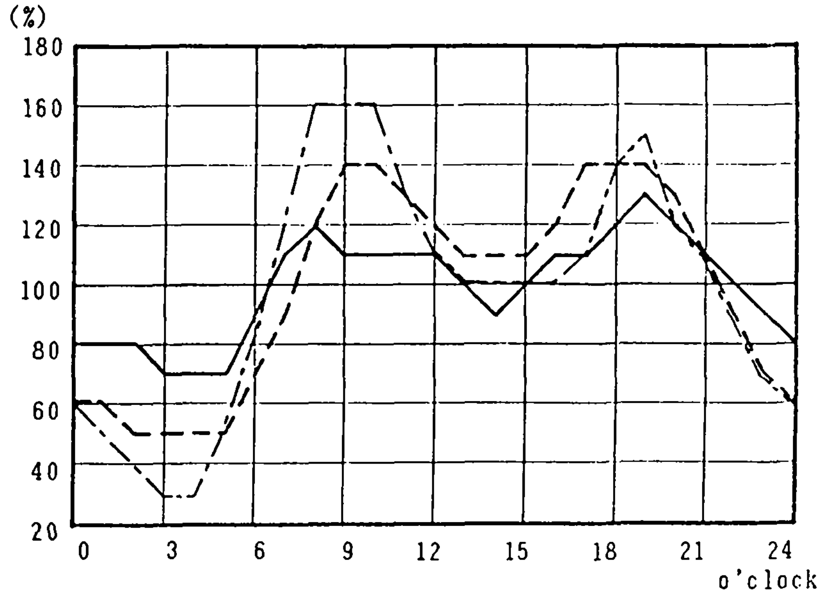
Fig.2 Patterns for classified district

Domestic use pattern

A pattern

B pattern

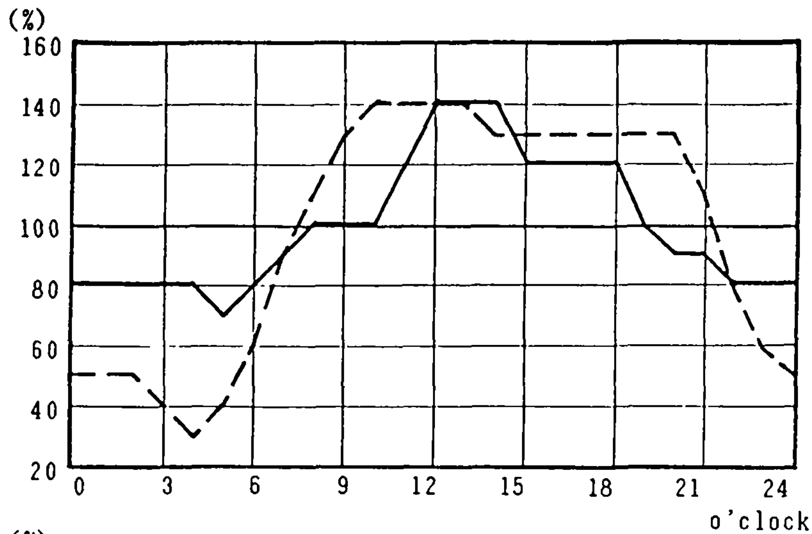
C pattern



Bussiness and comercial use pattern

A pattern

B pattern



Industrial use pattern

A pattern

B pattern

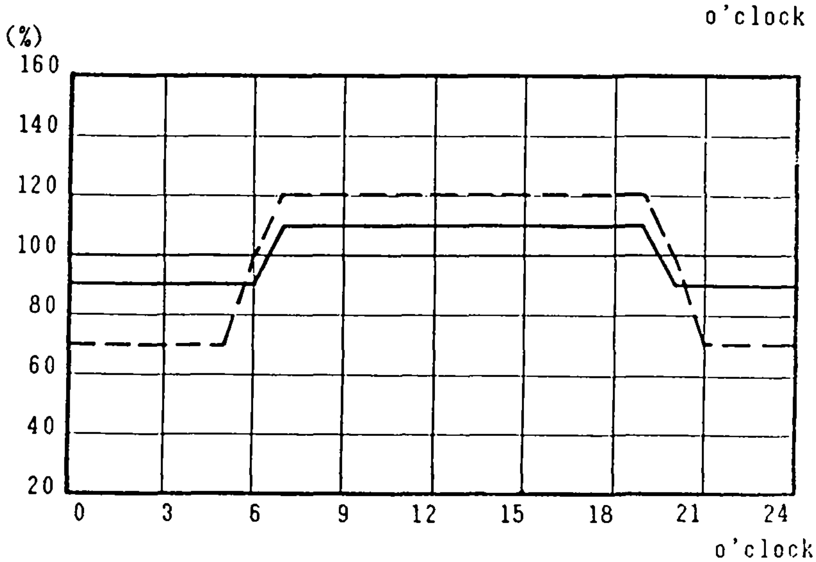


Fig.3 Process of graphic representation

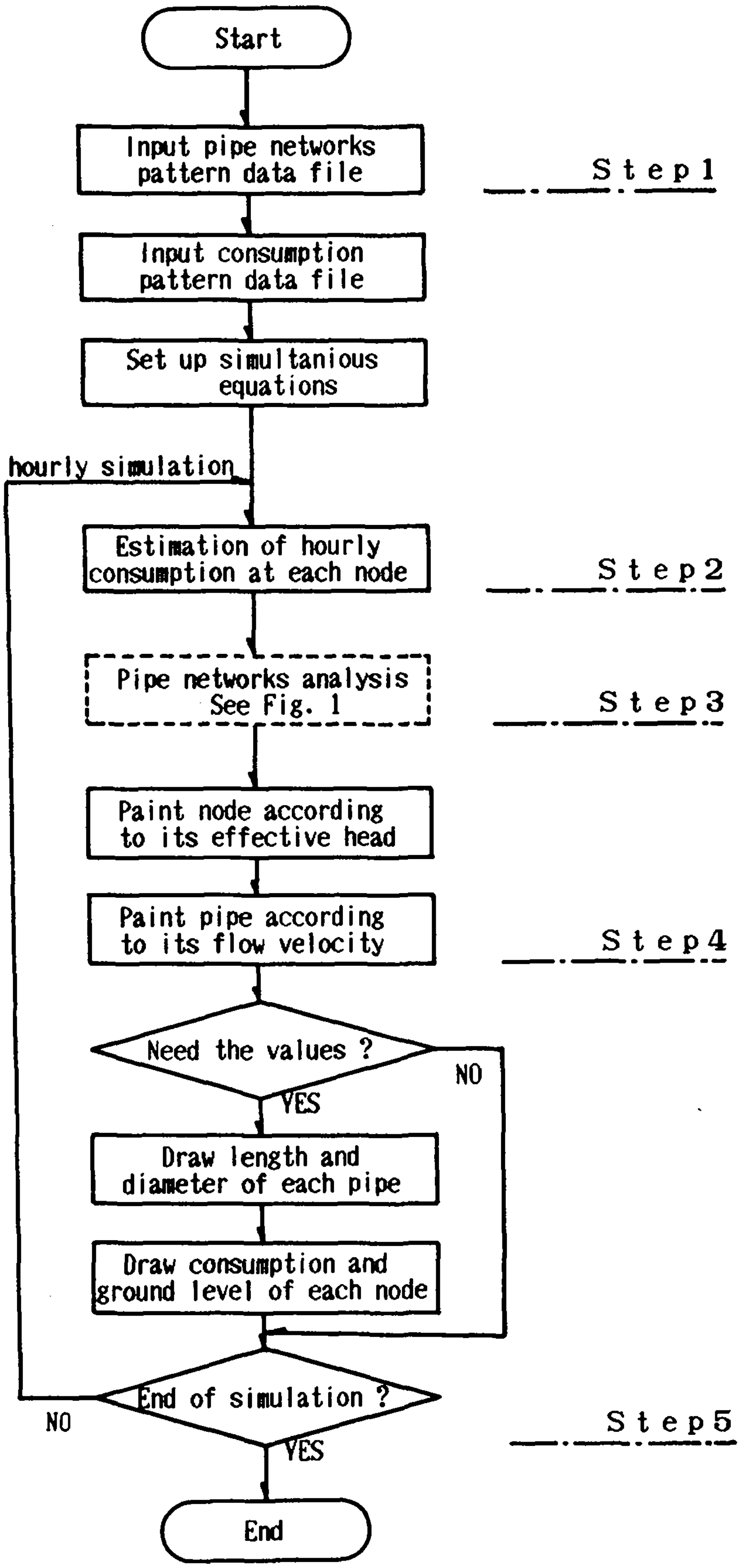
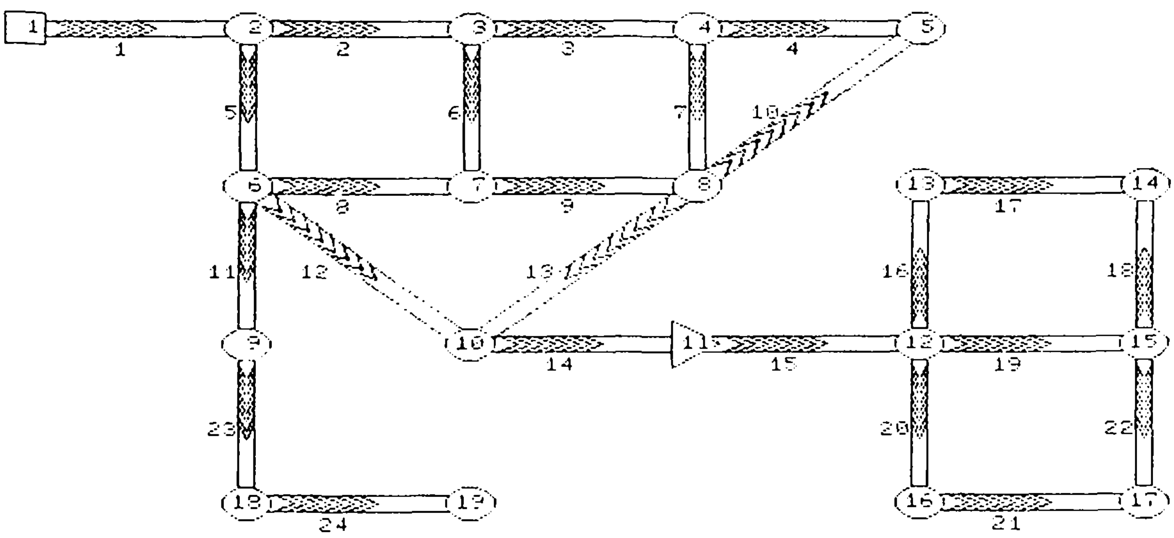


Fig.4 Result of graphic representation



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18 o'clock H.C(m3/hr)/M.D.C(m3/hr)= 2934 / 2304 (127 %)

****

pipe	nodes (i	j)	L(m)	D(mm)	C	Q(l/s)	V(m/s)	H(m)	HG(%)	TH(m)	DH(m)	GL(m)	EH(m)
1	1	2	1000	800	100	815.00	1.62	4.28	4.3	4.28	165.72	132.00	33.72
2	2	3	500	350	100	132.38	1.38	4.15	8.3	8.43	161.57	130.00	31.57
3	3	4	500	250	100	64.48	1.31	5.63	11.3	14.06	155.94	120.00	35.94
4	4	5	1000	150	100	15.90	0.90	10.15	10.2	24.21	145.79	110.00	35.79
5	2	6	800	700	100	626.62	1.63	4.04	5.0	8.32	161.68	125.00	36.68
6	3	7	1000	200	100	19.90	0.63	3.79	3.8	12.21	157.79	120.00	37.79
7	4	8	1000	250	100	24.57	0.50	1.89	1.9	15.95	154.05	118.00	36.05
8	6	7	500	400	100	181.87	1.45	3.90	7.8	12.21	157.79	120.00	37.79
9	7	8	500	400	100	177.77	1.41	3.73	7.5	15.95	154.05	118.00	36.05
10	8	5	500	200	100	44.10	1.40	8.26	16.5	24.21	145.79	110.00	35.79
11	6	9	800	300	100	90.00	1.27	6.88	8.6	15.20	154.80	120.00	34.80
12	6	10	1000	450	100	263.75	1.66	8.74	8.7	17.06	152.94	115.00	37.94
13	8	10	500	400	100	92.25	0.73	1.11	2.2	17.06	152.94	115.00	37.94
14	10	11	500	450	100	308.00	1.94	5.82	11.6	22.88	147.12	115.00	32.12
15	11	12	800	450	100	308.00	1.94	9.32	11.6	32.20	207.80	165.00	42.80
16	12	13	700	250	100	105.64	2.15	19.68	28.1	51.87	188.13	170.00	18.13
17	13	14	500	250	100	49.64	1.01	3.47	6.9	55.34	184.66	175.00	9.66
18	15	14	700	200	100	34.36	1.09	7.29	10.4	55.34	184.66	175.00	9.66
19	12	15	500	250	100	112.76	2.30	15.86	31.7	48.06	191.94	180.00	11.94
20	12	16	800	200	100	47.60	1.52	15.23	19.0	47.43	192.57	165.00	27.57
21	16	17	500	200	100	23.60	0.75	2.60	5.2	50.02	189.98	170.00	19.98
22	15	17	600	200	100	18.40	0.59	1.97	3.3	50.02	189.98	170.00	19.98
23	9	18	700	200	100	66.00	2.10	24.41	34.9	39.61	130.39	100.00	30.39
24	18	19	500	200	100	24.00	0.76	2.68	5.4	42.29	127.71	85.00	42.71

NOTE ; The low water level of reservoir (node No. 1) is 170 m.
NOTE ; The pump head of node No. 11 is 70 m.

[Appendix] Program 'PIPE NETWORKS'

```
1 '************************************************************************
2 '***     Program Pipe Networks (by the Energy Head Correction Method)    ***
3 '***          1987.06              The Civil Eng. Laboratory of T.M.U    ***
4 '***           Simulation by hour And Graphic representation            ***
5 '***             for  PC-9801XL(N88BASIC)  16 COLOR MODE  "PNETXL.N88"   ***
6 '************************************************************************
7  GOTO 1000 :' Jump to MAIN ---------------------------------------->
100 '************** Subroutine to solve the equations by Gauss' Method ******
105        *CAL5
110   N=NEQU : NJ=N+1 : LA=N-1
115   IF LA=0 THEN B(1,2)=B(1,2)/B(1,1): RETURN:'---In case of one element---
120   FOR L=1 TO N : L1=L+1 : BY=100000!
125     FOR K=L TO N: BX=-.00001: Y=B(K,L)
130     IF B(K,L)=0 THEN 160
135       FOR J=L TO NJ: B(K,J)=B(K,J)/Y
140          IF (L-J)*(NJ-J)=0 THEN 150
145          IF ABS(B(K,J))>BX THEN BX=ABS(B(K,J))
150       NEXT J
155       IF BX<=BY THEN BY=BX : M=K
160     NEXT K
165     IF L=N THEN 195
170     FOR J=L TO NJ: Y=B(L,J): B(L,J)=B(M,J): B(M,J)=Y: NEXT J
175     FOR I=L1 TO N: IF B(I,L)=0 THEN 185
180       FOR J=L TO NJ: B(I,J)=B(L,J)-B(I,J): NEXT J
185     NEXT I
190   NEXT L
195  FOR J1=1 TO LA : J=NJ-J1
200    FOR I1=J1 TO LA : I=N-I1
205       B(I,NJ)=B(I,NJ)-B(I,J)*B(J,NJ)
210    NEXT I1
215  NEXT J1
220 RETURN
225 '**************************************************** END CAL5 ***********
230 '**************** Subroutine to reduce the equations (Part 2) ***********
235        *CAL4
240  L=1 : JX=JM+1 : NM=NN-MM : S(0)=0
245  FOR IA=1 TO NM
250    I=KS(IA,1): M=ABS(I)
255    IF I>0 THEN 285
260      Y=RIGHT(M)
265      FOR J=2 TO JX
270         K=KS(IA,J): N1=ABS( MS(M,J-1) )
275         Y=Y+S(N1)*DEL(K)
280      NEXT J : DEL(M)=Y/SUMS(M) : GOTO 335
285    ELSE
290      X=0: ME=0: Y=-RIGHT(M)+SUMS(M)*DEL(M)
295      FOR J=2 TO JX
300         K=KS(IA,J) : N1=ABS( MS(M,J-1) )
305          IF K<0 THEN ME=-K: X=X+S(N1)
310          IF K>0 THEN Y=Y-S(N1)*DEL(K)
315      NEXT J
320    IF ME=0 THEN B(L,LA)=Y: L=L+1: GOTO 335
325    IF X=0 THEN DEL(ME)=0: GOTO 335
330      DEL(ME)=Y/X
335  NEXT IA
340 RETURN
345 '**************************************************** END CAL4 ***********
350 '**************** Subroutine to reduce the equations (Part 1) ***********
355        *CAL3
365  FOR LA=1 TO NEQU+1
370    FOR I=1 TO NN: DEL(I)=0: NEXT I
375    IF LA>1 THEN M=NS(LA-1): DEL(M)=.01
380    GOSUB *CAL4
385  NEXT LA : N1=NEQU+1
395  FOR I=1 TO NEQU: Y=B(I,1)
400    FOR J=1 TO NEQU: B(I,J)=B(I,J+1)-Y: NEXT J : B(I,N1)=-Y
405  NEXT I
410  GOSUB *CAL5
415  FOR I=1 TO NN: DEL(I)=0: NEXT I
420  FOR I=1 TO NEQU: L=NS(I): DEL(L)=B(I,N1)*.01: NEXT I
425  LA=1: GOSUB *CAL4
430 RETURN
435 '***************************************************** END CAL3 **********
440 '**************** Subroutine of Newton-Raphson's iteration *************
445        *CAL2
450 NM=NN-MM : A1=A-1 : NREP=-1
455 NREP=NREP+1: QMAX=0:'---------------------- ROOP START -----------
470   FOR K=1 TO JJ: I=JS(K,1): M=JS(K,2)
475     E1=E(I) : IF JS(K,0)>0 THEN E1= E(I) + HP( JS(K,0) )
480     X=ABS( E1 -E(M) ): IF X=0 THEN X=.000001
485     S(K)=SLA(K)*X^A1 : Q(K)=S(K)*( E1 - E(M) )
495   NEXT K
500   FOR IA=1 TO NM: I=ABS(KS(IA,1))
505     SUMS(I)=0: RIGHT(I)=-P(I)
510     FOR J=1 TO JM: K=ABS(KS(IA,J+1)): IF K=0 THEN 525
515       M=ABS( MS(I,J) ) : Z=SGN( MS(I,J) )
520       SUMS(I)=SUMS(I)+S(M): RIGHT(I)=RIGHT(I)-Q(M)*Z
525     NEXT J
530     Z=ABS(RIGHT(I)): IF QMAX<Z THEN QMAX=Z
535     RIGHT(I)=RIGHT(I)/A
540   NEXT IA
545 IF QMAX<FLMAX THEN  RETURN:'------------------ EXIT ----------------
550 IF NREP>=50 THEN PRINT "The iteration is forced to stop !!":RETURN
555   GOSUB *CAL3
560   Z=.5: FOR I=1 TO JJ
565           M=JS(I,1): K=JS(I,2): EM=E(M)
570           IF JS(I,0)>0 THEN EM= E(M) + HP( JS(I,0) )
575           X = EM - E(K)
580           IF X*(X+DEL(M)-DEL(K))<=0 THEN 590
585         NEXT I: Z=1
590   FOR I=1 TO NN: E(I)=E(I)+Z*DEL(I): NEXT I
630 GOTO 455 :'-------------------------------- ROOP END ---------------
635 '***************************************************** END CAL2 **********
640 '************************ Subroutine to set up the equations **********
650        *CAL1
655  JM=0
660  FOR I=1 TO NN : KS(I,1)=I
665    FOR J=1 TO 6: KS(I,J+1)=0: MS(I,J)=0: NEXT J: IX=0
670    FOR J=1 TO JJ
675      IF I=JS(J,1) THEN IX=IX+1: KS(I,IX+1)=JS(J,2): MS(I,IX)=J
680      IF I=JS(J,2) THEN IX=IX+1: KS(I,IX+1)=JS(J,1): MS(I,IX)=-J
685    NEXT J : IF IX>JM THEN JM=IX
690  NEXT I
700  N=NN-MM : JX=JM+1
710  FOR I=1 TO NN : IY=0
715    FOR J=1 TO JX: IF KS(I,J)=0 THEN 760
720      IF MM=0 THEN 740
725        FOR K=1 TO MM
730          IF ICON(K)=KS(I,J) THEN KS(I,J)=-ICON(K): GOTO 760
735        NEXT K
740      IF J=1 THEN 755
745        FOR K=1 TO J-1: IF KS(I,J)=KS(I,K) THEN 760
750        NEXT K
755      IY=IY+1
760    NEXT J
765  KM(I)=IY : NEXT I
```

```
770  IY=NN
775  FOR I=1 TO MM
780    FOR J=1 TO IY : IF IRES(I)=ABS(KS(J,1)) THEN 790
785    NEXT J
790    IF J=IY THEN 820
795      I1=IY-1 : K=KM(J)
800      FOR L=J TO I1: KM(L)=KM(L+1): NEXT L : KM(IY)=K
805      FOR M=1 TO JX: K=KS(J,M)
810         FOR L=J TO I1: KS(L,M)=KS(L+1,M) : NEXT L
815      KS(IY,M)=K : NEXT M
820  IY=IY-1 : NEXT I
825  IY=1 : NEQU=0
830  '----------------------------------------- WHILE -----------------
835  IF IY>N THEN 920
840    MIN=1000
845    FOR I=IY TO N: IF KM(I)<MIN THEN  M=I : MIN=KM(I)
850    NEXT I
855    FOR I=1 TO JX: K=KS(IY,I): KS(IY,I)=KS(M,I): KS(M,I)=K: NEXT I
860    K=KM(IY): KM(IY)=KM(M): KM(M)=K
865  IF MIN=0 THEN IY=IY+1: GOTO 835
870    FOR I=1 TO JX: IF KS(IY,I)>0 THEN 880
875    NEXT I
880    K=-KS(IY,I): IF MIN=1 THEN KM(IY)=KM(IY)-1: IY=IY+1
885    FOR I=IY TO N: L=0: FOR J=1 TO JX
890       IF K+KS(I,J)=0 THEN KS(I,J)=K: IF L=0 THEN L=1: KM(I)=KM(I)-1
895    NEXT J : NEXT I
900  IF MIN=1 THEN 835
905    NEQU=NEQU+1 : NS(NEQU)=-K
910  GOTO 835
915  '------------------------------------------ WEND  -----------------
920  FOR I=1 TO N: FOR J=1 TO JX: KS(I,J)=-KS(I,J): NEXT J: NEXT I
925 RETURN
930 '**************************************************** END CAL1 **********
1000 '*********** MAIN PROGRAM ***********************************************
1010 WIDTH 80,25 : CLS
1020 PRINT "****************************************************"
1030 PRINT "***   Program Pipe Networks                      ***"
1040 PRINT "***      1987.07   16 COLOR MODE   'PNETXL.N88'  ***"
1050 PRINT "****************************************************"
1055 PRINT : INPUT "Check data files (Y/N) ? ",M$ : PRINT
1060 PRINT : INPUT "Data File Name ? ",F$ : PRINT
1070 OPEN F$ FOR INPUT AS #1
1080   INPUT #1,NN,MM,JJ,NP,FLMAX : IF M$="N" THEN GOTO 1110
1090       LPRINT "number of node =";NN;"    number of inflow =";MM
1095       LPRINT "number of pipe =";JJ;"     number of pump =";NP
1100       LPRINT "allowable error of flow continuity [l/sec]=";FLMAX
1110     DIM IRES(MM),ICON(MM),IPUMP(NP),HP(NP)
1120     DIM JS(JJ,2),KS(NN,11),MS(NN,10),KM(NN)
1130     DIM LENG(JJ),DIA(JJ),C(JJ),SLA(JJ),S(JJ),V(JJ),Q(JJ),H(JJ)
1140     DIM P(NN),E(NN),RIGHT(NN),SUMS(NN),DEL(NN),GL(NN),TL(NN),KP(NN,NP)
1150     DIM LXY(NN,2),LSW(JJ),DX(JJ),DY(JJ),DC(JJ),DS(JJ)
1160     DIM PX(JJ),PY(JJ),PC(JJ),PLX(JJ),PLY(JJ)
1170     DIM AX1(JJ),AX2(JJ),AY1(JJ),AY2(JJ)
1180     DIM CNO(15),CPIP(10),CNOD(10),VPIP(10),ENOD(10)
1190     DIM B(20,21),NS(20)
1200   FOR I=1 TO MM: INPUT#1,IRES(I): NEXT
1205   FOR I=1 TO MM: INPUT#1,ICON(I): NEXT
1210   IF M$="N" THEN GOTO 1240
1215     LPRINT: LPRINT "node No. of inflow ":
1220     FOR I=1 TO MM: LPRINT IRES(I): : NEXT : LPRINT
1225     LPRINT: LPRINT "node No. of fixed energy head ":
1230     FOR I=1 TO MM: LPRINT ICON(I): : NEXT : LPRINT
1240   IF NP=0 THEN GOTO 1280
1250     IF M$="Y" THEN LPRINT:LPRINT "pump No.  node No.   pump head[m]"
1260     FOR I=1 TO NP: INPUT#1,IPUMP(I),HP(I)
1265       IF M$="Y" THEN LPRINT SPC(4):I:SPC(7):IPUMP(I):SPC(5):HP(I)
1270     NEXT
1280   FOR I=1 TO JJ: INPUT#1,JS(I,1),JS(I,2),LENG(I),DIA(I),C(I)
1290   DIA(I)=DIA(I)/1000 : NEXT
1300   FOR I=1 TO NN : INPUT#1,P(I),E(I),GL(I),LXY(I,1),LXY(I,2)
1310   P(I)=P(I)/1000 : NEXT : FLMAX=FLMAX/1000
1320   IF M$="N" THEN GOTO 1400
1330     LPRINT:LPRINT"pipe No.  node No. length[m]  diameter[mm]  coef."
1340     FOR I=1 TO JJ:LPRINT USING"  ###    ###  ###    ";I;JS(I,1);JS(I,2);
1350     LPRINT USING"#####      ####       ####";LENG(I);DIA(I)*1000;C(I):NEXT
1360     LPRINT:LPRINT"node No.  consumption[l/sec] energy head[m] ";
1370     LPRINT"ground level[m]  location"
1380     FOR I=1 TO NN:LPRINT SPC(3);I;SPC(11);P(I)*1000;SPC(12);E(I);SPC(9);
1390     LPRINT GL(I);SPC(8);LXY(I,1);"-";LXY(I,2) : NEXT
1400   LPRINT: LPRINT "The data is read from file ";F$;".": LPRINT: LPRINT
1410 CLOSE : PRINT "Input from data file ";F$;" is ended." : PRINT
1415 INPUT "Node No. of fire fighting water ? (if not, enter 0) ",NODF
1420 IF NODF>0 THEN INPUT"Fire fighting water flow rate(l/sec)? ",FP:FP=FP/1000
1425 '------------------------ Input of Hourly Fluction Coef. Data -----------
1430 PRINT : INPUT "Repeat number of simulation ? ",NTIME
1440   IF NTIME<1 THEN NTIME=1
1450   DIM PBAS(NN),PR(NN,NTIME)
1460   Z=0 : FOR I=1 TO NN: PBAS(I)=P(I): Z=Z+P(I): PR(I,1)=1: NEXT
1470   PBAS(0)=Z   :'-----PBAS(0);total of muximum daily consumption-----
1480 IF NTIME=1 THEN GOTO 1550
1490   INPUT "Name of hourly fluction coefficient data file ? ",F$ : PRINT
1495   OPEN F$ FOR INPUT AS #1
1500     FOR I=1 TO NN: FOR J=1 TO NTIME: INPUT#1,PR(I,J): NEXT: NEXT
1505   CLOSE : PRINT "Input from hourly fluction data file ";F$;" is ended."
1510   IF M$="N" THEN GOTO 1545
1515     LPRINT " node";: FOR J=0 TO 11:LPRINT USING" ##:00";J;:NEXT:LPRINT
1520     LPRINT "  No.";:FOR J=12 TO 23:LPRINT USING" ##:00";J;:NEXT:LPRINT
1525     FOR I=1 TO NN : LPRINT : LPRINT USING "  ## ";I;
1530       FOR J=1 TO 12:LPRINT USING"  #.# ";PR(I,J);:NEXT:LPRINT
1535       LPRINT SPC(5);:FOR J=13 TO 24:LPRINT USING"  #.# ";PR(I,J);:NEXT
1540     LPRINT: NEXT : LPRINT : LPRINT
1545   LPRINT "The hourly fluction coefficient data is read from file ";F$;"."
1550 A=.54    :'--- A : order of energy head in Hazen-Williams formula ---
1560   FOR I=1 TO JJ:SLA(I)= .27853*C(I) * DIA(I)^2.63 / LENG(I)^.54:NEXT I
1570 '--------------------------- Definition of Graphic Data ---------------
1580 FOR I=1 TO NN: LXY(I,0)=-1: NEXT :'-----LXY(n,0)<0 : node-----
1590   FOR I=1 TO MM                      :'-----LXY(n,0)=0 : inflow-----
1600     LXY(IRES(I),0)=0
1610   NEXT I
1620 IF NP=0 THEN GOTO 1720 :'-----JS(J,0) : pump no.-----
1625   FOR I=1 TO NP
1630     FOR J=1 TO JJ
1635       IF JS(J,1)<>IPUMP(I) THEN GOTO 1665
1640       JS(J,0)=I : J1=JS(J,1) : J2=JS(J,2)
1645       X1=LXY(J1,1):Y1=LXY(J1,2): X2=LXY(J2,1):Y2=LXY(J2,2)
1650       LXY(J1,0)=I : IF Y1=Y2 AND X1>X2 THEN LXY(J1,0)=2
1655                     IF X1=X2 AND Y1<Y2 THEN LXY(J1,0)=3
1660                     IF X1=X2 AND Y1>Y2 THEN LXY(J1,0)=4
1665   NEXT J : NEXT I                   :'-----LXY(n,0)>0 ; pump-----
1670   FOR I=1 TO NP
1672     FOR J=1 TO JJ: IF JS(J,0)=I THEN J1=J : GOTO 1677
1675     NEXT
1677     KP(JS(J1,2),I)=-1: N=0
1680     FOR K=1 TO NN
1682     IF KP(K,I)>=0 THEN GOTO 1705
1685       KNOD=K : FOR J=1 TO JJ
1690       IF JS(J,1)=KNOD AND KP(JS(J,2),I)=0 THEN KP(JS(J,2),I)=-1: N=N+1
1695       NEXT
1700     KP(KNOD,I)=I
1705     NEXT K
1710   IF N>0 THEN N=0 : GOTO 1680
1715   NEXT
1720 DLX=7*16: DLY=5*16: DX0=16: DY0=16: RX=12: RY=8: CX=9: CY=8: RR=RY/RX
1740 DX1=5 : DX2=13 : DY1=4 : DY2=12 : DD=CX-DX1 : PSTEP=13
```

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1800                             ----- Initialize of Picture -----
1810 CONSOLE 0,25,0,1 : SCREEN 3,,0,1 : COLOR 7,0,,7,2 : CLS 3
1820   FOR I=0 TO 15 : READ CNO(I) : NEXT
1840     DATA    0,&H00F,&H0F0,&HFF0,&HF00,&HF0F,&H0A0,&HFFF
1850     DATA &HCAC,&HAC8,&HACA,&H080,&HC08,&HAF0,&HAAC,&HAAA
1860   FOR I=0 TO 15 : COLOR=(I,CNO(I)) : NEXT
1870   NND=5 : FOR I=1 TO NND: READ CNOD(I): NEXT
1890           FOR I=1 TO NND: READ ENOD(I): NEXT
1900           DATA  2, 3, 4, 5, 7,  75, 40, 15, 0,-9999999
1910   NPP=5 : FOR I=1 TO NPP: READ CPIP(I): NEXT
1930           FOR I=1 TO NPP: READ VPIP(I): NEXT
1940           DATA 2, 13, 3, 4, 5,   6,  4, 2,.3, 0
2000 '------------------------------Caluculation and Graphic----------------
2005 LOCATE 12,15: PRINT "Caluculating !!  Please wait half a minute. "
2010 GOSUB *CAL1
2030 FOR TIME=0 TO NTIME-1
2040   Z=0: FOR I=1 TO NN: P(I)=PBAS(I)*PR(I,TIME+1): Z=Z+P(I): NEXT
2050   P(0)=Z     :'-----P(I):total of hourly consumption-----
2055   IF NODF>0 THEN P(NODF)=P(NODF)+FP: P(0)=P(0)+FP
2060   GOSUB *CAL2 : GOSUB *PRIN
2080   FOR J=1 TO JJ
2090     J1=JS(J,1): J2=JS(J,2): IF V(J)<0 THEN J1=JS(J,2): J2=JS(J,1)
2100       IF V(J)<0 THEN J1=JS(J,2) : J2=JS(J,1)
2110     X1=LXY(J1,1): X2=LXY(J2,1): Y1=LXY(J1,2): Y2=LXY(J2,2)
2120     IF Y1=Y2 THEN LSW(J)=0: DC(J)=SGN(X2-X1): DS(J)=0 : GOTO 2160
2130     IF X1=X2 THEN LSW(J)=1: DC(J)=0 : DS(J)=SGN(Y2-Y1): GOTO 2160
2140     LSW(J)=2: Z=SQR((X2-X1)*(X2-X1)+(Y2-Y1)*(Y2-Y1))
2150     DC(J)=(X2-X1)/Z : DS(J)=(Y2-Y1)/Z :'----DC:COS(θ), DS:SIN(θ)----
2160   NEXT
2170   COLOR 0,15,,0 :CLS 3 : CBK=15: CBK2=14: CONSOLE 24,1,0,1
2180   LOCATE 50,23 : PRINT TIME;"o'clock      (";
2190                  PRINT USING" ### ";P(0)/PBAS(0)*100;:PRINT "% ) "
2200   GOSUB *PIPE : GOSUB *PAINTN : CBK=15
2230   GOSUB *PAINTP
2250   LOCATE 0,24 : INPUT "Need the values of pipe networks ? (Y/N) ",M$
2260   IF M$="N" THEN GOTO 2290
2270   GOSUB *LENDIA : GOSUB *QGL
2290   LOCATE 0,24
2300 NEXT
2305 COLOR 7,0,,7 : CONSOLE 0,25,1,1: END
2310 '****************************************** END MAIN PROGRAM ***********
2320 '*************** Print the Results ***************************************
2330       *PRIN
2335 IF TIME=0 THEN GOSUB *PRIN2
2340 LPRINT : LPRINT : LPRINT : LPRINT"****************"
2350           LPRINT SPC(2);TIME;"o'clock";SPC(7);"H.C(m3/hr)/M.D.C.(m3/hr)= ";
2355           LPRINT P(0)*3600;"/"PBAS(0)*3600; "     (";
2358           LPRINT USING" ### ";P(0)/PBAS(0)*100;: LPRINT "% ) "
2360           LPRINT"****************"
2370 FOR I=1 TO JJ: K=JS(I,1): L=JS(I,2)
2380   EK =E(K) : IF JS(I,0)>0 THEN EK=E(K)+HP( JS(I,0) )
2390   H(I)= EK - E(L)                 :'----interval head loss[m] ----
2400   Z=1 : IF H(I)<0 THEN Z=-1
2410   Q(I)= Z * SLA(I) * (Z*H(I))^A    :'----flow rate[m3/sec]----
2420   V(I)= Q(I) / (3.14159*DIA(I)^2/4) :'----velocity of flow[m/sec]----
2430 NEXT
2435 FOR I=1 TO NN : DEL(I)=E(I) : NEXT
2440 IF NP=0 THEN GOTO 2465
2445   FOR M=1 TO NP : FOR I=1 TO NN
2450     IF KP(I,M)>0 THEN  DEL(I) = DEL(I) - HP(M)
2455   NEXT : NEXT
2465 FOR I=1 TO NN : TL(I)=DEL(IRES(1))-DEL(I):'----total head loss[m]----
2470   FOR M=1 TO MM
2475     TLM=DEL(IRES(M))-DEL(I)
2480     IF ABS(TLM)<ABS(TL(I)) THEN TL(I)=TLM
2485 NEXT M : NEXT I
2490 LPRINT "pipe nodes L(m) D(mm) C  Q(l/s) V(m/s)  H(m) HG(%)";
2500 LPRINT " TH(m)  DH(m)  GL(m)  EH(m)" : LPRINT "    ( I  J)"
2510 FOR I=1 TO JJ  : Z=1  : L=JS(I,1) : M=JS(I,2)
2520   IF Q(I)<0 THEN Z=-1 : L=JS(I,2) : M=JS(I,1)
2530   LPRINT USING "### "; I;
2540   LPRINT USING "###"; L;M;
2550   LPRINT USING "#####";   LENG(I); DIA(I)*1000;
2560   LPRINT USING "####";    C(I);
2570   LPRINT USING "####.##";Z*Q(I)*1000;
2580   LPRINT USING "###.##";   Z*V(I);
2590   LPRINT USING "####.##"; Z*H(I);
2600   LPRINT USING "###.#";    Z*H(I)/LENG(I)*1000;
2605   LPRINT USING "####.##";    TL(M); E(M); GL(M); E(M)-GL(M)
2610 NEXT I : LPRINT
2615 FOR M=1 TO MM:LPRINT"  NOTE : The low water level of reservoir (node No.";
2620 LPRINT IRES(M);") is ";E(IRES(M));"m." : NEXT
2625 IF NP=0 THEN GOTO 2640
2630   FOR I=1 TO NP:LPRINT"  NOTE : The pump head of node No.";IPUMP(I);
2635   LPRINT " is ";HP(I);"m." : NEXT
2640 IF NODF=0 THEN GOTO 2650
2645 LPRINT"  NOTE : Node No."NODF"contains fire fighting water"FP*1000"l/sec"
2650 RETURN
2660      *PRIN2
2665 LPRINT : LPRINT : LPRINT : LPRINT : LPRINT
2670   LPRINT"* * * * * * * * * *  OUTPUT TABLE  * * * * * * * * * * * * *"
2680   LPRINT"*                                                            *"
2690   LPRINT"*  H.C.    ;  total of hourly consumption [m3/hr.]           *"
2700   LPRINT"*  M.D.C.  ;  total of maximum daily consumption [m3/hr.]    *"
2710   LPRINT"*  pipe    ;  pipe No.                                       *"
2720   LPRINT"*  nodes   ;  node No. of inflow and outflow                 *"
2730   LPRINT"*  L(m)    ;  length of each pipe [m]                        *"
2740   LPRINT"*  D(mm)   ;  diameter of each pipe [mm]                     *"
2750   LPRINT"*   C      ;  Hazen-Williams friction coefficient            *"
2760   LPRINT"*  Q(l/s)  ;  flow rate in each pipe [l/sec]                 *"
2770   LPRINT"*  V(m/s)  ;  velocity of flow in each pipe [m/sec]          *"
2780   LPRINT"*  H(m)    ;  interval head loss [m]                         *"
2790   LPRINT"*  HG(%)   ;  interval gradient ( HG = H / L * 1000 )        *"
2800   LPRINT"*  TH(m)   ;  total head loss of outflow node [m]            *"
2810   LPRINT"*  DH(m)   ;  dynamic head [m] ( DH = L.W.L. - TH + PH )     *"
2820   LPRINT"*  GL(m)   ;  ground level of outflow node [m]               *"
2830   LPRINT"*  EH(m)   ;  effective head [m]  ( EH = DH - GL )           *"
2835   LPRINT"*  L.W.L   ;  low water level of reservoir [m]               *"
2840   LPRINT"*  PH      ;  pump head [m]                                  *"
2845   LPRINT"*                                                            *"
2850   LPRINT"* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *"
2860 LPRINT: LPRINT
2870 RETURN
3000 '*********************************************** END PRIN ***********
3010 '************** Subroutine to set the values of pipe networks **********
3020        *PUTNUMB    :' Z,M,M$,N3,K3,SX,SY will be reset in this subroutine
3030  Z=NUMB : M$="N"
3040  FOR M=N1 TO N2 STEP -1: N3=INT(Z/10^M) : K3=N3+19*16
3060    IF M$="N" AND N3=0 THEN GOTO 3100
3070    IF M=-1 THEN PUT (SX,SY),KANJI(&H12E),PSET,0,CBK:SX=SX+8
3080    PUT (SX,SY),KANJI(K3),PSET,0,CBK : M$="Y"
3100    SX=SX+8 : Z=Z-N3*10^M: IF M=N2+1 THEN M$="Y"
3110  NEXT
3120 RETURN
3130 '******************************************** END PUTNUMB ***************
3140 '********************* subroutine to draw pipes and pipe No. ***********
3150      *PIPE
3160  FOR J=1 TO JJ : J1=JS(J,1) : J2=JS(J,2)
3180    WX1=DLX*LXY(J1,1)+DX0+CX   : WX2=DLX*LXY(J2,1)+DX0+CX
3190    WY1=DLY*LXY(J1,2)+DY0+CY   : WY2=DLY*LXY(J2,2)+DY0+CY
3200    LINE (WX1+DD*DS(J),WY1-DD*DC(J))-(WX2+DD*DS(J),WY2-DD*DC(J)),0
3210    LINE (WX1-DD*DS(J),WY1+DD*DC(J))-(WX2-DD*DS(J),WY2+DD*DC(J)),0
3220    SX=(WX1+WX2)/2-20 : SY=(WY1+WY2)/2+7
3230      IF LSW(J)=2 THEN SX=SX-10
3240      IF LSW(J)>0 THEN SY=SY-7
3250    NUMB=J: N1=1: N2=0: GOSUB *PUTNUMB
3260  NEXT
3270 RETURN
3280 '******************************************* END PIPE *****************
```

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3290 '***************** subroutine to paint nodes and draw node No. **********
3300      *PAINTN
3310  LA=RY+2
3320  FOR N=1 TO NN
3330    WX=DLX*LXY(N,1)+DX0+CX : WY=DLY*LXY(N,2)+DY0+CY
3340    FOR J=1 TO NND
3350      IF E(N)-GL(N) >= ENOD(J) THEN PNO=CNOD(J): GOTO 3370
3360    NEXT
3370    IF LXY(N,0)<0 THEN CIRCLE (WX,WY),RX,0,,,RR,F,PNO  : GOTO 3470
3380    IF LXY(N,0)=0 THEN LINE(WX+LA,WY+RY)-(WX-LA,WY-RY),0,BF,PNO:GOTO 3470
3390    X1=-DD*3: Y1=-DD*3: X2=0: Y2=DD*6: X3=DD*6: Y3=-DD*3: X4=-X3:Y4=Y3
3400      IF LXY(N,0)=2 THEN X1=DD*3: X3=-DD*6 :X4=-X3
3410      IF LXY(N,0)>=3 THEN X2=DD*6:Y2=0: X3=-DD*3:Y3=DD*5.5: X4=X3:Y4=-Y3
3420      IF LXY(N,0)=4 THEN Y1=DD*3: Y3=-DD*5.5: Y4=-Y3
3430      LINE (WX+X1,WY+Y1)-STEP(X2,Y2),CBK2: LINE -STEP(X3,Y3),CBK2
3440      LINE -STEP(X4,Y4),CBK2: PAINT (WX,WY),PNO,CBK2
3450      LINE (WX+X1,WY+Y1)-STEP(X2,Y2),0 : LINE -STEP(X3,Y3),0
3460      LINE -STEP(X4,Y4),0 : IF LXY(N,0)=2 THEN WX=WX+3
3470    SX=WX-8  : SY=WY-4 : CBK=PNO : IF LXY(N,0)=3 THEN SY=WY-10
3480    NUMB=N: N1=1: N2=0:  GOSUB *PUTNUMB
3490  NEXT
3500 RETURN
3510 '******************************************** END PAINTN *****************
3520 '********************************** subroutine to paint pipes *************
3530      *PAINTP
3540 FOR J=1 TO JJ
3550   J1=JS(J,1): J2=JS(J,2) : IF V(J)<0 THEN J1=JS(J,2) : J2=JS(J,1)
3560     IF V(J)<0 THEN J1=JS(J,2) : J2=JS(J,1)
3570   X1=LXY(J1,1): X2=LXY(J2,1): Y1=LXY(J1,2): Y2=LXY(J2,2)
3580   AR=2 : IF LSW(J)=0 THEN AR=2.5
3590   PLX(J)= DLX*(X2-X1)-2*RX*DC(J): DX(J)=( PLX(J)-DD*AR*DC(J) )/PSTEP
3610   PLY(J)= DLY*(Y2-Y1)-2*RY*DS(J): DY(J)=( PLY(J)-DD*AR*DS(J) )/PSTEP
3630   PLX(J)=PLX(J)-DX(J)      : PLY(J)=PLY(J)-DY(J)
3640     IF LSW(J)=0 THEN DY(J)=0 : PLY(J)=0
3650     IF LSW(J)=1 THEN DX(J)=0 : PLX(J)=0
3660   PX(J)=DLX*X1+DX0+CX+(RX+DD*AR)*DC(J)+DX(J)*.4
3670   PY(J)=DLY*Y1+DY0+CY+(RY+DD*AR)*DS(J)+DY(J)*.4
3680   FOR K=1 TO NPP
3690     IF ABS(V(J)) >= VPIP(K) THEN PC(J)=CPIP(K): GOTO 3710
3700   NEXT
3710   AX1(J)=-DD*AR*DC(J)+DD*DS(J): AY1(J)=-DD*AR*DS(J)-DD*DC(J)
3720   AX2(J)=-DD*AR*DC(J)-DD*DS(J): AY2(J)=-DD*AR*DS(J)+DD*DC(J)
3730 NEXT : L=0
3740 L=L+1                                   :'----- draw arrows -----
3750   FOR K=0 TO PSTEP-1
3760     FOR J=1 TO JJ
3770       WX=PX(J)+DX(J)*K : WY=PY(J)+DY(J)*K :PNO=PC(J)
3780       LINE (WX,WY) -STEP(AX1(J),AY1(J)),PNO
3790       LINE (WX,WY) -STEP(AX2(J),AY2(J)),PNO
3800       IF ABS(DX(J))<10 AND ABS(DY(J))<10 THEN GOTO 3850
3810       IF K=PSTEP-1 THEN GOTO 3850
3820       WX=WX+DX(J)/2 : WY=WY+DY(J)/2
3830       LINE (WX,WY) -STEP(AX1(J),AY1(J)),PNO
3840       LINE (WX,WY) -STEP(AX2(J),AY2(J)),PNO
3850     NEXT
3860   NEXT
3870 IF L=INT(L/2)*2 THEN LOCATE 0,24 : INPUT "Continue ? (Y/N) ",M$
3880   FOR J=1 TO JJ                          :'----- erase arrows -----
3890     WX1=PX(J)-DD*AR*DC(J) : WY1=PY(J)-DD*AR*DS(J)
3900     LINE (WX1+DD*DS(J),WY1-DD*DC(J))-STEP(PLX(J),PLY(J)),CBK2
3910     LINE                   -STEP(-DD*2*DS(J),DD*2*DC(J)),CBK2
3920     LINE                          -STEP(-PLX(J),-PLY(J) ),CBK2
3930     LINE                   -STEP( DD*2*DS(J),-DD*2*DC(J)),CBK2
3940     PAINT (PX(J),PY(J)),CBK,CBK2
3950     LINE (WX1+DD*DS(J),WY1-DD*DC(J))-STEP(PLX(J),PLY(J)),0
3960     LINE (WX1-DD*DS(J),WY1+DD*DC(J))-STEP(PLX(J),PLY(J)),0
3970   NEXT
3980 IF M$="Y" THEN GOTO 3740
3990   FOR J=1 TO JJ                          :'----- paint arrows -----
4000     LINE (PX(J),PY(J))-STEP(AX1(J),AY1(J)),PC(J)
4010     LINE (PX(J),PY(J))-STEP(AX2(J),AY2(J)),PC(J)
4020   NEXT
4030 FOR K=2 TO PSTEP-1 STEP 2
4040   FOR J=1 TO JJ
4050     WX=PX(J)+DX(J)*(K-2): WY=PY(J)+DY(J)*(K-2): PNO=PC(J)
4060     LINE(WX,WY)-STEP(AX1(J),AY1(J)),PNO
4070     LINE-STEP(DX(J)*2,DY(J)*2),PNO:LINE-(PX(J)+DX(J)*K,PY(J)+DY(J)*K),PNO
4080     LINE(WX,WY)-STEP(AX2(J),AY2(J)),PNO
4090     LINE-STEP(DX(J)*2,DY(J)*2),PNO:LINE-(PX(J)+DX(J)*K,PY(J)+DY(J)*K),PNO
4100     PAINT ( WX+DX(J),WY+DY(J) ),PNO,PNO
4110   NEXT
4120 NEXT
4130 RETURN
4140 '******************************************** END PAINTP *****************
4150 '************ subroutine to draw length and diameter of each pipe ******
4160      *LENDIA
4170  FOR J=1 TO JJ : J1=JS(J,1) : J2=JS(J,2)
4190    SX = DLX*(LXY(J1,1)+LXY(J2,1))/2+DX0 + 22*LSW(J)
4200    SY = DLY*(LXY(J1,2)+LXY(J2,2))/2+DY0+4: IF LSW(J)=0 THEN SY=SY+20
4210    PUT (SX-8,SY),KANJI(&H14C),PSET,0,CBK
4220    PUT (SX,SY),  KANJI(&H13D),PSET,0,CBK : SX=SX+8
4230    NUMB=LENG(J): N1=3: N2=0: GOSUB *PUTNUMB
4240    SX = DLX*(LXY(J1,1)+LXY(J2,1))/2+DX0+22*LSW(J): SY=SY+8
4250    PUT (SX-8,SY),KANJI(&H144),PSET,0,CBK
4260    PUT (SX,SY),  KANJI(&H13D),PSET,0,CBK : SX=SX+8
4270    NUMB=DIA(J)*1000: N1=3: N2=0: GOSUB *PUTNUMB
4280  NEXT
4290 RETURN
4300 '******************************************** END LENDIA *****************
4310 '****** subroutine to draw consumption and ground level of each node ****
4320      *QGL
4330  FOR N=1 TO NN
4340  IF LXY(N,0)>=0 THEN GOTO 4470
4350    WX=DLX*LXY(N,1)+DX0+CX: WY=DLY*LXY(N,2)+DY0+CY
4360    LINE (WX+3,WY-6)-STEP( 8,-16): LINE (WX+3,WY-7)-STEP( 8,-16)
4380    LINE -STEP( 0,4) : LINE -STEP(-2,0) : SX=WX+12 : SY=WY-20
4400    PUT (SX,SY),  KANJI(&H171),PSET,0,CBK
4410    PUT (SX+8,SY),KANJI(&H13D),PSET,0,CBK : SX=SX+16
4420    NUMB=P(N)*1000+.4: N1=2: N2=0 : GOSUB *PUTNUMB
4430    SX=WX+12 : SY=WY-12
4440    PUT (SX  ,SY),KANJI(&H147),PSET,0,CBK
4450    PUT (SX+8,SY),KANJI(&H13D),PSET,0,CBK : SX=SX+16
4460    NUMB=GL(N): N1=2: N2=0:  GOSUB *PUTNUMB
4470  NEXT
4480  FOR I=1 TO MM : N=IRES(I)
4490    WX=DLX*LXY(N,1)+DX0+CX: WY=DLY*LXY(N,2)+DY0+CY
4500    SX=WX-RY-2 : SY=WY-RY-16
4510    PUT (SX,SY),  KANJI(&H14C),PSET,0,CBK
4520    PUT (SX+8,SY),KANJI(&H157),PSET,0,CBK
4530    PUT (SX+16,SY),KANJI(&H14C),PSET,0,CBK: SY=SY+8
4540    PUT (SX,SY),KANJI(&H13D),PSET,0,CBK : SX=SX+8
4550    NUMB= E(N): N1=2: N2=0:  GOSUB *PUTNUMB
4560  NEXT
4570  IF NP=0 THEN RETURN
4580  FOR I=1 TO NP : N=IPUMP(I)
4590    WX=DLX*LXY(N,1)+DX0+CX: WY=DLY*LXY(N,2)+DY0+CY
4600    SX=WX-DD*3:SY=WY-DD*3-16: IF LXY(N,0)>=3 THEN SX=WX+DD*3:SY=WY-8
4610    PUT (SX,SY),  KANJI(&H168),PSET,0,CBK
4620    PUT (SX+8,SY),KANJI(&H13D),PSET,0,CBK : SX=SX+16
4630    NUMB=HP(I): N1=2: N2=0:  GOSUB *PUTNUMB
4640    SX=WX-DD*3:SY=WY-DD*3-8: IF LXY(N,0)>=3 THEN SX=WX+DD*3 : SY=WY
4650    PUT (SX,SY),  KANJI(&H147),PSET,0,CBK
4660    PUT (SX+8,SY),KANJI(&H13D),PSET,0,CBK : SX=SX+16
4670    NUMB=GL(N): N1=2: N2=0:  GOSUB *PUTNUMB
4680  NEXT
4690 RETURN
4700 '******************************************** END QGL ******************
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Removal of Pesticides from Water by Chemical Coagulation

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ABSTRACT

During an investigation of the quality of the water sources for drinking water supply, it was found that there were trace amounts of Aldrin and p,p'-DDE in waters, sediments and soils around Pin-lin which was located in the reservation area for the water supply of the Taipei metropolitan. Although the uses of these two pesticides, Aldrin and p,p,'-DDT (the precursor of p,p'-DDE), has been banned for several years, trace amount of these chemicals slowly released from soils and sediments may still cause problems in supplying safe drinking water.

It is shown in the literature that typical water treatment processes (i.e., coagulation, sedimentation and filtration) are not very effective in removing trace organic pesticides. However, since these pesticides have high tendency to be asssociated with natural sorbents, we might be able to reduce the unremovable dissolved pesticides in the water by adding some removable sorbents during the chemical coagulation process. The purpose of this work is to identify the mechanisms for the removal of trace organic chemicals during coagulation processes, evaluate the removal efficiency of some modified coagulation treatment approaches, and use an adsorption model to explain the observed experimental results.

Two chlorinated hydrocarbon pesticides (i.e., Aldrin and p,p'-DDE) were choosed as model compounds in this study. Experiments of flocculation and coagulation were performed in Jar-testers with synthetic waters containing kaolinite as the source of turbidity. The following substances or their combinations were used in the coagulation test: coagulants (i.e., aluminum sulfate or polyaluminum chloride), coagulant-aids (i.e., anionic polyelectrolytes, nonionic polyelectrolytes and cationic polyelectrolytes), and supplemental sorbents (i.e., backwash wastewater and sludge from treatment plants).

Experimental results show that the conventional coagulation treatment can only remove 30% to 65% of added hydrocarbons in water with negligible turbidity. However, the removable fraction can be as high as 90% for highly turbid water. In addition, the strong correlation between the removal efficiency of pesticides and the removal of turbidity indicates that the major part of pesticides in water is associated with suspended solids.

Addition of coagulation-aids (with concentrations about 2% of the alum dosage) does not help the separation of pesticides from the water because the concentrations of these coagulation-aids are too low to contribute to the pesticide adsorption. Applying alum sludge or backwash wastewater greatly enhances the adsorption and scavenging of pesticides from the water by increasing available adsorbents. For example, 96% of Aldrin can be removed with the addition of 0.3% of alum sludge. Adsorption isotherms of these two pesticides with kaolinite, backwash wastewaters and sludges were also studied and used to quantify the speciations of pesticides in the solutions. Based on this adsorption model and the observed turbidity removal rates, predictions on the pesticide removal efficiency were made and compared with the observed values.

1. BACKGROUND AND THEORY

Many organochlorinated pesticides (e.g. DDT, Lindane, Aldrin, Dieldrin, and Heptachlor) had been extensively used in this country during 1961 to 1974. There is great concern about the effects of the residues of these pesticides in the environment on the health of the public and biota because it was reported recently that organochlorinated pesticides had been found in soils, sediments, and aquatic biota very frequently. According to Chiang et al. (1985), trace amount of p,p' DDE (derivative of DDT) and Aldrin were found in the surface water at Pin-lin and Kuei-shan monitoring stations which are located in the reservation area for the water supply of the Taipei metropolitan. It is believed that the pesticides were originally applied to tea plants and orchards and transported to soils and sediment beds by rainfalls and runoffs. Because of the high persistency and strong tendency to be associated with natural particles, these pesticides were well preserved in soils and sediments and slowly released from river beds into surface waters. Since many of these contaminated river waters may be used for public water supply, it is our great interest to develop an efficient treatment method to remove these trace organochlorinated pesticides from the water.

The studies on removal of pesticides from the raw water by using granual activated carbon has been reported (Edwards, 1970; Thebault et al., 1981; and Tseng, 1985). However, due to its high treatment cost, activated carbon adsorption method has not been used in public water supplying system. Other methods have the same disadvantages of high cost and low efficiency.

Coagulation and filtration are two major processes in the typical water treatment plants. It is, therefore, of great interest to use the existing coagulation precess to remove trace organic pollutants. There will be at least three advantages which are: 1. no additional construction, 2. low operation cost, 3. no special technique needed (Kavanaugh, 1978).

In spite of the advantages, the efficiency has been reported poor for removal of DDT, Lindane, Aldrin, Dieldrin, and Toxaphene from waters with coagulation (Carollo, 1945; Cohen et al., 1960; Robeck et al., 1965; Whitehouse, 1967; and Cater and Suffet, 1982). Kavanaugh (1978) concluded in his report that coagulation can only reduce the concentrations of trace organic pollutants to an extent which are very often still over the safe drinking water standards. However, we believe that better understanding of the mechanism of pesticide removal by coagulation may help us to improve the removal ratio.

Coagulation and subsequent clarification can only remove particles. Therefore, the removable part of pesticides must be in adsorbed form and the adsorbing particles should be removable by the clarification precedure. Generally, organochlorinated pesticides are hydrophobic. They tend to be adsorbed by hydrophobic surfaces or organic matters on the natural particles. Consequently, the ratio of the total removable fraction to the total remaining fraction highly depends on the distribution ratio of the pesticide of interest between the water and the suspended particles and also depends on the total amount of suspended particles in the water.

According to this rationale of the removal mechanism, it is suggested that the removing rate can be estimated by knowing the concentration of suspended solids, the particle removal rate, and the distribution ratio of the pesticide. The simple relationship is

$$\text{Pesticide removal rate} = \frac{\text{conc. of pesticide on SS x removable SS}}{\text{total amount of pesticide}}$$

$$= \frac{r.C.Kd.SS}{C + C.Kd.SS} \quad (1)$$

or

$$R = \frac{r\cdot(Kd\cdot SS)}{(1 + Kd\cdot SS)} \quad (2)$$

in which R is the removal rate of the pesticide of concern, r is the removable fraction of suspended solids, C is the dissolved pesticide concentration in the water (mg/L), Kd is the distribution ratio of the pesticide between suspended solids and the water (cm^3/g), and SS is the concentration of suspended solids (g/cm^3).

The purposes of this study are to test the validity of this model, and to evaluate the feasibility of some modified coagulation methods for removing pesticides in the water.

2. MATERIALS AND METHODS

Jar Test

The pesticide removal rates under different treatment conditions were evaluated with jar-test experiments. Water containing Aldrin or p,p'-DDE were treated with different coagulants then quickly mixed at 90 rpm in an 1 L jar tester for 0.5 to 5 minutes, and mixed at 30 rpm for other 10 to 40 minutes. The removal rate was estimated by comparing the concentration in the supernatant and the original concentration after coagulation procedure at optimal conditions.

Chemical Analyses

4 g of sodium chloride was added to 100 ml of supernatant in a 250 ml separation funnel. The solution was extracted twice with 40 ml of n-hexane. Two n-hexane extracts were combined, dewatered with 10 g of sodium sulfate anhydride, and concentrated to a volumn of 5 ml by using a rotary vacuum evaporator. Finally, the extract was poured into a cleaning column packed with 6 g of aluminum oxide, 2 g of

sodium sulfate anhydride, and 0.5 g of activated carbon. The pesticides were eluted with 150 ml n-hexane (containing 6 % of ether) and concentrated again with a rotary vacuum evaporator.

Coagulation test

Experiments of coagulation were performed in Jar-testers with synthetic waters containing kaolinite as the source of turbidity. The following substances or their combinations were used in the coagulation test: coagulants (i.e., aluminum sulfate or polyaluminum chloride (PAC)), coagulant-aids (i.e., anionic polyelectrolytes, nonionic polyelectrolytes and cationic polyelectrolytes), supplemental adsorbents (i.e., backwash wastewater and sludge from treatment plants). Some properties of the supplemental sorbents are shown in Table 1.

Adsorption Experiments

Experiments of the adsorption of pesticides by kaolinite, backwash wastewater and sludge from treatment plants were performed. Adsorbents were added to pesticide solutions which were then shaken for a certain period of time. sorbents were separated by settling for 24 hours or by centrifugation. The supernatants were analysed for pesticide concentrations.

3. RESULTS

The Results of Adsorption Experiments

The time courses of adsorption of Aldrin and p,p'-DDE to Koalinite, backwash wastewater and alum sludge are shown in Figure 1, 2, 3. Adsorption reaches aboout 90% of completion in 30 minutes. There is only little change after one day. Equilibrium is reached in two days. The adsorption isotherms are shown in Figure 4. The adsorption relationships are not linear. It seems that the adsorption of pesticides on particle surfaces facilitate further adsorption. Empirical Freundlich adsorption relationships are used to express these results (Table 2).

Removal of Pesticides in the Water by Adding Alum

When alum is added to remove turbidity as well as pesticides in the water, the removal rates of pesticides highly depends on the original turbidity in the water. For water turbidity are 100 NTU, 20 NTU and 1.9 NTU, the optimized removal rate for Aldrin and p,p'-DDE are about 90%, 70% and 25% respectively (Figure 5, 6, and 7).

Turbidity, in fact, is another expression of the concentration of suspended solids in the water. Higher turbidity indicates higher adsorbent concentration and that more pesticide molecules are associated with particles. Consequently, there are more chances for pesticides to be removed by coagulation in more turbid water. However, in low turbidity water, fewer pesticide molecules are associated with suspended solids. Therefore, the removal efficiency is poor for less turbid water. The experimental results agree with the model prediction.

In the coagulation tests with only alum added, the remaining concentrations of pesticides are strongly correlated with the remaining turbidity for waters with high turbidity (Figure 5). This is due to that a very high fraction of pesticide molecules is in the adsorbed form. The really dissolved concentration contributes only very little to the total concentration.

The Effects of Additional Adsorbents

In addition to Kaolinite, backwash wastewater and alum sludge from a treatment plant are added to the water to increase the available adsorbent. Figure 8 and Figure 9 show the effects of adding backwash wastewater and alum sludge on the pesticide concentrations remaining in the supernatants after coagulation and settling. It is obvious that the added suspended solids enhance the removal of pesticides by bringing more pollutants with them when removed by coagulation. The scavenging effect increases quickly with the increase of the dose of the adsorbents, however, it approaches a constant level when the dosage is high.

The Effects of Coagulant-aids

Addition of coagulation-aids (i.e., anionic polyelectrolytes, nonionic polyelectrolytes and cationic polyelectrolytes all with concentrations about 2% of the alum dosage) does not help the separation of pesticides from the water (Figure 10). Coagulation-aids may behave as supplemental adsorbents to carry some pesticide molecules. However, because the concentrations of these coagulation-aids are too low to contribute to the pesticide adsorption the effect is not significant. Adding polyaluminum chloride (PAC) has no difference from adding alum on removing pesticides.

4. DISCUSSIONS AND MODEL PREDICTIONS

Predicting the Removal Efficiency at Different Turbidity

By using the adsorption isotherm with known initial concentration we can calculate the equilibrium concentration, Ce, at a given concentration of suspended solids (or turbidity) and the distribution ratio, Kd, in each case. In the high turbidity coagulation test, the Kd is 33700 cm^3/g and Kd·SS is 7.42. Therefore, the linear relationship between R and r in Equation 1 is correct because Kd·SS is much greater than 1 in this case. On the other hand, when Kd.SS is close to or less than 1, the linear relationship between the turbidity removal rate and the pesticide removal rate will not exist. This is the reason why good correlation can not be seen in coagulation test with slightly turbid water (Kd.SS = 0.43) and with the water with very low turbidity (Kd.SS = 0.009) (Figure 6 and 7).

Since the removal rates for turbidity were experimentally measured in this study, they are used as input parameters in the model simulations. Model predictions of removal of Aldrin at different initial turbidity were done by using the removal model and the experimental conditions listed in Figure 5, 6, 7 and plotted in Figure 11, 12, 13.

For highly turbid water the prediction is quite good except at very high alum dosage (Figure 11). The model underestimates the removal efficiency for slightly tubid water (Figure 12). Also, it is predicted that almost no removal of pesticides for very low turbidity which is obviously not true (Figure 13). The discrepancy may be due to that we neglect the scavenging effect of alum added (0 mg/L to 50 mg/L) which may adsorb some Aldrin and also due to the loss of Aldrin to the surfaces of the jar tester. When the concentration of the adsorbent in the water is lower and the alum dosage is higher the discrepancy is more significant since more pesticide molecules are adsorbed on alum flocs and glass surfaces.

Estimating the Efficiency of Supplemental Adsorbents

The phenomenon of enhancement of removal by adding supplemental adsorbents can be quantitatively predicted by using Equation 2. When Kd·SS is much less than 1, R is equal to r·Kd·SS. It is obvious that the removal rate (R) will increase with the addition of adsorbent (SS). However, when SS is sufficiently large that Kd·SS is greater than 1, R is equal to r which in this case is nearly a constant. This may explain the observed increase of removal rate with adding backwash wastewater and alum sludge at low dosage and a constant removal efficiency at very high dosage.

The implications of these results are: 1. Supplemental adsorbents are able to facilitate the removal of some hydrophobic pesticides from the water by using coagulation process. 2. If Kd is small, adding SS is not an effective way to increase the removal rate of pollutants. 3. When SS is already high in the water, additional adsorbent may not effectively enhance the removal of pollutants. Instead, additional adsorbent will cause problem of high turbidity in the supernatant.

4. CONCLUSION

From the results of this study we may conclude that:

1. Removal of pesticides by using coagulation is only effective when turbidity is high. The removal rate is highly correlated with the turbidity removal rate. Also experimental results indicates that a large part of pesticide is associated with particulate solids in the water.
2. Adding backwash wastewater and alum sludge can greatly enhance the pesticide removal because these supplemental suspended solid behave as additional scavenging adsorbent. The effects approach a limit when the concentration of added sorbents increases. In conclusion, the removal rate is controlled by three important factors which are the distribution ratio of a pesticide between the water and the suspended particles, total amount of suspended solid (or turbidity), and the removal rate of suspended solids.
3. By using the pesticide removal model with the knowledge about the pesticide adsorption isotherm and the suspended solid removal efficiency, we can quantitatively predict the pesticide removal rate. The results of this study provide means to evaluate the feasibility of the coagulation method in treating pesticide-contaminated waters and help to choose the best alternative and the optimal operation conditions for remove pesticides from the water.
4. Future researches are necessary to illucidate the mechanism of pesticide adsorption on natural particles, the adsorption behavior of alum flocs, the effects of adsorbent concentration on the distribution coefficient, Kd, and the effects of other environmental factors on the adsorption of pesticides on particles.

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Table 1. Some properties of backwash wastewater and alum sludge

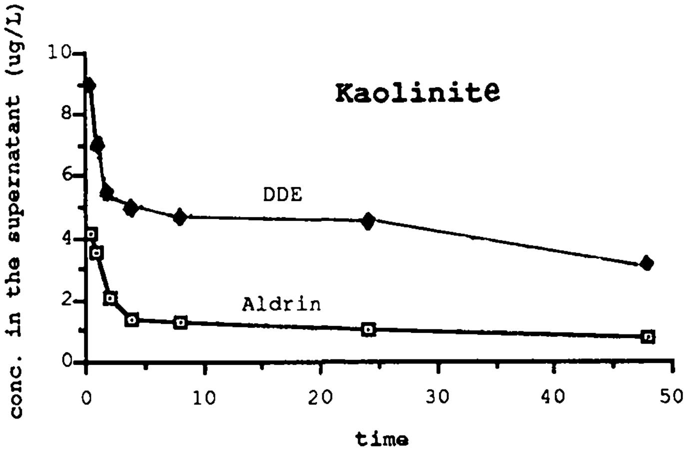
properties \ sorbent	backwash wastewater (from sand filter)	alum sludge (from settling tank)
pH	7.02	6.62
suspended solid (mg/L)	2795	115870
turbidity (NTU)	170	-
solid content (%)	0.27	10.6

Table 2. The Freudlich expressions for three adsorbents.

adsorbents \ sorbates	Aldrin	p,p'-DDE
kaolinte	$\frac{X}{M} = 10^{-4.12} \times Ce^{\frac{1}{0.287}}$	$\frac{X}{M} = 10^{-8.54} \times Ce^{\frac{1}{0.376}}$
backwash wastewater	$\frac{X}{M} = 10^{-5.12} \times Ce^{\frac{1}{0.244}}$	$\frac{X}{M} = 10^{-6.88} \times Ce^{\frac{1}{0.217}}$
alum sludge	$\frac{X}{M} = 10^{-1.79} \times Ce^{\frac{1}{0.178}}$	$\frac{X}{M} = 10^{-2.42} \times Ce^{\frac{1}{0.472}}$

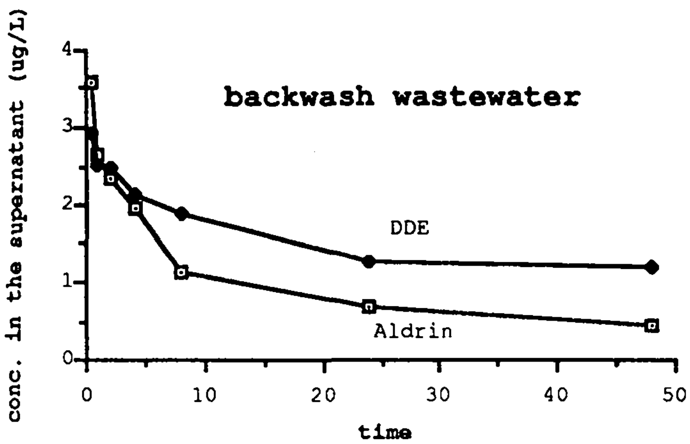
X/M = adsorbed conc. on suspended solids (ug/mg solids)

Ce = dissolved pesticide concentration (ug/L)



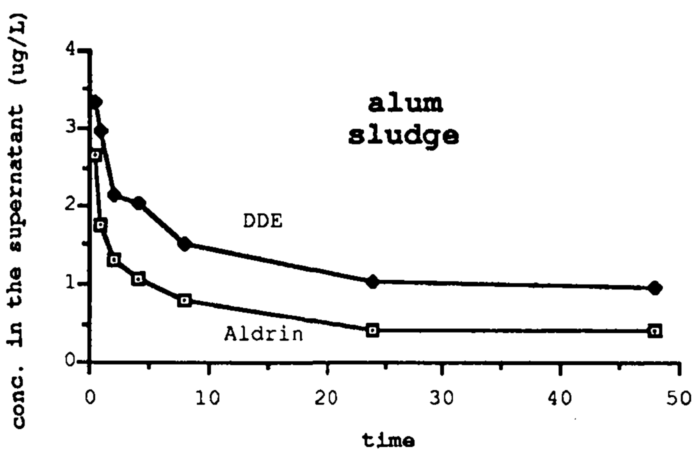
Aldrin 100 ug/L
p,p' DDE 100 ug/L
kaolinite 200 mg/L
pH 7.6
temperature 26 C

Figure 1. Time course of adsorption of pesticides on kaolinite.



Aldrin 100 ug/L
p,p' DDE 100 ug/L
backwash wastewater 100ml/L
pH 7.6
temperature 27 C

Figure 2. Time course of adsorption of pesticides on backwash wastewater.



Aldrin 100 ug/L
p,p' DDE 100 ug/L
alum sludge 5ml/L
pH 7.6
temperature 27 C

Figure 3. Time course of adsorption of pesticides on alum sludge.

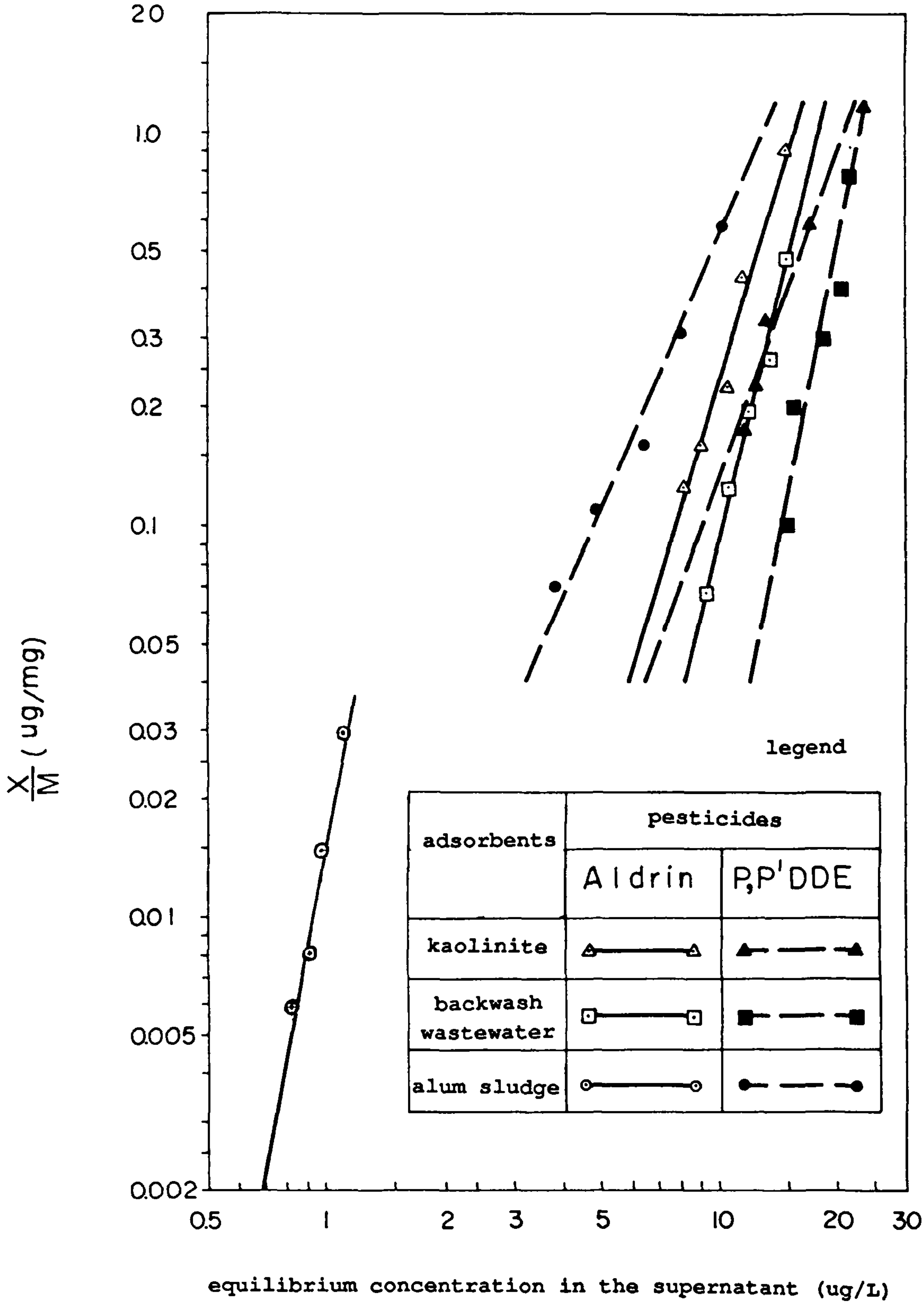
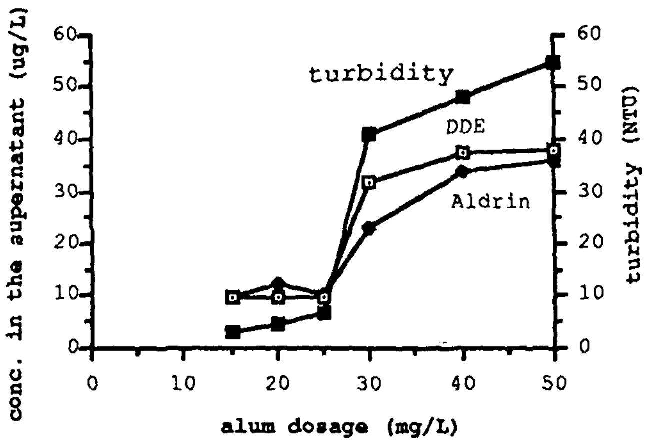
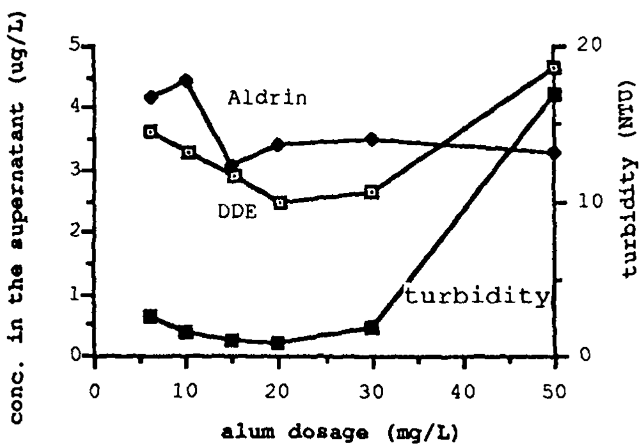


Figure 4. Adsorption isotherms of Aldrin and p,p'-DDE on three adsorbents.



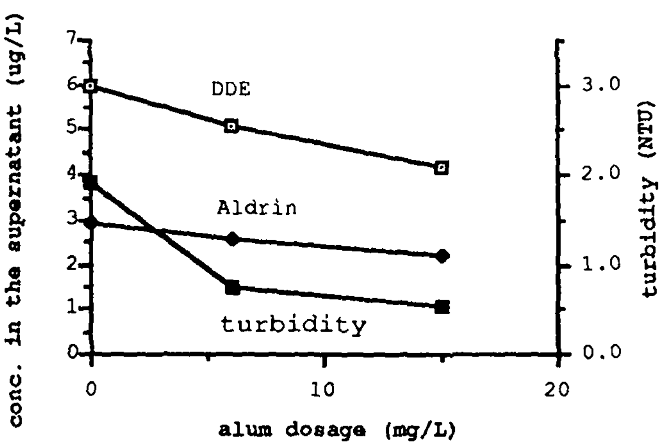
turbidity	100 NTU (210 mg/L)
Aldrin	100 ug/L
p,p' DDE	100 ug/L
pH	7.6

Figure 5. Removal of pesticide in highly turbid water by adding alum.



turbidity	20 NTU (45 mg/L)
Aldirn	10 ug/L
p,p' DDE	10 ug/L
pH	7.6

Figure 6. Removal of pesticide in medium-turbid water by adding alum.



turbidity	1.9 NTU (4 mg/L)
Aldrin	4 ug/L
p,p' DDE	7.5 ug/L
pH	7.6

Figure 7. Removal of pesticide in low-turbid water by adding alum.

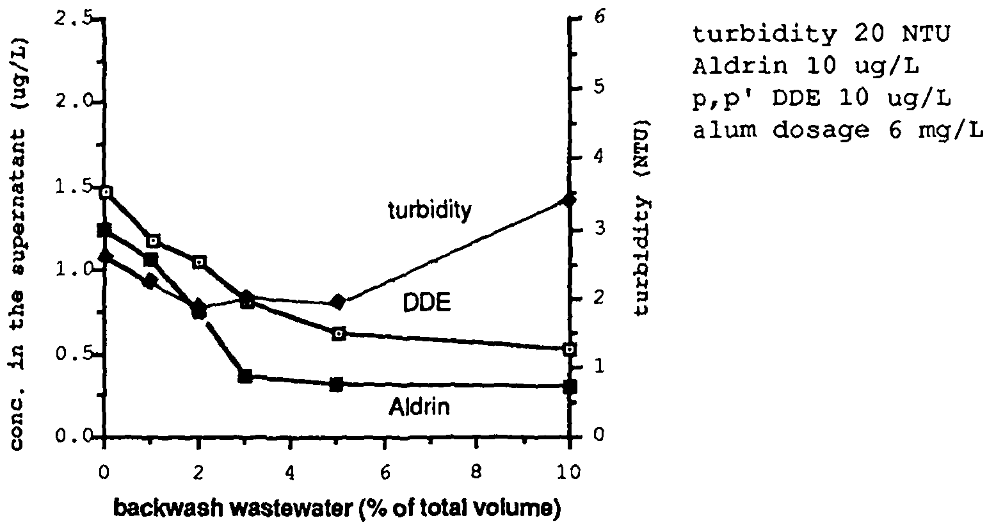


Figure 8. The effect of adding backwash wastewater on the removal of pesticides.

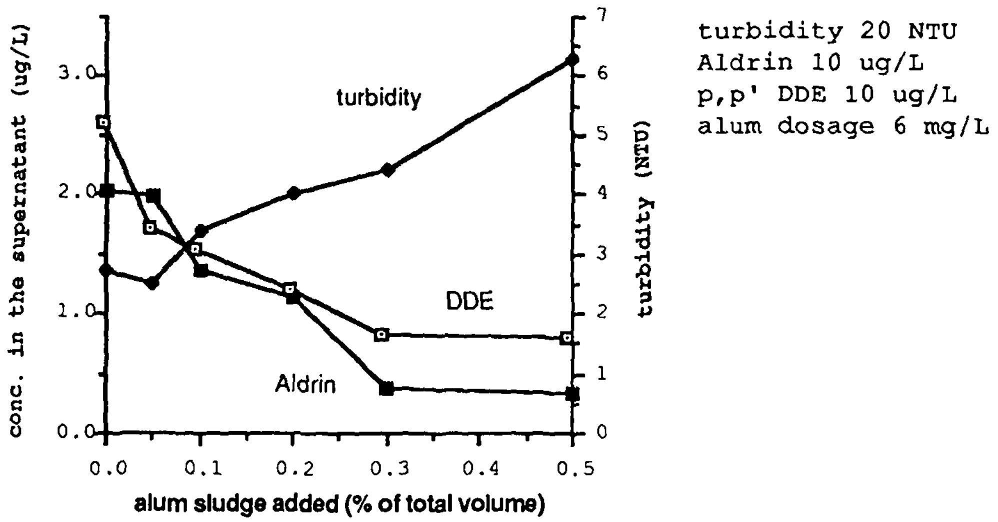
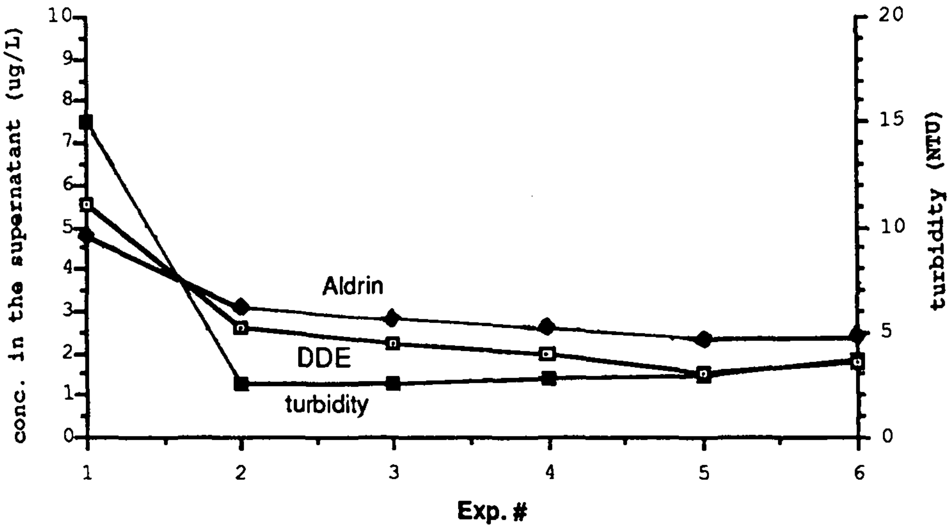


Figure 9. The effects of adding alum sludge on the removal on pesticides.



coagulant	-	alum	PAC	alum	alum	alum
dosage (mg/L)		6	10	6	6	6
coagulant aid	-	-	-	cationic polymer	nonionic polymer	anionic polymer
dosage (mg/L)		-	-	0.1	0.1	0.1

turbidity = 20 NTU, Aldrin = 10 ug/L, p,p' DDE = 10 ug/L
pH = 7.6, temperature = 20 C.

Figure 10. The effects of adding PAC and coagulant-aids on the removal of pesticides from water with low turbidity.

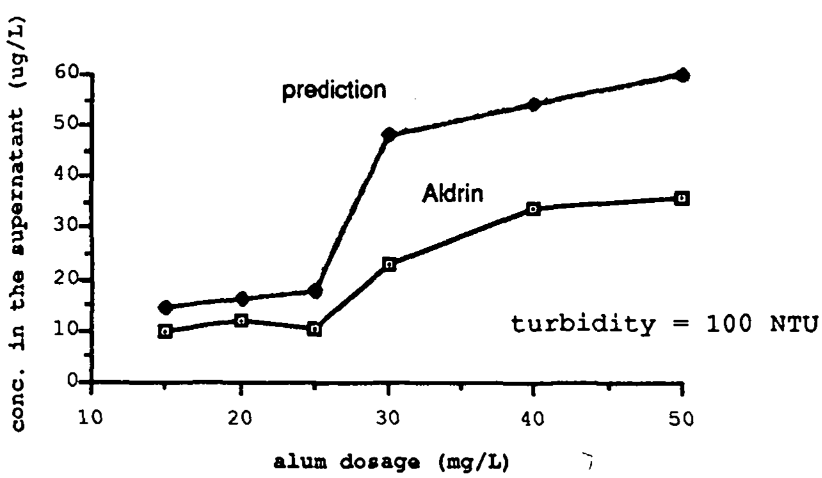


Figure 11. Comparison of model prediction and experimental results of Aldrin removal in highly turbid water.

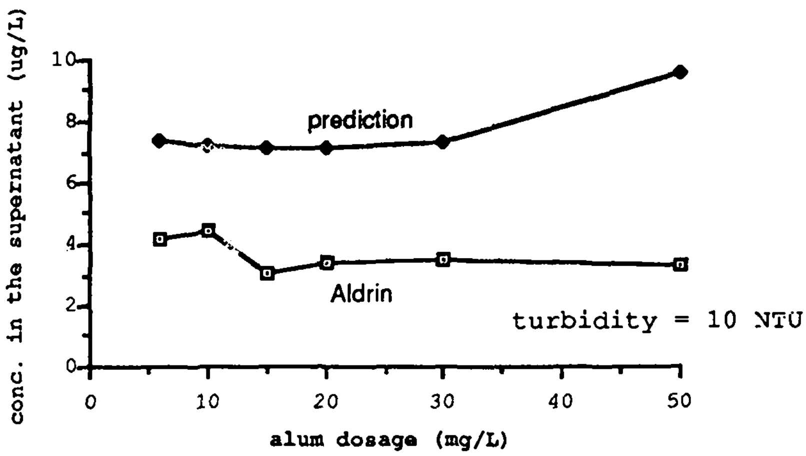


Figure 12. Comparison of model prediction and experimental results of Aldrin removal in slightly turbid water.

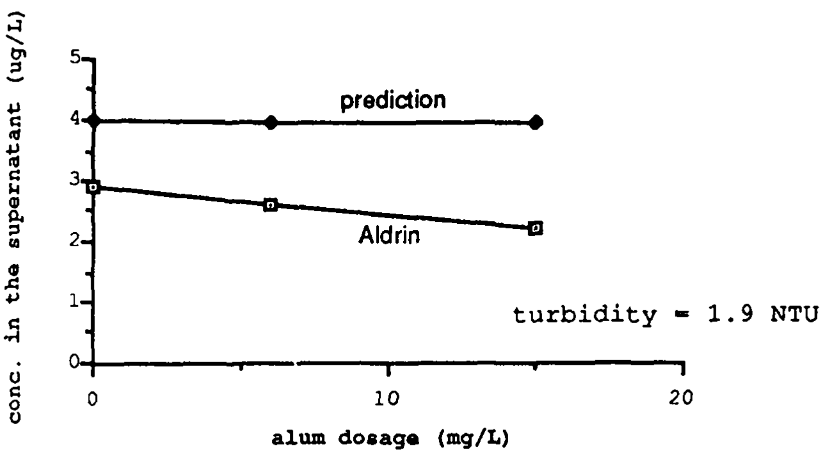


Figure 13. Comparison of model prediction and experimental results of Aldrin removal in water with very low turbidity.

STUDIES ON BIOLOGICAL ACTIVATED CARBON FILTER PROCESSES

by :

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1. Introduction

Many public waterworks are compelled to take water from organic polluted sources for public water supply in Japan. For water purification plant taking water from such organic polluted sources, to provide the safe drinking water is difficult if the water is purified by conventional generally applied method of rapid sand filtration.

Under the circumstances, the experimental work have conducted on a biologically activated carbon filtration system which would concurrently achieve both physical adsorption and biological oxidation, by either replacing the silica sand to the granular activated carbon, or by installing an activated carbon filter between the coagulation sedimentation tank and the rapid sand filter. The advanced water treatment method using biologically activated carbon is already entering the stage of practical application in Europe, but it has not been developed to a practical use in Japan although some experiments have been performed. Accordingly we built an experimental plant and performed experiments in order to clarify the problems that would arise when applying the biologically activated carbon filtration as well as reviewing a hazardous contaminants removal mechanisms under the reflection of the characteristics of Japanese drinking water source.

2. Experimental Method

For the experiment, we used an experimental plant having a treatment capacity of 4 m^3/d, as shown in Figure-1. Four columns were installed in the experimental plant and experiment was conducted under the filtration conditions shown in Table-1.

The filter medium as follows ,the garanular activated carbon(Filtersorb-400) with the size range 0.50 to 0.59mm and the silica sand with the effective diameter 0.6mm, were charged into filter. Each filter have a 15cm support media consisting 1mm diameter glass beads, up to a filter layer height of 60cm. Each filter column was prepared by connecting an acrylic tubular column(50mmX1500mm)to the top of a polyvinyl square column (50mmX 60mmX1000mm),making a total length of 2500mm.

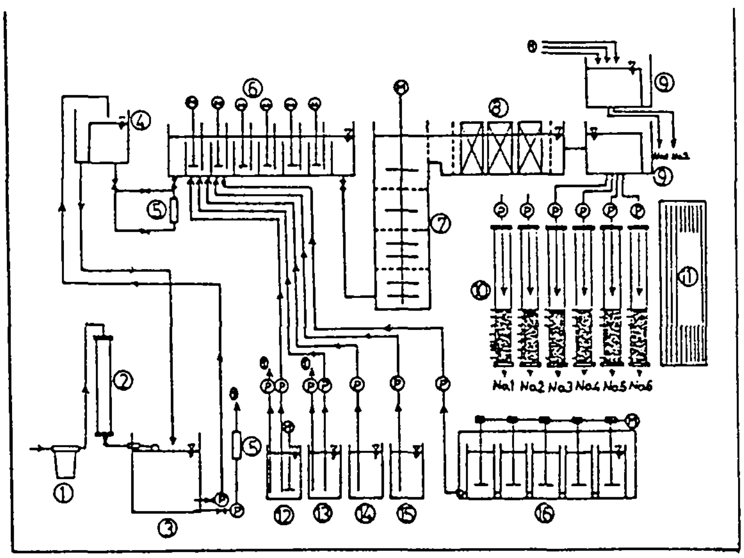
Table-1 Experimental Conditions of Biological Activated Carbon (BAC) Filter

Filter No.	F−1	F−2
Filter Media	GAC	SAND
Filter Size (mm)	0.50~0.59	0.50~0.59
Void Volume (%)*	62.5	46.1
Bed Volume (g)	761	2,300
Velocity ($m \cdot d^{-1}$)	120	120

$$* \frac{\text{Total Volume} - \text{Volume of Media}}{\text{Total Volume } (50\times60\times600 \text{ mm})} \times 100$$

Kaolinite and sodiumbicarbonate were added to dechlorinated city tap water in the proportion of kaolinite 20mg/l and sodiumbicarbonate 10mg/l. Then collective human excreta treatment plant effluent was added until the solution contained 1mg/l of ammonium nitrogen. We consider this a fair simulation of the actual source water for public water supply in Japan, since the major cause of water source pollution in Japan is household effluent.

Aluminium sulfate was used as the coagulant. 8.5mg/l of $Al_2(SO_4)_3 \cdot 18H_2O$ was added. Then, hydrochloricacid was used to adjust the pH value after coagulation to 7. The coagulation condition was set to the one making the optimum dosage after conducting a jar test. When the water depth above the filter surface reached 105cm, filtration was stopped and the column was washed. The backwash procedure is as follows: flowing through dechrolinated water for 18 minutes at back washing speed of 0.653m/min through sand and 0.392m/min. through activated carbon. Also,air cleaning was given concurrently for three minutes after starting backwashing by feeding 0.5kg/cm^2 of compressed air from the bottom of



1	Pre-filter	9	Headder
2	Column of activated Carbon	10	Filter barrel
3	Raw water tank	11	Manometer
4	Flow controll tank	12	Kaoline
5	Flow meter	13	$Al_2(SO_4)_3$
6	Rapid mixing tank	14	Na_2CO_3
7	Floculater	15	HCl
8	Settling tank	16	Secondary effluent by night-soil treatment plant

Figure-1 BAC Pilot Plant

each filter. The filter was backwashed everyday, the filter media being attached biological film.

Table-2 shows the characteristics of water flowing into the filter.

Table-2 Water Quality of the Influents

	Ave.	Max.	Min.
Water Temperatur (℃)	16.9	28.8	6.0
Turbidity (unit)	1.16	9.60	0.10
pH	6.81	7.80	6.15
Alkalinity ($mg \cdot \ell^{-1}$)	30.3	78.2	12.0
D O ($mg \cdot \ell^{-1}$)	9.23	13.4	5.47
NH_4-N ($mg \cdot \ell^{-1}$)	0.99	1.37	0.51
NO_2-N ($mg \cdot \ell^{-1}$)	0.14	0.57	0.01
NO_3-N ($mg \cdot \ell^{-1}$)	2.67	4.34	1.01
T O C ($mg \cdot \ell^{-1}$)	1.92	4.50	0.55
P V ($mg \cdot \ell^{-1}$)	3.26	5.76	1.37
E-260 (cm^{-1})	0.017	0.046	0.002
THM FP ($\mu g \cdot \ell^{-1}$)	41	58	22
TOX FP ($\mu g \cdot \ell^{-1}$)	161	275	70

3. Results and Discussion

3.1 Removal of turbid substances

One of the purpose of conducting biologically activated carbon filtration is removal of the turbid substances in the effluent of clarifier. Although the turbidity of the water fed to the filter varied within the range of 0.10 to 9.60 turbidity unit according to the change in the coagulation practice and source water temperature, the mean value was about 1.0. Almost all the turbid substances which could not be removed by the filter are only an extremely small turbidity unit such as 0.00 to 0.37 turbidity unit leaked out in the process up to the back wash level. On each filter medium in the state of receiving deposits with organisms after continuous filtration for 468 days, the positional variation of the filtered substances per unit filter medium from the filter medium surface to the lower part was measured, the result is shown in Figure-2. The activated carbon filtration seized 89.2% and the sand filtration seized 95.5% of the turbid substances within 5cm of the filter top. This means that both activated carbon and sand function with surface filtration, and sand filter having a slightly greater surface filtration effect.

3.2 Removal of Ammonium Nitrogen

As shown in Table-2, the quality of water flowing into the filter is almost constant and the ammonium nitrogen concentration is about 1.0 mg/l.

As shown in Figure-3, the relationship between the ammonium nitrogen removal rate and the water temperature in the steady state condition of the filter media being holding nitrifying bacteria is that the removal rate started to become smaller at about 17℃ with sand and at about 10C with activated carbon when the water temperature was decreasing, whereas activated carbon showed 100% removal rate even at 4℃, which was the lowest temperature in this series of

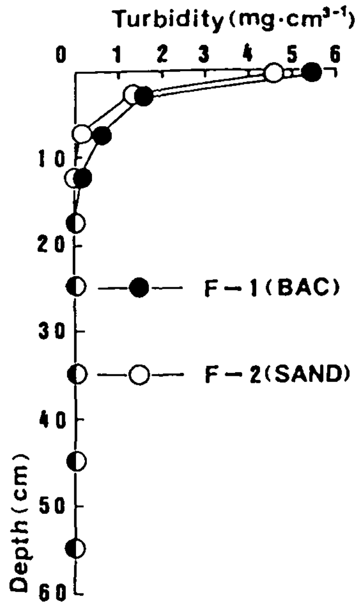


Figure-2
Effect of Temperature to Ammonium Nitrogen Removal

experiments.

On the other hand, when the water temperature was increasing, the removal rate obtained in a rapid filtration system was about 50% by activated carbon at 10℃ and about 50% by sand at 20℃. This implies that once the activity of the nitrifying bacteria allowed down as the water temperature decreased, a long time was needed to recover the activity.

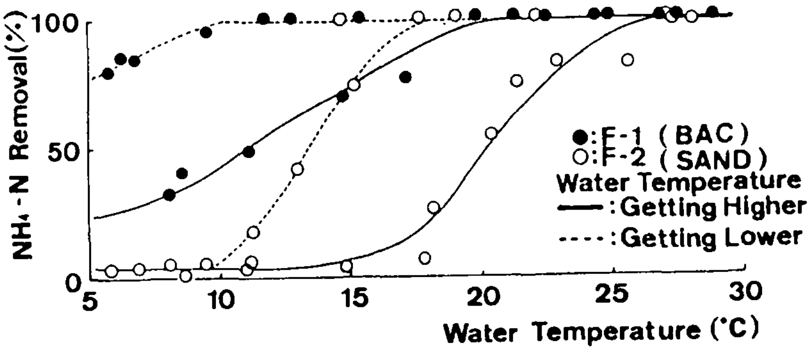


Figure-3 Effect of Temperture to Ammonium Nitrogen Removal

The thermal effect coefficients that influence the ammonium nitrogen removal rate may be obtained from the Arrehnius equation shows below

$$K_1 / K_2 = \beta (T_1 - T_2) \quad \cdots\cdots\cdots\cdots \quad (1)$$

In the above;
T1 and T2; Water temperatures
k1 and k2; Removal rate at T1 and T2
β ; Thermal effect coefficient

The thermal effect constant related to the ammonium nitrogen removal rate is 0.72 with activated carbon and 1.22 with sand filtration when the temperature is decreasing and 0.96 with activated carbon and 1.01 with sand when the water fluctuations in water temperature is increasing, clearly indicating that fluctuation in water temperature have less influence on activated carbon in either condition.

The conceivable causes for this difference are that activated carbon has a large number of micro pores than sand has, resulting in a larger surface area which nitrifying bacteria can be hold and that the micro pore inside is not directly influenced by the fluctuation of water temperature.

3.3 Removal of Potassium Permanganate Consumption Value and Total Organic Carbon

As shown in Figure-4, no pottasium permanganate consumption value(PV) removal effect can be expected with sand filtration system for about 30 days from the filter operation, but PV can be reduced by close to 50 % with an activated carbon filtration system because of the physical adsorption effect of activated carbon. After then, when organisms are grown on the filter media, the maximum PV removal rate is 30 to 60% in the case of a sand filtration system and 60 to 70 % in the case of an activated carbon filtration system. In the case of sand filtration , when the water temperature is decreasing, the PV removal rate slowly decreases in a rapid filtration system to almost zero. However , activated carbon filtration provides a removal rate of 20 to 30% even under the worst conditions. On the other hand, when the water temperature is high, the removal rate is about 70% with activated carbon and about 40% with sand. However the PV removal rate of activated carbon become similar to that of sand when it is used for about 400days. When the water temperature decreases

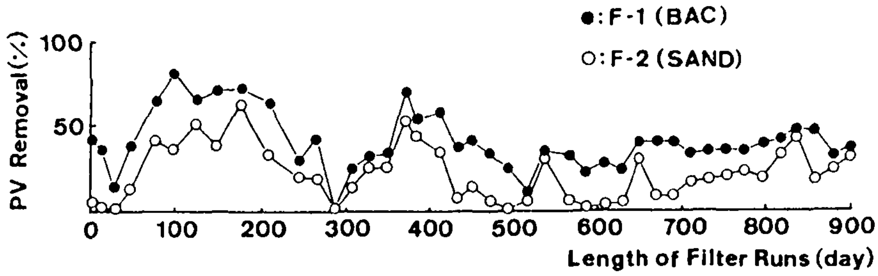


Figure-4 Daily Variation of Potassium Permanganate Consumption Value Removal

to 10℃ or below, the PV removal rate decreases in the both case , but the influence of water temperature is not as great as it is on ammonium nitrogen.

The behaviour of total organic carbon(TOC) removal is similar to that of PV removal. In consideration of the changes on the E260 absorbance to TOC ratio of treated water in various treatment process, Tanbo and others proposed the effectiveness of this ratio to evaluate the process performance. Table-3 shows the average TOC/E260 ratios in summer and winter. The table shows that this ratio is smaller for all filtrated water in summer, when the organisms are more active, then in winter, indicating that the TOC components are biologically decomposed and stabilized. Also, Figure-5 shows that the TOC/E260 ratio decreases as more TOC is removed.

3.4 Removal of Trihalomethanes precursor and Total organic Halides Precursor

Figure-6 shows the relationship between the number of filter operation days and the removal rate of trihalomethanes precursor(THMFP), and Figure-7 shows the relationship between the number of filter operation days and the removal rate of total organic halides precursor(TOXFP). On both THMFP and TOXFP , the behaviour is about same as that of the quality of water flowing into the filter since the filtration start in the case of sand filtration , and the removal rate is in the low range of 10 to 15%. On the other hand, the removal rate is as high as 90 to 100% for both THMFP and TOXFP since the filter starts in the case of activated carbon filter. This indicate that these precursors are physically adsorbed and removed in the activated carbon.

When the filter operate further, the removal rate gradually decrease even in the case of activated carbon filter, reaching an apparent steady state in about 70 days. Since the time at which the removal rate becomes constant coincides with the time at

	Influent	Effluentes	
	Coagu-Sed.	F－1	F－2
Spring (10.5 ~17.0)	72	78	94
Summer (21.8 ~26.4)	136	98	56
Autumn (17.2 ~20.5)	135	115	99
Winter (7.9 ~8.6)	252	229	294

*( ): Temperature of Coagulation-Sedimentation Effuluent(℃)
From 1985'2.13 to 1986'8.27

Table-3 Seasonal Variation of TOC/E260 Ratio

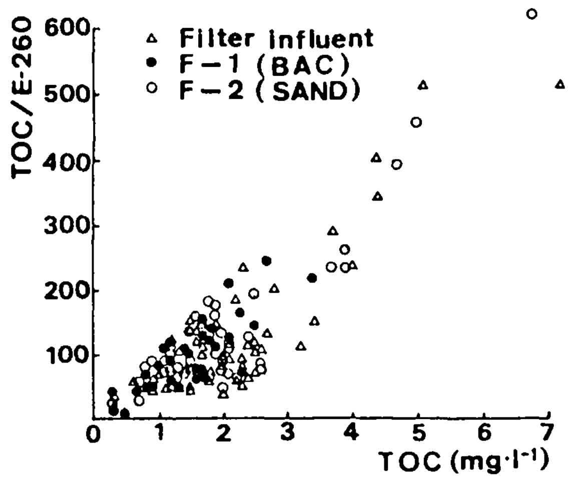


Figure-5 The Relationship between TOC/E260 Ratio and Remain TOC

which the PV and TOC removal rate have reached the steady state, that is, the time of biological activity has stablized, it is considered that microorganisms are influenced in the removal of THMFP and TOXFP.

The removal rate gradually decreased for up to 180 days of continuous filtration and after that it reaches a steady state although it is influenced by water temperature and other factors. The removal rate of biologically activated carbon after reaching steady state is about 40% with THMFP and about 50% with TOXFP . That is , although TOXFP in the water flowing into filter is higher than THMFP by one order of magnitude, the removal rate are almost same as in TOXFP and THMFP.

In order to clarify the theoretical maximum adsorption and actual adsorption of activated carbon used for the experiments, batch activated carbon adsorption tests using powdered activated carbon which was obtained by grinding granular activated carbon were implemented.

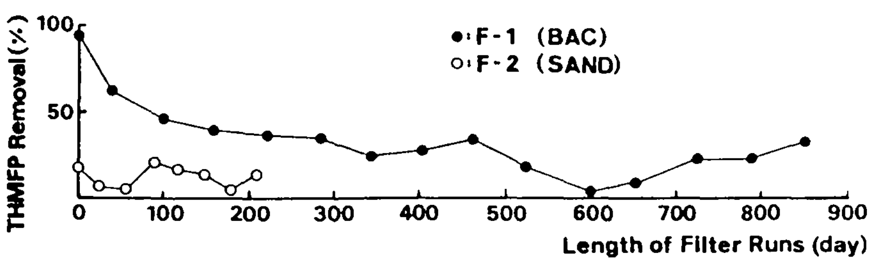


Figure-6 Daily Change of Trihalomethane Precursor Removal

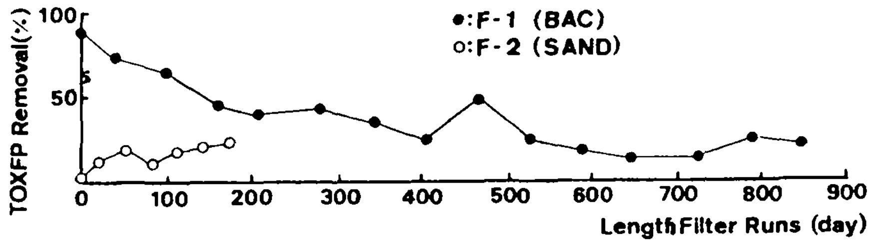


Figure-7 Daily Change of Total Organic Halides Precursor Removal

When the Langmuir equation is used as the adsorption isothermal expression;

$$C / q = 1 / (\alpha \cdot \beta) + C / \alpha \quad \cdots\cdots\cdots (2)$$

In the above;

c: Equilibrium concentration (mg/ l)
q: Amount of adsorbed (mg / g AC)
α: Maximum adsorption (mg / g AC)
β: Constant (l / mg)

Based of the results of the experiments, we obtained the following adsorption isotherm equations of TOXFP and THMFP.

$$\text{TOXFP: } c/q = 0.094 + 0.029\,c \quad \cdots\cdots (3)$$
$$\text{THMFP: } c/q = 0.096 + 0.132\,c \quad \cdots\cdots (4)$$

Using the above equations, theoretical maximum adsorption of TOXFP is 26.3g(34.5mg/gAC) and that of THMFP is 5.8g(7.6mg/gAc). On the other hand, the actual measured adsorption for up to 500 days after starting to feed water in the experiment plant is 47.6g of TOXFP and 9.4g of THMFP. From this, it is assumed that the theoretical maximum adsorption is reached in about 300 days after starting to feed water. Nevertheless, since the activated carbon has the removal ability of THMFP and TOXFP even after 850 days in actually, we consider organisms to greatly influence removal.

Based on these considerations, it may be said that , in the case of bilogically activated carbon filtration, physical and chemical adsorption continuously functions even upon reaching apparent saturation, in addition to the mere biological removal of organic substances. In other word, it is assumed that the precursors adsorbed into the micro pores of activated carbon are gradually decomposed by the aerobic bacteria grown in the filter layer, resulting in regeneration of the adsorption sites of activated carbon.

Observation of the biologically activated carbon through and electron microscope disclosed that the pores on the particle were covered by an organism film and the substances adsorbed onto the activated carbon were placed in a situation of not easily diffusing into the particle inside. Also, it is generally said that the physical adsorption speeds of TOXFP and THMFP are slower than that of other organic substances and this slow stage is maintained for along time without reaching the theoretical exhaust of adsorption capacity.

The batch adsorption study using the biologically activated carbon that had been used for filtration for 300 days was sterilized for 20 minutes at 2.0kg/cm2-121°C, and dried, crushed, sorted 150-200meshes and the adsorption test was conducted. Figure-8 shows the Freundrich isothermal curve of TOC as an example of this experiment. Although the internal adsorption capacity of the activated carbon was extremly low, compared with fresh activated carbon, it is known that the activated carbon still had adsorption capacity from the gradient of the isotherm curve. The time needed for biologically activated carbon, added at 1000mg/l to reach adsorption equilibrium was 96 hours, which was much longer than the 24 hours needed by fresh activated carbon. Since the experiment was conducted under a condition of close to no bacteria, allowing no entry of organisms and with sufficient agitation, the difference on the laminar film diffusion velocity between fresh activated carbon and biologically activated carbon may be ignored and the inclination of the adsorption isotherm curve and the difference in the time reaching equilibrium concentration seem to be attributable to the diffusion velocity in the micro pores.

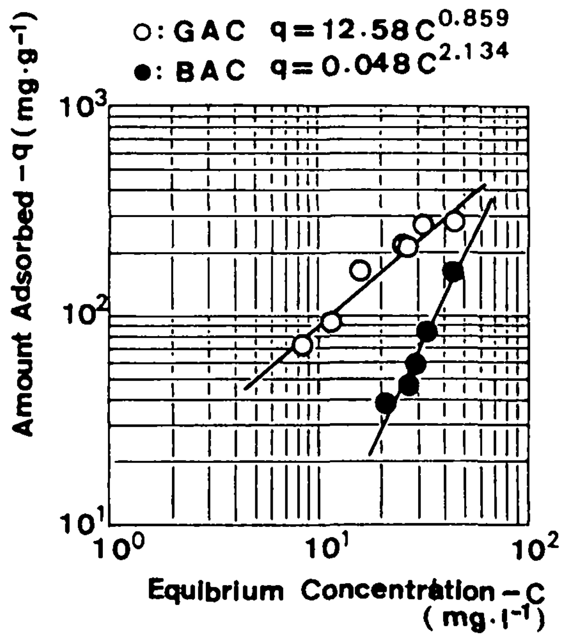


Figure-8 Comparisn of Adsorption Isotherms between GAC and BAC

4 . Conclusion

We have studied the properties of the biologically activated carbon filter from the view points of the removal of turbid substances, ammonium nitrogen ,and some organic pollutants, using an experimental plant and referring to the conventional rapid sand filtration. The knowledge obtained from the experiment is summarized below.

Biologically activated carbon is superior to rapid sand filtration both in duration of effective filtration and in total turbid substances seized. The removal rate of ammonium nitrogen is affected by water temperature, however biologically activated carbon filter is less influenced than sand filtration. Activated carbon is also superior to sand filtration for removal of TOC and PV. Even in the steady state after the exhaust of the adsorption capacity of activated carbon, biologically activated carbon filter can continiungly remove THMFP and TOXFP.

Therefore we conclude that biologically activated carbon filtration system has greater advantages than rapid sand filtration system especially in the case of treating organic polluted surface water.

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ALTERATIONS OF THE POTABLE WATER CHARACTERISTICS IN CONSEQUENCE OF MODIFICATIONS INDUCED INTO THE GROUND BY ACID RAINS

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SUMMARY

It is known that humic substances constitute a great part of the organic component in the ground. The properties of these substances, particularly the capacity to form complexes, are of considerable importance, since they prevalently control the quality of the ground and of the waters.

The complexing degree of such substances, especially that of the fulvic acid, one of the principal components, sensibly depends on the pH of the surroundings, since the ionic dissociation degree of the acid increases as the pH decreases. Therefore the phenomenon of the acid rains tends to increase the concentration of metallic ions, eventually of toxic nature, in the water and in the ground. On the other hand, this fact is already noticed in some Canadian lakes, as well as in grounds where a remarkable increasing of the free aluminium, no more fixed by the fulvic acid, has been pointed out as a consequence of acid rains.

The above considerations prove the importance as well as the actuality of studies, such that we propose in this paper, devoted to a more accurate characterization of the behaviour of the humic substances in order to foresee the effects of the pH modifications induced by acid rains.

In such a way, also on the basis of suitable statistic surveys on the precipitations, it is possible to find out some methodologies and zones of intervention in order to prevent, or to remedy to, the pollution of the water beds used for the supplying of potable water.

This problem, even if of relatively recent date, obliges the legislator to revise, in a dynamic and updated way, the legislation codes for the acceptability of the potable waters.

INTRODUCTION

The phenomenon of the acid rains, although well known from long time, only lately has taken the right care, chiefly owing to the decreasing of the pH of the waters. Such phenomenon is now widely spread and has become important all over the world. In fact the pollutants are transported by air streams, also in regions, where they are not directly produced and released in the atmosphere.

The interest for this problem is confirmed by a lot of recent studies, concerning the monitoring of the acid rains in many regions in every countries (1-6).

The acid rains show immediately their effects on the plants, which are submitted both to the direct action of the rain and to indirect one of the ground, and on the animals, living in the surface water, where the pH changes very quickly.

In last years, many efforts has been devoted to evaluate the effects of the acid rains on the animal and plant life (8-11).

Beside these macroscopic effects, there are some secondary consequence of the acid rains, which are less evident, but not less important. The acid rain water penetrates into the ground and can interact both with the inorganic part, dissolving eventually the metallic ions (12-13), whose concentrations in water will increase, and with the organic part, especiallly with the humic substances (14).

The properties of the humic substances, and in particular their capability to form complexes, have a great importance in agriculture and in geo-chemical. In fact these substances determine the characteristics of the ground and of the waters. The complexation degree of these substances, and mainly of the fulvic acid, strongly depends on the pH of the environment, that is to say the acid/free ion dissociation increases when the pH decreases.

Then it is clear that the phenomenon of the acid rains raises the concentrations of metallic ions, frequently toxic, in the ground and in the waters. Such event has been already noticed in some Canadian lakes (15) and in some grounds, where the acid rains have produced a large growth of the free aluminium, no longer fixed by the fulvic acid (16).

The above considerations emphasize the interest for the studies regarding the characterization of the behaviour of the humic substances, in order to foresee the effects of the variation of pH due to individuate methods and zones of eventual intervention, also on the basis of suitable statistical collection of the precipitation data.

CHARACTERISTICS OF THE METALLIC ION/HUMIC SUBSTANCES BOND

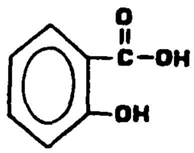
Although the humic substances are known for over a century, only in the last time it has been proved that they have properties similar to those of the polyelectrolytes at weak acidity, with a wide range of molecular weight, solubility and acidity (17-18). Their structure is not yet completely defined, but it has been found that they have a mainly tridimensional structure, formed by aromatic rings, with many functional groups and lateral chains.

The fractions with low molecular weight can sometimes aggregate, while the fractions with high molecular weight are essentialy in gel state.

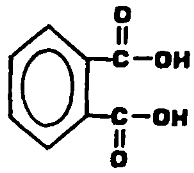
Two main types of reactions has been identified (17-18):

- formation of a bond of electrostatic kind, depending on the presence of electric charges on the surface of the polyelectrolyte (19);
- formation of an "internal" complex (20-21), with phenomena of chelation (20).

The functional groups, which, most likely, are involved in the metal/humic substances bond are aromatic carboxylates and phenolic structures of the type:



Salicylic acid

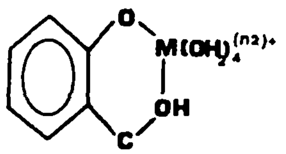


Phtalic acid

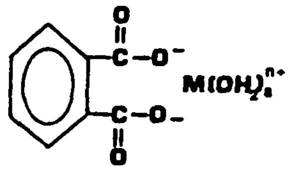
Fig. 1

Such components are often found in the structures of the humic substances and in particular of the fulvic acids.

With reference to the two above said components (see fig.1), the metal/acid equilibrium is controlled by the substitution of the water molecule in the metallic site. If the metal is, so to say, "preferred" to the water, an "internal" complex is formed (fig. 2-a); on the contrary, if the water replaces the metal, an "external" complex is constituted.



2a



2b

Fig. 2

METHODS FOR THE CHARACTERIZATION OF THE HUMIC SUBSTANCES

In order to identify the type of complexes formed in the humic substances, two different methods can be utilized.

The first one, formerly developed to investigate the protein/metal complexes (22), is based on the influence of a paramagnetic metallic ion on the NMR effect of the protons of the acqueous solution (23). In such a way, for istance, it has been shown that Fe^{3+} and Cu^{2+} form "internal" complexes, while Mn^{2+} forms "external" complexes (23-24).

The second one is based on the comparison of the kinetics of formation and dissociation with other kinetics, relevant to complexes with a known structure; such method has been utilized to demonstrate that Fe^{3+} forms an "internal" complex.

For the investigation of the structure of the humic substances, the potentiometric titration with different ionic strenght is used. In fact, if the molecule is little and monomeric, the curve of the parameter

$$pH-\log[\alpha/(1-\alpha)]\ (=pK)$$

versus α (where α is the neutralization degree), will result nearly

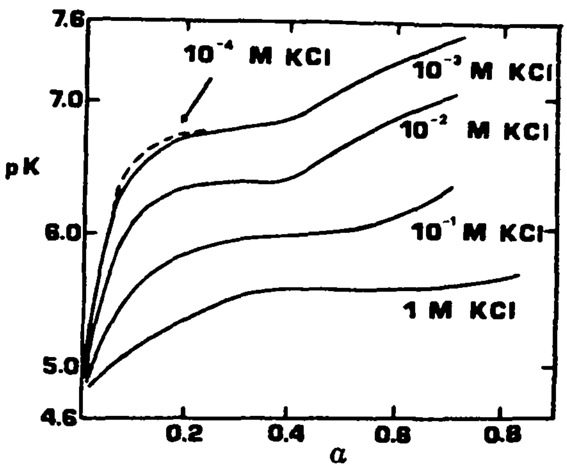


Fig. 3 Potentiometric titration of polymethylacrylic acid (c_{PMA}=0.01 eq/l).

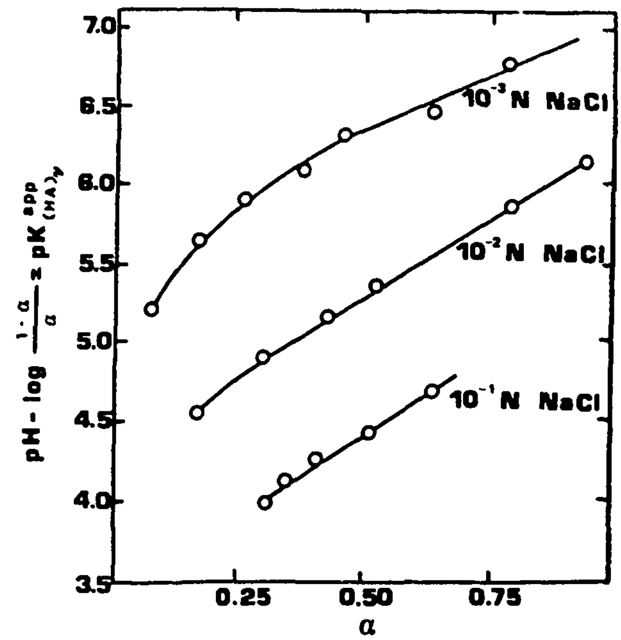


Fig. 4 Potentiometric titration of a peat gel.

indipendent from the ionic strenght. On the contrary, if we are dealing with a linear hydrophobe polymeric structure, unaccessible to water and salts, a strong effect of the ionic strenght on the above said curve will be found. The greater differnce among the curves will be noticed, the higher dissociation degree will be present. Furthermore all the curves will converge in one point for $\alpha=0$ (see fig. 3).

At least, if the molecule has a tridimensional structure with a part accessible to water and salts, its potentiometric properties will be similar to those of a gel substance (see fig. 4).

In fig. 4, the curves for different ionic strenght are shown. They have a nearly parallel trend, with higher value of pK for weaker ionic strenght, at the same dissociation degree.

The method of potentiometric titration, at different ionic strenght, performed both on the substances without addition and in presence of the ion of an heavy metal allows to evaluate the behaviour of the humic substances. Furthermore, on the basis of suitable models, it is possible to calculate the equilibrium costants of the various functional groups in different substitution conditions. This method can be applied more extensively than other proposed systems.

This last aim involves many difficulties, because of the lack of knowledge about the actual structure of the substances considered. Instead such investigation can be carried out for simpler components, with fewer functional groups.

The comparison between the behaviour of these last components and the behaviour of more complex substances allows to extrapolate the values so calculated to the case of humic substances.

For istance, in the case of phtalic acid, which represents one of the most frequent functional groups in the humic substances, the reference model of the carboxylic acid can be adopted.

It involves the following dissociations:

$$H_2A \rightleftharpoons HA^- + H^+$$

$$HA^- \rightleftharpoons A^{--} + H^+$$

$$MHA \rightleftharpoons M_F \cdot + HA^-$$

$$MA \rightleftharpoons M_F + A^{=}$$

with the relevant equilibrium constants:

$$K_1 = \frac{(HA^-)\,(H^+)}{(H_2A)} \qquad (1)$$

$$K_2 = \frac{(A^{=})\,(H^+)}{(HA^-)} \qquad (2)$$

$$\beta_1 = \frac{(MHA)}{(M_F)\,(HA^-)} \qquad (3)$$

$$\beta_2 = \frac{(MA)}{(M_F)\,(A^{=})} \qquad (4)$$

From the mass balance:

$$\Sigma H = 2\,H_2A + HA^- + MHA + b \qquad (5)$$

$$\Sigma A = A^{=} + HA^- + MHA + MA \qquad (6)$$

$$\Sigma M = M_F + MA + MHA \qquad (7)$$

where

ΣH = actual proton molarity;
ΣA = actual acid anion molarity;
ΣM = actual metal molarity;
b = actual base molarity;
M_F = actual free metallic ion molarity.

Among the terms present in the foregoing equations, only the following ones are known:

ΣA and ΣM initial amounts of humic substance and metal;
b added base;
ΣH and ΣM_F measured values.

Therefore the system (1-7) is indetermined, (seven equations and nine unknown values); for its solution it is possible to use, for istance, the following method.

The ratio "n", defined as:

$$n = \frac{\text{Bonded}(H,M)}{\text{To bond}(A)} = \frac{\Sigma H - b + \Sigma M - M_F}{A} \qquad (8)$$

can be easily calculated during the titration since the terms appearing in its definition are known.

The combination of the above written eight relations allows to obtain the following four equations:

$$\frac{n}{1-n}\,\frac{1}{(H^+)} = \frac{1}{K_2} + \frac{2-n}{1-n}(H^+)\left(\frac{1}{K_1K_2} + \frac{M_F\,\beta_1}{K_2\,(H^+)} + \frac{1-n}{2-n}\,\frac{\beta_2\,M_F}{(H^+)^2}\right) \qquad (9)$$

$$\frac{1-n}{2-n}\,\frac{1}{(H^+)} = -\frac{1}{K_1} + \frac{n}{2-n}\,\frac{1}{(H^+)^2}\left(K_2 - \frac{2-n}{n}\,\beta_1 M_F (H^+) - \frac{1-n}{n}\,\beta_2 M_F K_2\right) \qquad (10)$$

$$\frac{n}{1-n}\,\frac{1}{M_F} = \beta_2 + \frac{2-n}{1-n}(H^+)\left(\frac{(H^+)}{K_1K_2M_F} + \frac{\beta_1}{K_2} + \frac{1-y}{2-n}\,\frac{1}{K_2\,M_F}\right) \qquad (11)$$

$$\frac{1-n}{2-n}\,\frac{1}{M_F} = -\beta_1 + \frac{n}{2-n}\,\frac{1}{(H^+)}\left(\frac{K_2}{M_F} - \frac{2-n}{n}\,\frac{(H^+)^2}{K_1\,M_F} - \frac{1-n}{n}\,\beta_2 K_2\right) \qquad (12)$$

Each of these equations allows to calculate reliable values of the equilibrium constants, by a suitable graphic representation and subsequent approximations.

With the aid of such methods the AA have begun a series of experimental tests with various metallic ions, with the objective, on the one hand, to determine the equilibrium data of some humic substances, and on the other hand, to characterize the fulvic acid, one of their simplest components.

The results till now obtained, still under elaboration and examination, show for the tested fulvic acid, a structure constituted by an aggregate of linear molecules and then with a potentiometric curve of the type reported in fig. 3.

CONCLUSIONS

The foregoing considerations point out the importance of humic substances, with their capacity of distributing and redistributing the metallic ions in the ground and in the waters. These equilibria, changed by the acid rains, cause modifications in the concentrations of some metal in the water, both underground and on surface, with possible risk of making it not drinkable.

For that reason, it is very useful to know the behaviour of the humic substances mostly in the case of external modifications. Such knowledge needs a very large amount of experimental work, owing to the complexity of the substances, the heterogeneity of their composition and the variability of their characteristic, depending on the region of origin.

The best approach, in our opinion, for this investigation consists in:

- a basic work for the complete characterization of simple components, holding functional groups typical of the humic substances;
- an applied work, regarding the various humic substances, performed by comparison with the behaviour of the basic components, pure or in mixture;
- a methodological work for the forecast of the effects of the acid rains in

the ground and in the waters, on the basis of systematic meteorologic investigations.

In such a way, it will be possible to individuate some methods and zones of intervention, in order to prevent, or to eliminate, the pollution of the water resources, used for the supply of drinking water.

The problem must be faced by the legislator, in a dynamic and careful way, revising continuously the standards for the acceptance of the drinking water.

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PACKAGE 3

OPERATION AND MANAGEMENT STRATEGY

ECONOMIC ENVIRONMENTS SURROUNDING THE MANAGEMENT OF THE OSAKA MUNICIPAL WATER SUPPLY AND ITS WATER RATES POLICY

by :

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1 Introduction

Most of the water works in Japan are publicly owned utilities, and they are, as a whole, financially independent from the general administration. Therefore, the cost of service must be covered by the price charged on consumers.

Since revenues are generated through water rates, a water utility is entitled to recover through the rates the sum of all of its cost. On the other hand, because of its public characteristics, relatively low rates must be maintained for a minimum necessary consumption. How to set rates in order to recover all of the costs while maintaining low rates for the civil minimum has become a very difficult problem to solve.

At present, water rates for a residential use in Osaka city is settled at 500 yen for below 10m^3 per month. Customers who use 20m^3 per month are charged 1,050 yen, which means 55 yen for a unit volume consumed above 10m^3.

As the average monthly consumption of families in Osaka city is 19m^3, the monthly water rates charged are, on an average, 955 yen. This water price is fairly low compaired with that in other cities throughout Japan. As of April 1, 1986, the national average water rates for the consumption of $10m^3$ and $20m^3$ per month are 1,162 yen and 2,371 yen, respectively. The rates charged in Osaka city are less than one half of the national average. One of the traditional characteristics of the rates setting of Osaka city has been to maintain the water rates as low as possible for some minimum level of consumption.

These cheap water rates for a residential use are partly derived from relatively low costs for water production.

Osaka city established its water works as the first fourth public utility in Japan. It can be said that Osaka city has inherited the so-called "subsidy from the past", because of the earlier investment. The city area (about 210 Km^2) is so compactly populated that the investiment efficiency is high for its large enterprize scale.

Osaka city has been blessed with a large amount of water for raw water supply because of the neibouring presence of lake Biwa and the Yodo River, which has saved the city from paying much money for water resources developments. These are the main reasons for the relatively low costs of the supplied water in Osaka.

Speaking of the rates setting policy adopted in Osaka city, the increasing block rates structure starting in 1965 contributes to the fact that the water is cheap for the groups of customers who use little water.

In Osaka city, consumers who use $100m^3$ per month pay the price which is nearly equal to the full service costs. In other words, customers who use less than $100m^3$ per month get their water at a price lower than the cost. Most of the families living in the city, namely 98 per cent, belong to this group. They consume totally about 60 per cent of the total water supplied, but the revenue from them is only about 30 per cent of the total income from all of the consumers. It can be said from these considerations that the groups who use small quantity of water are supported in terms of water rates by the groups who use large quantity of water.

2 Historical Change in Water Demand

Osaka city has beeen industrialized for long years and its economic activity is highly centralized throughout the city.

Osaka water works were established in 1895, and since then they had been forced to keep enlarging their facilities in order to meet the then increasing demand.

The maximum capacity at the time of foundation was 50,000 m^3 per day. Water demand had been constantly increasing since then because of the enlargement of the city area, increasing population, and developments of social and economic activities. Especially after 1955, an increasing rate of water consumption had been so steep year by year as to reach a record of the maximum daily consumption of 2,417,700m^3 in 1970, with a highly economic growth as a background.

During the years of 1973 to 1974, however, the water demand changed from its increasing trend to a decreasing one, and this decreasing tendency is still proceeding even these years. Osaka water works have never experienced before such a phenomenon for the water demand to decrease with time until these past some ten years. We have got used to taking measures against the increase of water demand, but as for the problems associated with its decrease, we are forced to take completely different measures from those we are accustomed to.

The change of the water demand tendency has caused a change in the rates setting policy of Osaka water works.

3 Change in Water Demand Structure

In 1973, when the water demand changed from its upward trend to downward, there occurred two symbolic happenings together which had strong effects on the water demand. These were the first oil crisis and a severe drought bringing about a water shortage.

In the previous years, 35% of the total water consumed was by residential users, 60% being consumed by industrial and commercial users. This pattern of water consumption structure had supported the cheap water rates for domestic uses.

However, in 1985, more water was spent for domestic purposes than for business ones (Fig. 1).

Table 1 shows that the water demand for residential uses have been growing constantly. On the other hand, the quantity of water used by offices and factories have been decreasing. Particularly, water consumption for industrial uses dropped to less than one half in 1985 compared with that in 1972.

It is said that elasticity of water demand is not high, but this is true only for the minimum domestic uses. In the case of business uses, however, water consumption is affected

Figure 1 Anual Water Quantity Used by Different Classes of Water Users Comparison Between 1972 and 1985

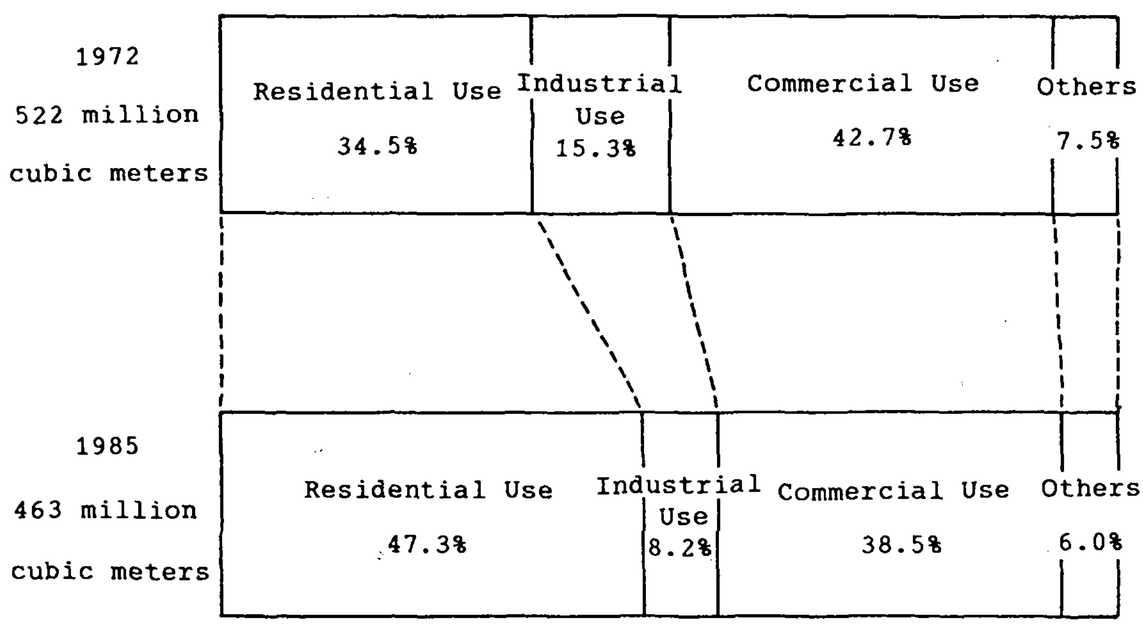

Table 1 Yearly Comparison of Water Consumption at Different Types of Users

Type	1972	1975	1980	1985
Residential	100	108	111	122
Industrial	100	75	56	48
Commercial	100	92	83	80
Others	100	80	67	72

by many factors associated with marketing principles.

Depression in business made industrial users to save water in order for the price of their products to maintain as low as possible. They tried to reuse spent waters over and over again in offices and factories.

Conciousness of saving water prevailed even in the households after the severe drought in 1973, which resulted in a decrease of quantity of water used.

One of the characteristics of the water demand structure in Osaka city had been that the quantity of water used by commercial and industrial users were much more than that for the residential uses. Because of this water demand structure, decrease in water consumption could not be stopped after the business recession of the year of 1973, which resulted in a decrease in revenue.

4 Water Rates Revision in 1984 and Water Rates Policy

Water works, which are financially independent from the general administration, place the most importance on their water rates system.

Since their foundation, Osaka municipal water works had been adopting a value-of-service pricing under which water price was determined according to the purposes of water use. Under this water rates system, there were more than 10 classifications as to the purposes of water usage.

In 1965, however, there was a modification in the water rates system, that is, increasing block rates system came into effect. At the same time, classification of water usage was reduced to 4 classes. Table 2 shows the water rates for each of the classes.

Table 2 Water Rates (per month)

Revised on May 1 1984

Type		Fixed Rate	Excess Rate per Unit Volume		
Individual	General	500 Yen for 10m³	11m³ -	20m³	55 Yen
			21 -	30	81
			31 -	40	96
			41 -	50	147
			51 -	100	180
			101 -	200	228
			201 -	500	258
			501 -	1,000	282
			1,001 -		298
	Business	500 Yen for 10m³	11m³ -	30m³	141 Yen
			31 -	50	216
			51 -		298
	Public Bath	500 Yen for 10m³	11m³ -		43 Yen
Common (per family)		230 Yen for 8m³	9m³ -		37 Yen

As a consequence, the water quantity spent in the business class occupied only a small part, 1.6%, of the total consumption, in this figure the public bath class being excluded.

By this modification importance was almost lost in differentiating the purposes of water use. On the other hand, in the class of general use, increasing block rates system took the important place of the former price setting system.

The increasing block rates system first introduced in Osaka at the revision of water rates in 1965 amied at receiving enough revenue from large-volume users to support a traditional low price for small users.

The previous water rates system which charged for water according to the characteristics of water use was to allocate the cost based on the value of service. In this rates system residential users were subsidized by the industrial and commercial users who paid higher price for a unit volume of water than the former did.

In the increasing block rate system higher price are allocated to larger-volume consumers to cover the deficit coming from lower price for smaller-volume consumers.

Osaka water works had to enlarge the facilities to meet the increasing water demand at the time of highly economic growth in 1955 to 1965.

The service cost increased because of a huge capital investiment injected for a construction works of the necessary facilities.

Osaka water works took a water rates policy for the increment of a unit cost to be covered by larger-volume consumers, because they were responsible for the cost increase. The increasing block rate system was introduced to maintain the minimum service block as low as possible and promote a reasonable water using at the side of large-volume users. The new water rates system succeeded in achieving these goals all right.

However, the problem was that there occurred an income decrease under the increasing block rate system, which jeopardized the management stability. High water rates at higher blocks resulted in encouraging large-volume users to take steps to eliminate unnecessary uses of water. Decrease in water consumption by large-volume users was also caused by the increasing rates for sewer service.

Table 3 Yearly Comparison of Water Consumption at Different Rate Blocks

Block	1972	1975	1980	1985
$0m^3$ - $20m^3$	100	110	110	116
21 - 50	100	113	123	136
51 - 100	100	95	84	86
101 - 1,000	100	84	75	70
1,001 - 10,000	100	81	70	63
10,001 -	100	83	55	49

Table 3 shows the ratios of the water quantity consumed at each of the blocks in the representative years, with that in 1972 being a basis. The quantity for the residential uses mostly lies in less than 50m³ per month. As for the block of 20-50 m³, there is an increasing tendency with time in the sum of water consumption.

On the other hand, the higher the block goes up, the greater a reduction rate is (Table 3). In the block of more than 10,000m³ per month, which large commercial and indstrial users belong to, the water consumption dropped at nearly one half in 1980 compared with that in 1972.

In 1984, when the water rates were revised, the ratio of a unit rate between the lowest block and the highest was greatly reduced from the previous ratio (Table 4). At the time of the water rates revision in 1980, there was also some reduction in the ratio between the blocks, but the reduction rate was too small to be effective.

Table 4 Change in the Water Rates (after 1965)

Revised in	Fixed Rate		Highest Block Rate (per 1m³)	Increasing Ratio	Number of Block
		per 1 m³			
1965	100 Yen for 8m³	12.5 Yen	51m³ - 25 Yen	2	3
1969	100 Yen for 8m³	12.5	201 - 42	3.36	6
1973	100 Yen for 8m³	12.5	1,001 - 78	6.24	9
1975	230 Yen for 10m³	23	1,001 - 180	7.83	9
1980	340 Yen for 10m³	34	1,001 - 240	7.06	9
1984	500 Yen for 10m³	50	1,001 - 298	5.96	9

The decrease in the ratio between the blocks was brought about by raising the price higher at lower blocks than at higher blocks. In 1980, lifeline rates at the minimum service block was raised by 47.8% in contrast with the average increase rate of 33.4%. The average increase rate at the revision of 1984 was 25.6%, while the lifeline rates was raised by 47.1%.

The public utility industry council in Osaka had been suggesting that the rates at the minimum service block should cover at least the operation and maintenance costs. The minimum service block rates were about 50% and 60% of the operation and maintenance costs at the water rates revision in 1980 and 1984, respectively. The suggestion by the council was not realized fully at the last two of the water rates revision.

5 Conclusions - Water Rates Policy is Changing

Water supply is indispensable not only for pleasant and wholesome life for the citizens, but also for the lively urban social and economic activities.

Water works are the fundamental facilities for the city life, and they are resposible for providing the citizens with ample water of good quality at a reasonable price. This is the basis of water supply policy.

The most difficult problem concerning the water supply is how equitably the service costs should be allocated to all customers.

Since the foundation of the public water works, it has been discussed all the time at what level the water price for the minimum service should be placed.

The Osaka water works have been supplying water for the minimum service at a price far less than the operation and maintenance costs.

It is under the internal subsidization from large-volume customers that Osaka water works have been able to keep the water rates for the residential uses at a considerably low level.

The increasing block rates once had a good reason for their existance.

At the time of expansion of the facilities, the increasing unit costs for construction of the new facilities should be covered by the responsible large-volume water consumers. But now is the time when demand and supply are balanced. There are no construction works carried out except for maintaining the existing system capacity. The increasing block rates system is now loosing its orginal rational reasons.

The social and economic environments are changing. The water rates policy should also be modified according to the change in the environments.

It is in the interest of equity that the charges to the customers are assessed in proportion to the cost of serving the customer. And still the water rates for the minimum service should be maintained as low as practicable.

WATER METER READING THROUGH TELEPHONE LINE

by :

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1. Introduction

Water authorities in Japan have made every effort to secure stable water supplies and to enhance the efficiency of operations such as meter reading and billing. Their efforts were supported by the advancement of electronic technology particularly in the field of instrumentation and telecommunication combined with computer technology, and this has given rise to a remarkable development in automatic meter reading systems.

This paper describes two kinds of automatic meter reading system, one of which is a polling system and the other is a calling system.

2. Types of Water Meter utilized in The Systems

Types of water meter are classified by their functions as follows.

-1. Active type water meter (refer to Photo 1)
This type of water meter sends a pulse signal per unit volume of water flow and can be subdivided as follows ;

The self-generating type which generates and transmits a pulsed voltage signal without any battery or other power source, the contact type which typically uses a reed switch or a latch relay or a micro-switch requiring power supply, and the non-contact type which uses a magnetic sensor also with power supply.

-2. Passive type water meter (refer to Photo 2)
In one of the passive type water meters, the total volume of water flowing through the meter is displayed on its pointer type counter or roller type totalizer as in conventional water meters, but this display is electrically readout, for example through the position of a rotating arm which makes contact with one of ten fixed contacts of a rotary switch for each digit for the decimal code.
The other type is so called electronic water meter in which the total volume of water can be memorized in IC and equipped with interface functions with terminal equipment for tele-metering.

-3. Active-passive type water meter (refer to Photo 3)
This meter sends a pulse per unit volume of water flow to an electronic counter which displays the total volume of water flow. This display is then electrically readout and also equipped with interface functions as in passive type water meter for tele-metering.

3. Automatic Meter Reading System using Telephone Cables

-1. Polling system
The idea to use telephone cables for data transmission dates back to approx. 20 years ago, but it has not been realized because of restrictions in technical matters and related laws.

In 1968, the Nippon Telegraph and Telephone Public Corporation (hereinafter called as "NTT")started a technical study for automatic meter reading systems using subscriber's telephone lines to work out the plan for a series of experiments to be conducted from April, 1969 in cooperation with The Bureau of Tokyo Metropolitan Water Works, The Sewage Bureau of Tokyo Metropolitan Government, Tokyo Gas Co. Ltd. and data transmission equipment manufacturers.

The experiments were carried out in four sessions over six years, resulting in confirmation of the technical feasibility of such systems. The possibilities of direct readout of total volume of water flow by electrical method, off-hook function to give priority to ordinary phone calls, form of transmission signals, no-ringing function and center-initiated calling method (polling method) etc. were technically confirmed. The experiments involved 70 units of various sizes of active and passive type water meters installed in scattered part of Tokyo. The meter reading center was located in The Tokyo Trunk Exchange Office, to which all data concerning the meter readings were gathered.

In October 1975, The Ministry of Postal Services set up the " Telemeter System Research Group " for studying the feasibility of automatic reading systems for remote meters and sensors by using electric communication lines, to which a number of researchers from The Bureau of Tokyo Metropolitan Water Works, Tokyo Gas Co., Ltd. The Federation of Electric Companies, NTT and tele-communication equipment manufacturers as well as well-experienced people in this research area have participated. The Group members conducted intensive researches, surveys and discussions, the result of which were summarized in a final report in December 1977.

In response to this report, The Ministry of Postal Services established the " General Tele-metering Development Conference " in July 1978 by gathering representatives from NTT, public authorities, tele-communication equipment manufacturers, meter manufacturers and well-experienced people with the view that utilization of the existing subscriber's telephone network is the most effective and feasible way of establishing transmission lines for the proposed telemetric meter reading system in view of the number of telephone subscribers (35,000,000 at that time) and transmission characteristics of the network. It had published annual reports from 1978 to 1982 showing the results of its R & D activities in each year.

The telemetric meter reading system defined by the Conference consists of three components ; centers, transmission lines and terminal equipments installed in customer's premises.(refer to Fig. 1) As for the process of meter reading, the center computer automatically selects the customer's telephone, connects the line and electrically readout all the data stored in the meter.

This system is standardized as no-ringing system in which priority is given to ordinary telephone calls and the process is tried repeatedly until the meters are read.

Examples of Application by Polling System.
Example 1 - The Automatic Meter Reading System in Tama New Town (refer to Fig. 2)

In the proposed system, the meter reading center is comprised of an automatic calling unit and a computer system which was installed in the main office of Tama New Town Water Service. For transmission lines, public telecommunication lines were used to connect the center and the terminal control unit (TCU) each of which covers a certain number of buildings, while private lines were newly laid to interconnect the TCU, the relay unit (RU) installed in each building and the signal output unit (SOU) and other devicces installed in all floors of the buildings.

Water meters used for the system were mostly of the 20mm passive type provided with a contact point storage device, and a totalizer in 4 decimal digits. The water meter and the SOU are connected by 14 core cable via a connector having 20-pcs. plug pins.

Also, active type water meters combined with electronic counter were used. This electronic counter was composed of semi-conductor elements to read out totalized value electrica-lly.

In every block for building management, the TCU and a public tele-communication line were installed with the view that coincidence of building management and meter reading can offer considerable advantages. A TCU covers a maximum of twenty RU's, a RU covers the same number of SOU's and a SOU covers four water meters or electronic counters in turn.

For meter reading, when the automatic calling unit in the center is activated, the unit automatically selects a building block (TCU) by dialing the telephone number according to the computer stored program. Then the activating signal is trans-mitted to the RU, and finally to the selected water meter. In return, the totalized value of the water meter raeding is converted to an electric signal and inputted to the SOU, in which the signal is further converted to a combined signal of two frequencies in the audible frequency range to be sent to the RU, the TCU and the center via the public tele-communication line.

The facilities in the center process the transmitted data and store it on magnetic tape which can then be sent to the computer center of joint utilities for billing. The system actually started it's operation in March 1977 covering 4,600 water meters and it covers 28,000 water meters at present.

Example 2 - The Automatic Water Meter Reading System in Saitama Kennan Water Supply Authority(refer to Fig. 3)

There are a large number of housing complexes which are managed by the Government, The Japan Housing Corporation, the related local government and private developers.

Both the passive type of 20 and 25mm with a contact point storage unit and the activew type of 40 to 150mm with a reed switch have been used since 1970 as water meters for collective dwellings in the area. Meter reading in such system was manually performed at the centralized read-out panel installed in each housing block.

In 1978, a method of collective meter reading for each housing complex was discussed along with the installation of a meter reading center. In 1979, the project partially materialized, dealing with four housing complexes covering 2,238 water meters which are to be automatically readout by means of telephone lines.

For this system, a space for the center was allocated within the area of the water authority. For data transmission, public tele-communication lines were used to connect the center and the subcenters which were located in each housing complex and privately laid lines were used to connect the subcenter and the water meters within the complex.

Once the automatic calling unit is activated in the center, the system automatically selects a subcenter by dialing the telephone number according to a computer stored program. The selected subcenter in turn selects a centralized read-out panel keeping the line to the center connected. Then the centralized read-out panel in its turn reads the totalized volume stored in the water meter keeping the line to the subcenter connected and it transmits it in return to the subcenter. The subcenter, after completion of the designated meter reading process, transmits the data to the center by way of public tele-communication lines. The units in the center output the received data onto floppy diskets.

Billing for the collected data is performed by The Saitama Prefecture Water Service Corporation, where the floppy diskets from the center are processed by the data processing units. The system covers 13,000 water meters at present.

Example 3 - The Automatic Water Meter Reading System in The Bureau of Tokyo Metropolitan Industrial Water Works. (refer to Fig. 4)

The system was a first utilization of the afore-mentioned standardized no-ringing type automatic metering system.

This polling method tele-metering system automatically read out from the center the total volume of approx. 730 units of industrial water meters widely scattered in Tokyo area, utilizing subscriber's telephone lines as the most popular media for communication in Japan without any ringing on customer's telephone set.

The center equipments consist of network control unit and computer system installed in the office of The Bureau of Tokyo Metropolitan Industrial Water Works. No-ringing trunk is additionally installed in nearby telephone exchange office to avoid ringing on the phone when the meter is read out.

In this system, newly developed passive type electronic water meter with built-in data transmitting function is installed. Partially, some active type water meters with built-in ratch-relay transmitter are used in combination with counter having data transmitting function. The electronic water meter or the counter are linked with telemeter no-ringing network control unit (TNR-NCU) which has various functions necessary for off-hook function and data transmission. The telephone set is also linked with TNR-NCU.

Meter reading is processed by polling method calling customer's water meter from the center. In Japanese subscriber's telephone lines, signal of 16Hz is transmitted from switch board to ring the telephone set. If the same process is applied on meter reading, it causes confusion to identify ordinary phone calls. To avoid the confusion, signal of 2,080Hz is transmitted through no-ringing trunk at telephone exchange office, to control TNR-NCU and identify ordinary calls. Total volume of water flow, meter serial No., water authority's code No. and other information on the selected water meter is transmitted to the center via TNR-NCU as electric signals. The time required for this process is approx. 15 seconds per one water meter. This system started operation in January 1983.

-2. Calling System

The above mentioned polling system with no-ringing trunk is available only in limited area of Japan. On the other hand, in case of calling system, meter reading process and data transmission is initiated from water meter side so that it is easy to avoid ringing on the phone and no-ringing trunk is not necessary. Namely, the area of utilization is not limited.

For the moment, there is no water authority which have utilized this calling system but some water authorities started feasibility study and experiment. The practical application of this system is expected in near future.

Example of Application by Calling System in LPG Distribution System (refer to Fig. 5)

In Japan, LP Gas is mostly distributed to the customer by cylinder and it is required to replace the cylinder in good timing to avoid gas shortage. For the above, automatic gas meter monitoring system is utilized to transmit gas shortage signal from customer side to the center through subscriber's telephone lines. In this system, functions such as periodical tele-reading of total volume of LPG meter and signal transmission in emergency shut-off are involved.

The system is composed of micro-computer with programmed software in the center, automatic calling unit(ACU) in the customer side which is provided with functions of totalizing, operation, off-hook and controlling of telephone lines.

The process of meter reading is as follows.
At inputted time and date, ACU automatically call out the center only in case of customer's telephone line is not busy and transmit the data. In cases that the customer's line is busy, the center is in receiving data from other ACU or the customer comes to use telephone(off-hook) in process of data transmission, then, ACU repeats the process again according to the inputted program. The time required for meter reading is 15 seconds per meter.

This system is also available in automatic reading of water meter using active type water meter. It is supposed that passive type and active-passive type water meters will be available in near future.

4. Conclusion

Various automatic water meter reading systems in Japan have been introduced. The following effects are reported from the utilities in which the systems are actually in operation.

-1 Economic effect

In case water meters are widely and scatteringly located, the metering by man power takes a lot of time to move, and as a result, the metering efficiency is low. This was greatly improved.

-2 Speed-up of data collection

The data of water consumption can be immediately collected for demand trend analysis.

-3 Improvement in detecting probable water leakage

By comparing normal pattern of water consumption by each customer with real consumption in a certain time, the chance to detect water leakage will be expected.

-4 Feedback to the water supply system

Timely feedback of data for demand trend analysis, supply pressure control and flow control by each distribution block has come possible.

In Japan, automatic water meter reading system utilizing subscriber's telephone lines is most popular at present. It is considered that recent rapid progress of electronic-based technology in measuring, communication, data processing and other related fields will make automatic meter reading system more and more attractive.

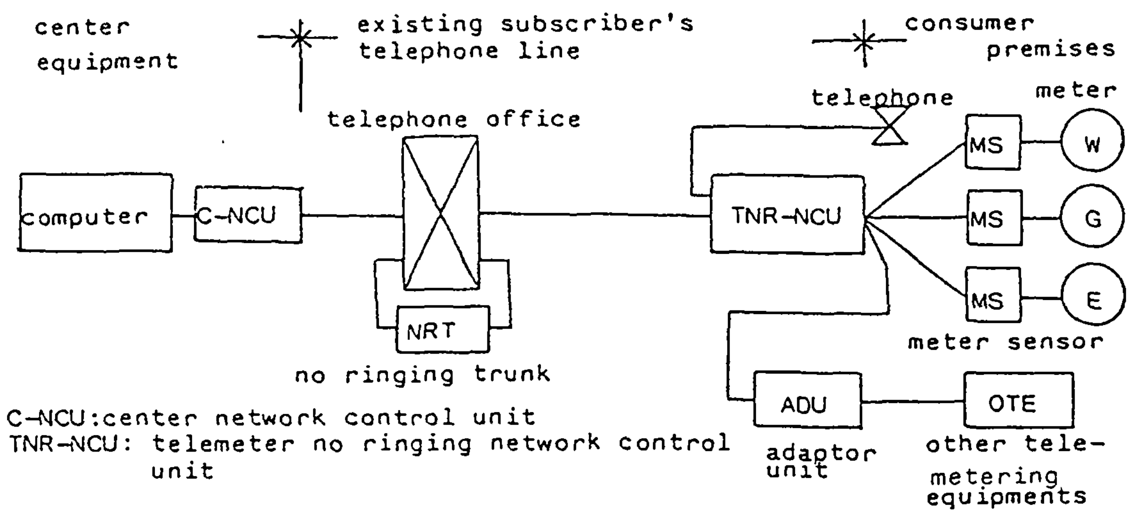

Fig. 1 - No ringing system

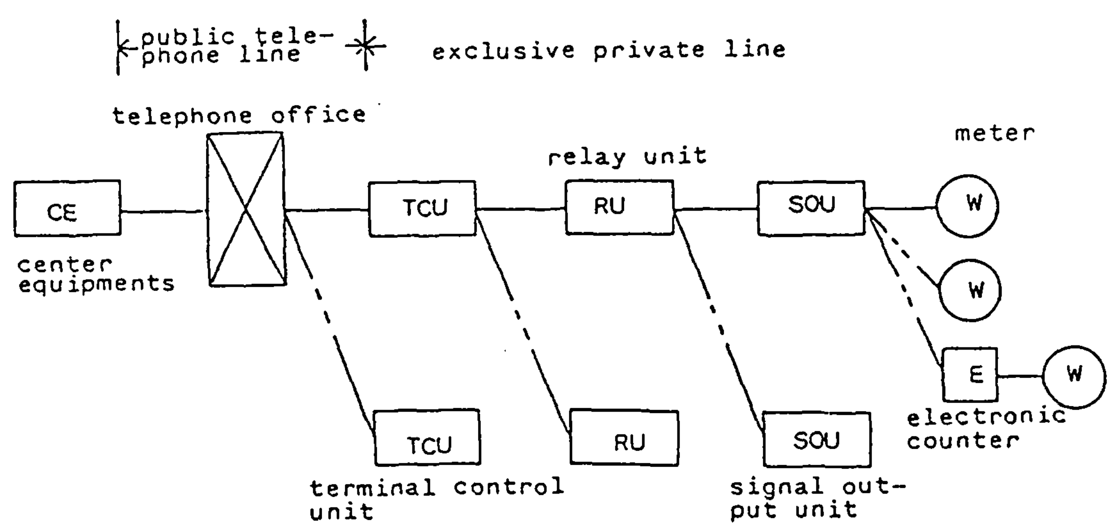

Fig. 2 - The system in Tama New Town Water Service

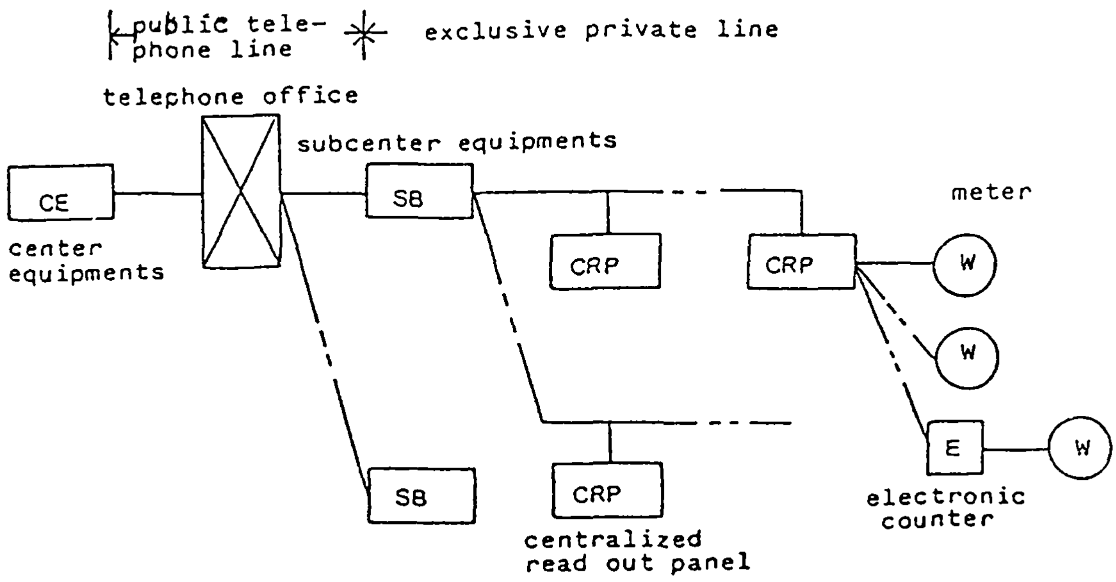

Fig. 3 - The system in Saitama Kennan Water Supply Authority

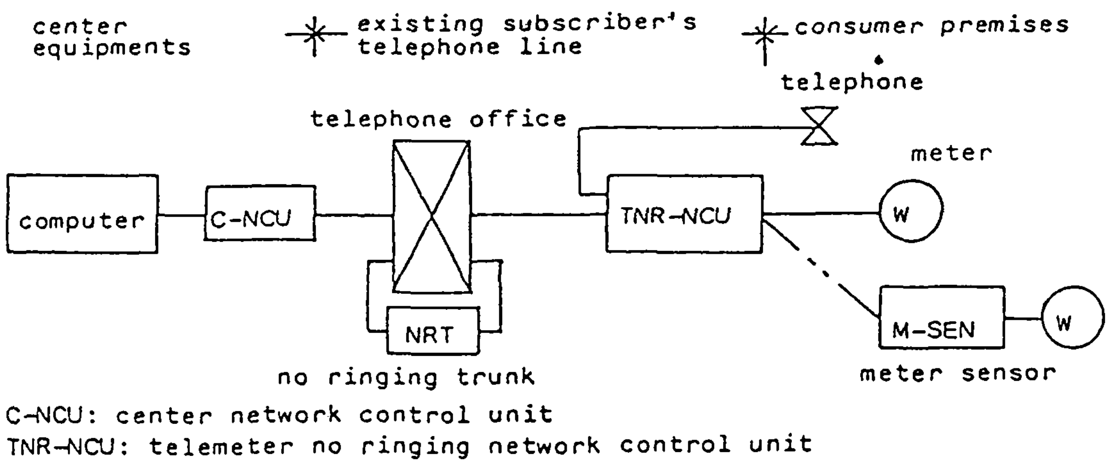

Fig. 4 - The system in The Bureau of Tokyo Metropolitan Industrial Water Works

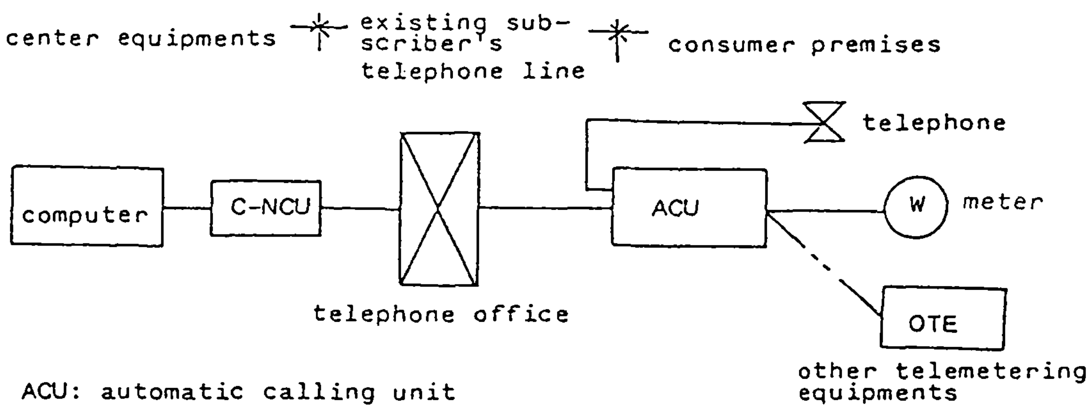

Fig. 5 - The calling system

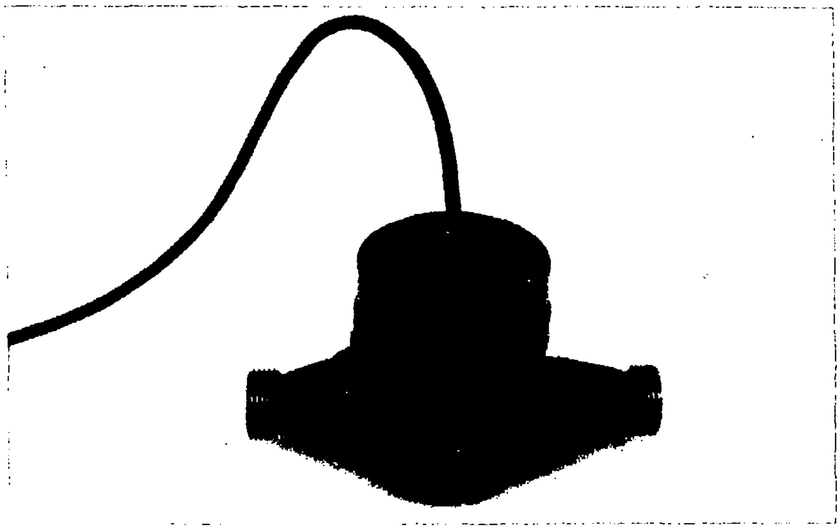

Photo 1 - Active type water meter

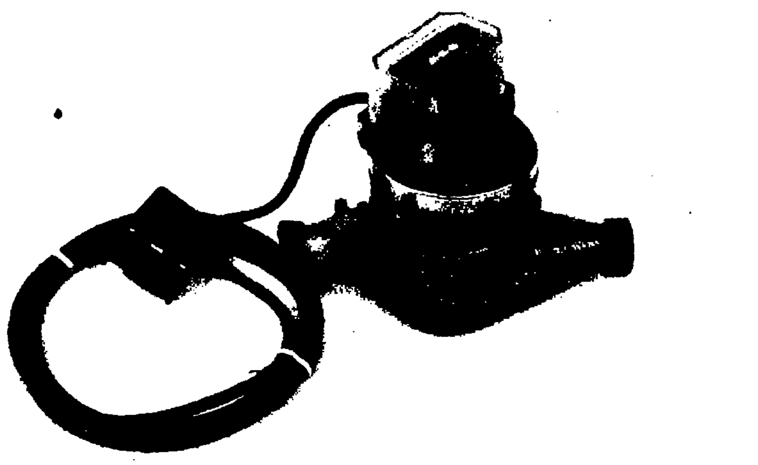

Photo 2 - Passive type water meter

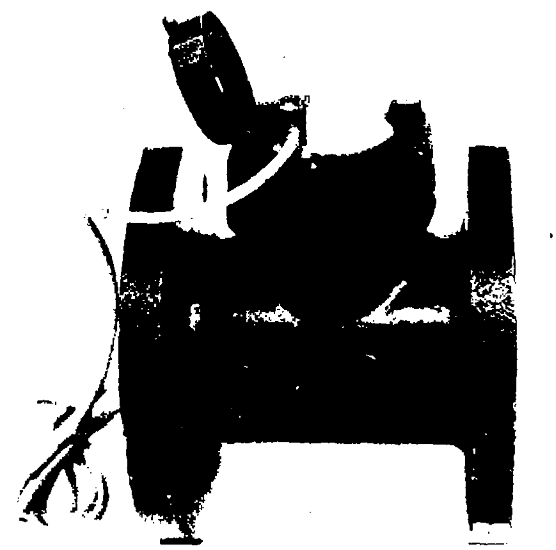

Photo 3 - Active-passive type water meter

HAND PUMPS–MANUFACTURING FACILITIES IN DEVELOPING COUNTRIES

By :

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The theme of the conference "Potable water facilities and standards" is indeed a very wide subject and, in all probability, would include papers and discussion on several diverse scientific and engineering areas. Amongst all these expositions, some of them perhaps bordering on the frontiers of science and technology (because a talk about standards of potable water involves human health care and wherever human health is concerned, the best that science has to offer must be applied) I was really wondering if a mundane and almost 19th century topic like hand pumps really fits in; and yet, the last 10 years have shown that hand pumps have made a significant contribution to the task of providing potable water to rural communities in the developing world...... and it is likely, that they would continue to play a vital role in this field. Given a choice, anyone would want piped water supply but where are the reasources for that ?. So, in the midst of hi-tech presentations from distinguished planners, engineers and scientists from all over the world I, a mere small scale manufacturer, venture to speak to this august assembly about hand pumps and the nitty-gritty of how they can be manufactured in the developing countries of Africa and South East Asia. Please bear with me if my talk is too elementary because it is directed solely to those countries which have yet not organised their production facilities for any well designed hand pump.

Again, I crave your indulgence because my experience with hand pumps is largely limited to the development and production of only the India Mark II and its various modified versions. There is no intention to overlook the good features of other hand pumps and it is not for me to make any claims about the advantages of the Mark II over other pumps. Experience has ofcourse shown that - so far - amongst all the designs of deep well pumps India MarK II has proved to be the best and most cost effective. Nearly a million of these pumps are successfully working in India and 50 other countries. Bulk of this impressive figure is no doubt in India and yet the estimated population of Mark II pumps outside is also not less than 40,000 to 50,000. I can say this with some conviction because my own company has exported nearly 30,000.

I must also hasten to add that we are already working on the development of certain other pumps and our deep sense of commitment to the Mark II is not inflexible. We are presently working, in close association with world bank engineers, on the development of another deep weel pump and also an intermediate depth pump. We are always open to suggestions regarding other good designs and would work on them as and when opportunities come our way.

I will first spend sometime on my perceptions of the excellent work done by the India Mark II and thereafter move on to a detailed discussion on the manufacturing and quality control procedures. The first part of my talk is essentially reading out from one of my articles which was recently published in an Indian magaine:

Interestingly, this article was titled **"The Miracle Pump Satisfying a basic human need"** I genuinely subscribe to this definition of the Mark II which has become a very familar sight in the Indian countryside. This galvanised box-like steel structure mounted on a massive pipe pedestal and with a long sturdy handle - a simple unimpressive contraption - often attracts a large part of the village population around it and with good reason too. This world renowned 'deep well hand pump' has created history over the last 10 years and is one of the few Indian products that have found world-wide acceptance, in preference over hand pumps offered by almost every industrialised nation. The India Mark II has indeed made its mark and, in the process, changed millions of lives. For the rural masses in India and other developing countries it is a miracle pump.

It is indeed impossible to visualise the change brought about in the lifestyle of people by a single good hand pump. It is only by visiting the villages that one realises the acute need for clean water and the tremendous change it can bring about in the lives of the people. Tales of women spending nearly half their lifetime fetching water from dirty ponds five miles away are common.

What does a hand pump do for the villagers who have never known clean water all their lives? We take water for granted. The irony of this indifference stares us in the face when rivers, streams and ponds dry up under the cruel tropical sun, and millions of parched mouths in villages pray for water as ardently as they pray to their gods. The new pump helps quench this thirst that enfeebles men, women and children not only in India but around the entire underprivileged world.

Clean drinking water is the key to human survival. It is the very essence of all life, the symbol of all that is pure, beautiful and serene. The connection between disease and lack of clean water is a well established fact. Surveys conducted by WHO in the seventies disclosed that 80 per cent of all diseases were associated with contaminated water. It was estimated that close to a billion people suffered from water related diseases.

The seriousness of the problem was appreciated by the United Nations and the interntional drinking water supply and sanitation decade was launched in 1977 with the specific objective of providing clean drinking water to every man, woman and child around the globe by 1990. Many leaders expressed the hope that if the decade was to be even partially successful it would have more impact than any UN programme ever launched for alleviating human suffering. Several solutions were considered. The initial assumption was that water supply could be delivered through centralised pumping systems administered by bureaucrats at the other end of the pipe-line. But when the global cost estimates ranged as high as US$600 billion, planners started to think about other cheaper and more practical options. Resources of this magnitude were considered impossible even though Americans alone spend $30 billion annually on soft drinks and ofcourse the global arms bill is estimated around a staggering $800 billion every year. Consequently experts met several times and assessed the costs and logistics as well as the maintenance and management issues involved in rural water supply. Their conclusion was that for the nearly two billion poor of Africa and Asia, the most feasible option would be the use of ground water and hand pumps. To quote one of the UNDP Project Managers **the conclusion was that if hand pumps and ground water were not the solution, then there was no solution at all.** It was estimated that hand pumps would mean an investment of between Rs.50 to Rs.350 per capita (low in Asia and high in Africa). Whereas the cost of piped water supply could range anywhere from Rs.1000 to Rs.10,000 per capita. When this was multiplied by one or two billion people, the astronomical figures themselves showed that either there should be a global effort to use ground water and hand pumps or there would be no improvement at all.

The hand pump is an old concept. However, the earlier pumps made from cast iron (and even wood) suffered from several draw-backs such as low discharge, inefficient operation requiring greater manual effort, shorter life span and danger of contamination from surface water. Also the common hand pump is a suction pump and this limits its ability to take out water from a maximum depth of about nine metres. The India Mark II is basically not a revolutionary design. It has merely taken care of all these handicaps. It is a positive displacement pump, thereby having no theoretical limit on the depth of operation. It is almost entirely made from steel and is fully galvanised so it is sturdy and long lasting. It has an excellent built-in mechanical efficiency and as such even children can operate it easily upto a depth of 30 metres. It is totally sealed from external contamination. Overall it seems to have offered an effective answer to all the requirements set forth by the world community. The design is so simple that it is easily manufactured by small units in India.

Agencies like UNICEF have done marvellous work in the standardisation of this pump. Today every pump installed in India or exported has to pass the rigid quality standards of UNICEF, assured through their inspection agencies - Crown Agents of UK and SGS of France. There is a detailed ISI standard for the pump and this institution also carries out a second inspection at the manufacturers' factories. The association of so many world class agencies has gone a long way in improving the quality of the pump and making it virtually trouble free. As I mentioned earlier, today, the India Mark II has achieved unanimous acclaim from water management experts all over the world. Although further developments continue, it is presently considered the ideal solution to the long search for a good community use deepwell hand pump. With minor changes it can easily pump water from as far as 80/90 metres. It can also be motorised or run with a windmill. In independent tests commissioned by the consumers association of UK., the Mark II came out a clear winner on most counts. The competition here was with hand pumps from U.S.A., Japan, Canada, U.k., Sweden, France, Holland, Belgium.....almost all the industrially advanced nations. In many world bank tenders this pump has been given preference over others and orders placed on Indian firms at prices higher than those offered by Americans and Europeans.

No man made product is, however, perfect and there have been problems in organising proper maintenance of pumps located in far-flung areas. The ideal solution is a pump which can be maintained by the users themselves but till recently such a pump was only an idea. Some external help is needed and that too urgently when a breakdown takes place. The fault may not always be caused due to substandard materials or workmanship; more often it is due to improper use and indeed abuse by villagers. It is a common sight to see buffaloes tied to pumps, children climbing over them and inserting small rocks and twigs through the spout. The logistics of a maintenance organisation, to cover an estimated one million pumps scattered all over India, are enormous and yet a lot of work has been done in this direction. In most African countries however maintenance still poses serious difficulties.

However, it is apt to say that there is perhaps no other single thing which has ever done so much for so many at such low cost.

We now come to a discussion on what is involved in the manufacture of a good quality Mark II pump. Before I start on this I must tell you about an incident from personal experience which is solely responsible for what we have achieved in the last 10 years. In a casual discussion at Unicef New Delhi in 1976 we learnt that they were looking for parties to manufacture the Mark II pump which had then been recently developed with the assistance of some Swedish engineers. We saw the Mark II drawings and accepted a trial order for 10 pumps. The price looked very attractive and promptly we made these 10 pumps in only a few days and invited Unicef for inspection. There was a large team from Unicef, Crown Agents and some others that visited us. Their first reaction was catastrophic. They declared that the 10 pumps put up by us were absolutely useless and we would never be able to handle the task. It was then that the realisation dawned on us that we had just not understood the importance of the matter. We had believed that a hand pump was a hand pump and therefore, it could literally be 'hand made' without the application of any engineering to it. This was a serious mistake. We requested for a few months time and when this was granted we got down to conceptualising, designing and developing a large number of jigs, fixtures and tooling required for the manufacture of every single component and sub-assembly. We also developed a set of gauges for inspection at each stage and of the final product. All this involved a lot of solid engineering work but the end result was good. This time we put up a batch of 100 pumps and not 10. Thereafter it is all history. Our company has manufactured and supplied over 400,000 Mark II pumps. Today we are manufacturing these in 4 different units located in North and Central India and we manufacture, on an average, 6000 pumps per month. AS I said earlier, we have exported nearly 30,000 pumps to perhaps 45 countries. By and large, the feed back is quite satisfactory.

The first concept that a prospective manufacturer of the Mark II must accept is that it is not just a hand pump; it is a well designed engineering product and it has to be manufactured with an excellence which would make it suitable for providing years and years of trouble free service to a community of between 250 to 500 population. It must also take into account a certain amount of unavoidable abuse and neglect. It should be sturdy and each part used in it should be made to a rigid standard so that there is total interchangeability of spares. The Bureau of Indian Standards (earlier known as Indian Standards Institution) has laid down a precise standard for each component. This standard covers both dimensional and material specification aspects - physical characteristics as well as chemical composition. There is a seperate panel at the Bureau, consisting of representative from BIS, Unicef, Crown Agents and some of the manufacturers as well as user departments. These people continuously meet and monitor feed back on the pump and discuss modifications if necessary. It is a live standard, having been modified on several occasions to incorporate changes arising out of comments from a mass user base.

● I shall complete the rest of my presentation by showing you several charts. The first set of charts is for all manufacturing operations against which I have indicated the required equipment and appx. production capacity per 8 hours shift. I have again divided these charts into two parts. The first one (A) showing operations which could be done by ancillaries and the second part (B) showing sub-assemblies which must be done inhouse.

The equipment requirements for a unit have to be calculated on the basis of required installed capacity and balancing of various inputs. Broadly the equipment which has substantial spare capacity is not suggested to be used in the main factory. Such equipment could possibly have spare capacity at another factory and could therefore be used as an ancillary unit. However, there is no hard and fast rule for this and, for a variety of reasons several operations must be done inhouse.

● **Project charts A & B Series**
and explain

Before explaining the quality control set up, I must tell you that no amount of inspection can 'produce' QUALITY unless QUALITY is 'built into' the product. Rather than making errors and then analysing and correcting them, I am convinced that one should go about the job in a different manner. It is necessary to design suitable tooling, fixtures & gauges for each stage of manufacture so that all conponents meet the specifications and there's just no room for error. The fixtures and gauges themselves need close monitoring and re-checking vis-a-vis some masters.

Let me now come to the other set of charts that deal with the quality control aspect. Maintly these are to explain the following areas of quality assurance:

Projection/Explanation of chart series C, D, E, F, G

- Receipt inspection of raw materials and components (C).
- Stage inspection during manufacture; both in house and at ancillaries (D).
- Inspection of sub assemblies and final product (E).
- Developmental tests/Life Tests/Type Tests (F).
- User based tests (G).

Manufacturing large quantities of these pumps on a regular basis involves on-going R & D activities. There are a variety of problems to be tackled. These could arise out of (a) non availability of certain materials and the need to use alternates (b) any premature failure report from the field and (c) need to develop modified versions or special executions based on consumer feed back. We have seen that our R & D Dept., which is ofcourse a small one, is constantly busy tackling more than one issue at any time.

Over the years, besides solving routine manufacturing problems, we have developed several modified versions for special applications. Some of these are:

1. Chain link mechanism is recommended for use at depth of 24 mtrs and above. For intermediate depths of 9 to 21 mtrs we provide heavier rods and/or **SOLID LINK** model instead of chain link.

2. Use of **EXTRA DEEPWELL** version (XDW) is recommended at depths above 45 m. Depending on actual depth XDW models provide for special features like heavier steel sections, longer handle with counter weights and T bar, heavy duty bearings, additional bucket washers in cylinder etc.

3. **STAINLESS STEEL** connecting **RODS**, stainless steel **CYLINDER BODY** and **FULL** stainless steel **CYLINDER** for use in highly aggressive waters.

4. **TELESCOPIC PEDESTAL** for installation on bigger casing pipes (150 mm NB) for perfect sealing.

5. Standard version with cast iron cylinder body requires minimum 100 mm ID bore hole. **FULL BRASS CYLINDERS**- in 50, 63.5 and 76 mm ID for installation in bore holes of minimum 70, 80 and 90 mm ID respectively. These cylinders have flush end caps (Bores must be plumb straight).

6. Standard design provides for mounting on a bore hole by means of pedestal with three legs grouted in concrete platform. **FLANGE MOUNTING** arrangements, instead of legs, facilitate shifting of pump from one bore hole to another.

7. Open top cylinder pump which is a **VLOM** pump. The plunger assembly can be pulled out for maintenance without dismantling the total pump.

8. Standard design is suitable for installation in bore holes. Pedestals can be suitably changed for use on **OPEN WEELS**.

9. Can be adapted for use with **WINDMILL** or for motorised operation.

10. Suction type **SHALLOW WELL** hand pumps for community use based generally on the India Mark II design.

WATER SUPPLY, SEWERAGE AND SANITATION SECTOR STUDIES : AN ASSESSMENT

BY :

DR. FLORENCIO F. PADERNAL
PROJECT MANAGER

I. INTRODUCTION

There has always been a need for developing countries to undertake sector studies such that lending institutions and grant-aid donors usually request governments to periodically prepare sector studies. In the case of the water supply, sewerage and sanitation sector, the studies are made in order to have a systematic assessment of the water supply and sanitation situation of a particular country especially that relating to the institutional aspect. The results of the exercise thus serve as a basis for decision whether or not to finance a certain project or a sector program.

Several studies were undertaken in the past two decades in the Philippines, namely: Water Supply and Sewerage Sector Study (1977), Water Supply and Sanitation Sector Study (1982), and Water Supply, Sewerage and Sanitation Sector Study (1986). These studies have led into a series of institutional changes.

This paper deals on the analysis of the effectiveness and responsiveness of undertaking sector studies. Two basic parameters will be applied to evaluate the sector studies, namely: accuracy of findings and the extent by which the recommendations were adapted.

The lessons learned from these exercises can be appraised by other developing countries similarly situated as the Philippines, for comparison and/or guide for future actions.

This paper will also be of interest by the proponent institutions since errors and gains from sector studies will be presented and analyzed.

II. RATIONALE OF CONDUCTING SECTOR PROFILE

In 1977, a WHO/IBRD Mission conducted a study of the sector with the purposes of (1) establishing the present water supply and sewerage/sanitation situation with the Philippines, and (2) evaluating the prepared program of investment covering the period 1977 to 1981.

The second time that a Sector Study was conducted in the Philippines was in 1982. The objectives of the WHO/IBRD Mission then were (1) to update themselves about the sector situation in the light of developments that occured between 1977 to 1982, (2) to review the current government policies and proposed development programs; (3) to identify constraints to sector development; and (4) to make recommendations that will remove or minimize the impacts of the constraints. The emphasis of the study was on the institutional aspect, manpower development and the activities needed to introduce a comprehensive sanitation program.

The third Sector Study was undertaken by the Government of the Philippines (GOP) itself in 1986. The GOP felt the need to rationalize the sector due to the presence of major issues and the urgency of resolving them. Again, priority was accorded to institutional issues.

From the above we can see that sector studies were under mainly because of the need to establish a profile depicting the actual water supply, sewerage and sanitation situation with emphasis on the institutional aspect.

However, an in-depth analysis of the rationale behind the conduct of such studies reveal that the results of studies are used by the lending institutions, and donor countries and organizations in deciding, whether to finance projects or not. And before such a project is approved, one critical issue must be resolved is who should be the implementing or executing agency. It is during the project appraisal stage that this issue should be resolved.

For the recipient government, decisions are greatly influenced by the results oif sector studies. In many cases government agencies may either be abolished, merged or created. Moreover, certain policies are developed or even repealed to make way for the recommendations contained in these sector studies.

III. 1987 WATER SUPPLY AND SEWERAGE SECTOR STUDY

The findings of the study focused on the following:

1. Organizationally the sector can be divided into three parts: one dealing with Metropolitan Manial, which is the responsibility of the Metropolitan Waterworks and Sewerage System (MWSS); a second dealing with Water Districts serving the larger urban communities in the provinces, which are assisted by the Local Water Utilities Administration (LWUA); and a third, "gray area", dealing with the rural areas and small provincial urban communities, where responsibilities are unclear or overlapping.

2. Diseases associated with poor sanitation, unprotected water supplies and insanitary disposal of excreta are a significant health problem in the Philippines and improvements in environmental sanitation are vital to the achievement of better health.

3. At the end of 1975 about 43% of the total population was estimated to be served with a public water supply. Metropolitan Manila was best served with a coverage of about 82%, other provincial urban areas had a 55% coverage and the rural areas about 33%. In recent years service in Metropolitan Manila more than kept up with the population growth; deteriorated in the provincial urban communities; and matched 92% of the growth in the rural areas.

4. With respect to sewerage and excreta disposal, it is estimated that 32% of the population is served by water-borne systems and 27% by latrines, pit privies and other non-water carriage systems.

5. Quantitative service level goals have not been established by the Government, however, an investment program proposed by various agencies for 1977-1981 has an implied overall service level goal for public water supplies of about 58%. Over 96% of the population in Metropolitan Manila and other urban areas would be covered as opposed to about 41% of the rural population. Investment for sewerage and excreta disposal is the sole concern of local government and only in Metropolitan Manila are investments planned for sewerage.

6. Apart from the projects proposed for Metropolitan Manila and a few other urban areas which have formed or are forming Water Districts, the proposed program for water supplies is a continuation of past activities except that it is on a scale of about 14 times larger than the preceding four years. It is considered doubtful whether funds of this magnitude will be made available or the agencies involved could cope with such an expansion in construction, operation and maintenance.

7. With the exception of Metropolitan Manila and a few Water Districts, plan for the sector is uncoordinated, unrelated to needs or resources, and lack the data upon which realistic targets and priorities could be established. A large part of these weaknesses are due to the lack of leadership and direction creating a vacuum which leaves a sizeable segment of the population adrift without an adequate program to deal with the problems in this "gray area".

8. Related to the weakness in the direction in the "gray area", is the lack of training programs for personnel at all levels. Such programs are necessary not only for new personnel, but also for present staff members in order to introduce new technical applications and upgrade the preparation and analysis of projects.

On the other hand, a package of recommendations were developed and presented hereunder.

1. High priority should be given to the establishment of a proper data base which is necessary to develop realistic policies, priorities and programs for the smaller urban/rural areas. This can be done with existing personnel and the report contained suggested procedures, guidelines and forms to facilities the collection of such data.

2. Equal priority should be given to improving institutional arrangements dealing with the "gray area" in order to provide direction, leadership and better service. The present organizations involved, i.e., the Provincial Waterworks Unit of the MWSS, the Waterworks Section and the Wells and Springs Unit within the Bureau of Public Works (BPW), currently give this area low priority. It is therefore recommended that a new Bureau incorporating the staff of the present units, be created within the Department of Public Works, Transportation and Communications (DPWTC), and new managerial staff with stature and initiative be assigned to establish this Bureau. The report contained a suggested set of objectives and functions for this organization as well as justification for the above recommendation and a discussion of other alternatives available to the Government.

3. Improved technology, in the construction of wells, the use of analytical tools to arrive at least cost solutions, and a change in policy regarding the suitability of properly protected shallow wells should reduce costs and permit services to be extended to many more communities. Specific suggestions for improvements were contained in the report.

4. Training of manpower on a continuous basis is considered to be absolutely essential if the investment in water supplies is to be protected and if a larger program is to be implemented. It was therefore recommended that an immediate decision be made to place the responsibility for establishing such a program in the planning and Project Development Office (PPDO) of DPWTC. The program should be designed for local government personnel, the staff of DPWH, and others associated with the operation, control and development of water supplies. To help initiate a program, a suggested curriculum for a short two weeks course for engineers was included in the report.

5. In addition to the foregoing recommendations, which have as its aim the better utilization of personnel, further improvement can be achieved by redefining or reorienting the activities of the sanitary engineers assigned to the Environmental Sanitation Division in the Department of Health. These well trained specialists should be more involved in developing water supplies and could fill the technical knowledge gap that exists at the provincial and district levels where they are now stationed. The report contained a suggested procedure for better utilization of their expertise in the smaller urban and rural piped water systems.

IV. 1982 WATER SUPPLY AND SANITATION SECTOR STUDY

Highlights of the findings are shown below.

1. Despite the clear cut allocation of responsibility the institutional structure of the sector remains complex as a number of other rural water supply development agencies are active and, because of the loose interpretation of urban/rural population distribution, the boundaries of LWUA's area of responsibility do not readily accord with the urban orientated development objecties of the agency. Additionally, National Water Resources Council (NWRC) is not presently structured to undertake the wide role expected of it.

2. For domestic water supplies both surface and groundwater are generally available in adewuate quantities, the rural population, in particular, making wide use of groundwater. The completion in 1981 of a national assessment of water supply sources has greatly added to water resources knowledge and will provide a useful tool for future water supply program planning.

3. As of 1980 it was estimated that about 21.4 million, 43% of the total population, was serviced by public water supply systems. Eighty-two percent was served in Metropolitan Manila, 55% in other urban areas and 33% in the rural areas. The "Integrated Water Supply Programme 1980-

2000" prepared by an inter-agency task force and published in mid-1980 projected that service levels will be improved and coverage extended to 91% of the total population by 1985 (98% in Metro Manila, 90% in other urban areas and 90% in rural areas) and to 93% of the total population by 1990 (99% in Metro Manila, 95% in other urban areas and 90% in rural areas).

4. For service to consumers Government has defined three levels of service: Level I being service from a point source such as a well or handpump; Level II being service from public standposts placed on piped distribution systems; and Level III being individual house connection from distribution networks.

5. In relation to water supply service, the provision of sewerage and sanitation facilities lagged so much behind. Apart from some 0.8 million people connected to waterborne sewerage systems in Manila the bulk of the population rely on on-site disposal facilities. A well defined program for sewerage and sanitation improvements is being implemented in Manila but no such program has been prepared for the areas falling under Local Water Utilities Administration (LWUA) control and the Department of Health (DOH) is in the preparatory stage only of drawing up a sanitation Master Plan. Because of the increasing number of municipalities enjoying a high level of water service following the establishment of Water Districts by LWUA, it is inevitable that problems associated with the proper collection, treatment and disposal of waste water will become the growing concern for public health reasons.

6. In the area of manpower development and training, the predominant issue is the coordination of the numerous existing training schemes, particularly in the rural subsector, into a coherent overall plan. Other issues that need to be addressed to are:

a) to increase the amount of practical "hands-on" training in ongoing training programs;

b) to reinforce the provision of regulatory (institutional development) services to provincial and municipal waterworks task forces and to Rural Water Supply's;

c) rationalize the manpower, training and technical support needs required for the systematic operation and maintenance of rural water supply systems.

7. Water quality surveillance is not being done on a systematic basis and analytical capacity is substantially below a desirable level. This latter problem will be alleviated considerably by an ongoing UNICEF project to upgrade regional laboratories and provide bacteriological equipment to provincial laboratories. Additional laboratory capacity

is to be provided to the DPWH by Japan's Overseas Economic Cooperation Fund. This will be a central lanoratory (in Manila) and two portable laboratory units for each of 45 DPWH districts.

8. LWUA is being squeezed financially from a falling return on new projects and increasing reliance on foreign loans at relatively high interest rates. The falling return on each new marginal project will not be favorably influenced by removing the rural areas from LWUA's jurisdiction (as LWUA's attempts to serve this population area financed by RWDC). However profitability could be greatly affected by increasing the use of Level II service combined with some recommended subdivision of Level II areas within Water Districts into communities served by one standpost. LWUA is reluctant to greatly expand its Level II service because it considers it has not solved the revenue collection problem. Some new Water District Boards should be asked to work out methods applicable to themselves for cost recovery in Level II areas which LWUA can then apply and systematize elsewhere.

9. Integrating the rural water program under the umbrella of the RWDC will eliminate the anomalies which currently exist between directly assisted-RWDC projects especially at Levels II and III and similar projects under the DPWH and the DLG Barangay Water Program. The differing degrees of benefit received by areas under each agency's politicize the program, create a sense of confusion and possibly intercommunal jealousy and tend to perpetuate themselves through foreign aid support of agencies programs.

The recommendations of the 1982 Sector Study are enumerated hereunder.

a) On the institutional aspect, the following are the recommendatons:

(i) that MWSS shall remain as the sole agency responsible for Metropolitan Manila;

(ii) that the LWUA's areas of responsibility be more clearly defined so as to link its responsibility to only urban core areas where urban type water supplies can be shown to be feasible;

(iii) that the rural water supply programs currently being undertaken by DPWH, the Barangay Water Program and LWUA be amalgamated within a single program under the responsibility of RWDC, all development funds for rural supplies being channeled through that agency. Appropriate staff transfer from the other agencies to form a technical wing within RWDC and to strengthen Provincial Engineer's Organizations, responsible for technical support to RWSs, to be carried out in parallel with the transfer of responsibility;

(iv) that Provincial Governors' Offices be responsible for the collection of principal and interest payments from RWSs, agency fees for this service being subject to bi-annual review and utilized to strengthen Provincial Engineer's organizations; and

(v) that NWRC be expanded and structured to cater for specific areas of national responsibility in the sector, that DOH be represented on the NWRC Council and that NEDA staff be seconded to work in the sector planning and programming unit within NWRC.

b) Attention should be given -

(i) to the review of LWUA's Charter to firmly determine its responsibilities; and

(ii) to the implementation of studies to determine urban sanitation requirements, the definition of a development program and the drawing up of procedures for project implementation and future operation.

c) In the rural subsector, it is recommended that an appropriate mechanism be established to coordinate training under the direction of RWDC. For rural water supply sector, it is further recommended that the regulatory system developed by the Barangay Water Program should provide the model for overall adoption.

d) The possibility of consolidating water laboratory service under one administration should be studied, together with the development of a programme for the systematic surveillance of drinking water quality. Surveillance implies that effective follow-up action can be enforced when drinking water samples tested fail to meet health criteria.

e) To achieve a permanent improvement in the skill profile of the sector work force, it is recommended that-

(i) instructor and supervisor training be reinforced

(ii) a skill testing and certification system for water-related skills should be developed;

(iii) simple, practical training methodology should be more widely introduced to enable physical skills to be developed through practice instead of through demonstration.

V. 1986 WATER SUPPLY SEWERAGE AND SANITATION SECTOR STUDY

The salient features of the sector study are below:

1. While MWSS serves Metro Manila while LWUA covers poblaciones in other urban areas, the fringes and rural areas in the territories served by MWSS and LWUA have been somewhat neglected by these agencies.

2. Three agencies - RWDC, MLG-BWP, and DPWH - provide all levels of water supply systems in the rural areas, hence, duplication of responsibility which led to not only waste of resources but confusing and counterproductive.

3. As more water becomes available, greater quantities of wastewater are generated. Even the MWSS has obligated to reduce its investment in sewerage systems development. As of 1975, there were only 73,720 connections.

4. The NWRC is responsible for the overall coordination and integration of water resources development. Coordination, however, is perceived to be inadequate.

5. In 1985, MWSS level of non-revenue generating water reached 61.5% of total production compared to an acceptable level of about 25%.

6. Given the relatively high per capita income in the MWSS area, and the lower price now being paid by residential customers in this area compared to the price paid by their counterparts in most of the other urban areas and some rural areas, it appears, that MWSS rates, at least for residential customers, could stand further increase. This will lessen the need for Government subsidy.

7. NWRC records show that there are about 680 registered ground water appropriators and this does not include many households using small wells. These registered appropriators are authorized to pump 4,142 liters per second. With 18 hours as the average extraction period, 269 million liters of groundwater is produced daily. Coupled with the extraction done by MWSS, depletion of groundwater resources is at an alarming rate. In 1981 the groundwater level was recorded in Metro Manila to be 50 to 200 meters below sea level. It is declining further at the rate of 4 to 10 meters every year.

8 LWUA and RWDC are having difficulty collecting loans from Water Districts and Rural Waterworks and Sanitation Associations, respectively. LWUAs collection efficiency averaged to 54% in 1985 while that of RWDC was even lower at an average of 25% to 30%.

9. The setting up of regional or provincial water districts is one way of reducing the cost of providing water. Common general and administrative expenses need not be duplicated, as is now the case with city or municipal water districts. It will also allow the charging of uniform rates.

10. In some cases, water costs more outside Metro Manila than inside. Household in some urban areas outside Metro Manila pay more for water than their counterparts in Metro Manila. MWSS operations benefit from economies of scale.

11. The average per capita investment for Level I system is about P180, for Level II it is around P524, and for Level III it is approximately P924, based on the computations arrived at by ADB consultants. Since current policy is for GOP to provide grant funding for 90% of the cost of Level I systems and source development for Level II and III systems, a per capita grant of P162 is needed for Level I, P134 for Level II and P248 for Level III. The 4% interest rate on RWDC loans, when comapred to an estimated 9% GOP cost of borrowing translates into subsidies of P109 and P188 for Levels II an III, respectively. On the whole, therefore, government assistance for rural water supply systems comes up to P162 for Level I, P243 for Level II, and P436 for Level III. For MWSS, government assistance takes the form of equity contribution. In 1985, it was P2,635 million.

12. Agencies in the sector craved needed to further strengthen their operational powers to improve their operations and serves their beneficiaries more efficiently.

The sector study thus recommended the merger of two existing corporations, LWUA and RWDC, and the consolidation with the merged corporations of the water related activities of two line ministries, i.e, DPWH and MLG.

MWSS will plan, fund, construct and operate water supply and sewerage in Metro Manila and contigous areas as may be authorized by its charter, while LWUA will be responsible for water supply and sewerage in other areas outside of MWSS jurisdiction where the MWSS and LWUA remain attached to DPWH.

VI. RESPONSIVENESS OF FINDINGS

The Sector Studies touched at length on the institutional issues and problems. These include the organization and management of the different concerned agencies, and the "softwares" needed, like the administration of training programs.

It is expected that there will be imbalance of discussion among the sub-sectors. Priority will definitely be on water supply sewerage and sanitation, basically because of actual community the level of investments required, and the capability needs of the government to finance such investments.

The thrust of the 1977 study was on the alleged "gray area" or the rural areas and small provincial urban communities not served with water supply services. There was limited discussion on the other sub-sectors, namely, sewerage and sanitation.

As expected, priority attention was on water supply. However, as observed by this writer, there was a biased discussion on the water supply service coverages. It was not only MWSS and LWUA operating them. As a matter of record, the then Bureau of ublic Works under the Department of Public Works Transportation and Communication was already implementing through its Central Office-based Wells and Springs, and Water Resources Division and its field offices or what is known as district offices.

The 1977 and 1982 studies limited their discussion on a handful of essential topics.

The mechanism of complementing the development of water supply and sanitation was not discussed.

Another important aspect omitted was on the involvement of the community in various stages of development.

Other important issues either not presented or touch midly in the report are cost recovery scheme, operation and maintenance, coordination among concerned agencies, the development of programs promoting self-reliant, self-sustained action, and the association of the water supply, sewerage and sanitation with relevant programs.

The 1986 study dealt on detailed, specific issues and problems reflective of the current sector condition.

Probably, due to the time constraint in conducting sector studies, in depth analysis of the role of the private sector in water supply, sewerage and sanitation development was not undertaken. There should be an analysis of the capabilities of manufacturers, contractors, consultant, non-governmental organizations and the like to respond to the accelerated development of the sector.

The last item noted as lacking in the studies is an in-depth analysis of operational policies affecting the sectors.

VIII. EXTENT BY WHICH THE RECOMMENDATIONS WERE ADAPTED

The 1977 study came out with four major recommendations, to wit: establishment of a data base, the creation of a new office to handle the "gray area" the introduction of well drilling technologies, and the implementation of training programs.

The 1982 study reconmmended five major items, namely: clearer delineation of responsibilities, annualization of rural water supply programs, water fees collection be handled by the Provincial Governor's Office, administration of training and the coordinatuion of training programs, and the consolidation of laboratories.

The 1986 study cited institutional realignment, financial arrangement improvements, and minor operating concerns that ought to be improved.

The most important recommendation dealt on the institutional aspect.

In 1981, a new agency was created named Rural Waterworks Development Corporation (RWDC), established for the purpose of being responsible for the rural areas. However, this was abolished in early 1987 and its functions and assets were absorbed by LWUA. Why did this happen?

There are several views but the more dominant arguments are as follows:

1. The RWDC was based centrally in Metro Manila, but its coverage is nationwide. The office was prohibited under existing laws to be decentralized.

2. Its operations was coursed through Ad Hoc Committee or the office of the provincial governor or the National Electrification Administration (The NEA Administrator was then concurrently the Acting General Manager of RWDC).

3. There were other several agencies working in the rural areas.

4. The RWDC was misplaced organizationally being attached to the then Ministry of Human Settlements and subsequently, the Office of the President.

In the 1986 study, it was recommended that a single agency be responsible for water supply development outside of the Metropolitan Manila, which is LWUA. Furthermore, LWUA should be decentralized gradually.

To date, LWUA has absorbed the functions of RWDC but is still in the process of reorganization. But one salient feature here is the retention of the Department of Public Works and Highways responsibility to implement the basic level of water service, point sources like shallow and deep wells, and developed springs.

There are two factors attributed to this arrangement, viz: financial policy and physical capability. LWUA, being a corporation is expected to be self-liquidating, hence, non-viable projects can not be handle by them without national government subsidy. As a general rule, the national government discourages the provision of subsidies to government corporations.

With the current central-based organizational set-up of LWUA, it may be difficult for the agency to handle totally the responsibility because of limited outreach to its clienteles. Eventually LWUA must decentralized to be more responsive to the growing responsibility.

As for training, programs were satisfactorily realized by all related agencies.

It may be worthwhile to note that the recommendations still did not consider much about sewerage and sanitation sub-sectors.

VIII. CONCLUSIONS

The three sector studies complemented each other on the institutional aspect particularly on the organization structures of concerned agencies and in the administration of training programs. But one conspicuous item inadequately discussed was the water-users associations.

Sector studies identify major issues and problems that have a bearing on project planning, construction, operation and maintenance, resource allocation and institutional arrangements. Corrective, remedial, interim and preventive actions are recommended for decision makers to adapt.

The accuracy of information gathered and the responsiveness of findings and recommendations are two vital factors for the success of sector studies. The degree of success can be measured on the extent of adoption of the recommendations.

The periodic conduct of sector studies, say, every five years, is reasonable and the exercise provides decision makers of the quintennial review of policies and operations vis-a-vis a foresight of the succeeding five years. The conduct of sector studies is highly recommended.

LEAKAGE DETECTION INSTRUMENTS IN THE UNITED STATES: AN OVERVIEW

By :
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Water system operators have known for many years that leaks in the distribution system will generate noise and cause the pipe to vibrate in the vicinity of a leak. The "leak noise" and vibration is created by the release of energy at the source of the leak. The energy in this case, is in the form of pressure. It is actually the pressure, which is present in all distribution systems, that enables the operator to detect and pinpoint leakage. The amount of pressure in a distribution system is usually measured or quantified in pounds per square inch (PSI), and will vary greatly from system to system, and in many cases will vary in sections within a distribution system, depending on the characteristics and variables in that system.

It has been established that all leaks will generate noise. Therefore, all leakage detection instruments are designed to detect this "leak noise" and alert the operator that a leak is present.

There are a wide variety of leakage detection instruments available on the market. Some of these instruments have the capability to both detect leakage and pinpoint the actual source of the leak, while others have only the capability to detect leakage, with virtually no means to pinpoint the source of the leak.

As you might expect, the wide variety of instruments available coincides with a wide cost range. Leakage detection instruments have a cost ranging from approximately $10.00 to $45,000.00 (US).

The selection of the proper instrumentation is a key element in establishing an effective program. It may be advisable to solicit the input of the employee(s) that will be utilizing this equipment in the field, before purchasing any leakage detection equipment. Since the employee(s) will be expected to produce good results with this equipment it is important that the employee(s) feel confident that the proper selection has been made. One of the questions that must be addressed in the selection process is the feasibility of training the employee(s) in the use of the equipment selected in order to achieve maximum benefits. Proper training in the use of the equipment selected is perhaps the most important aspect of an effective program. In essence, the effectiveness of the entire program depends upon the ability of the operator to utilize the equipment to its maximum potential. It is, therefore, essential that the employer provide proper training to insure that the employee(s) become proficient in the detection and pinpointing of leakage.

Close scrutiny and careful evaluation is necessary to insure that a program, when implemented, is an effective one. The selection of equipment should include the initial purchase price and the cost of providing proper training in its use. Practical application and proper training are key elements of an effective in-house program. The employee's ability to utilize the equipment selected to its maximum potential is often the difference between an effective program and an ineffective program.

OVERVIEW OF INSTRUMENTS:

Leakage detection instruments fall into two basic catagories: non-amplified and amplified. Non-amplified instruments are of a mechanical nature and are among the more basic devices utilized in the field. Amplified instruments are more sophisticated and contain various degrees of electronic circuitries which amplify the leak noises. The amplification of the leak sounds gives the operator far greater sensitivity, and improves his/her ability to detect and pinpoint leakage.

NON-AMPLIFIED

HUMAN EAR

The human ear is the least expensive leakage detection instrument known to man — it's free. Virtually every operator has used this — the most basic form of leakage detection. Stemming from the principal that all leaks create noise, you can actually hear a nearby leak when you place the "naked ear" to the barrel of a hydrant or to a valve wrench or key.

SCREWDRIVER — Cost: $2.00 - $6.00 (US)

In a manner similar to the naked ear, a common screwdriver is often utilized to listen for the presence of a nearby leak on a hydrant or a valve wrench or key. The metal shaft of the screwdriver transmits the leak noise to the ear.

LISTENING STICK (OR BAR) —— Cost: $10.00 - $40.00 (US)

Occasionally a Listening Stick or Bar is utilized to listen to mainline valves and/or service connections. Usually when this method is used, the operator has direct contact to the valve or the operating nut of the valve.

SONOSCOPE —— Cost: $10.00 - $40.00 (US)

This device, which resembles the receiver of an antique telephone, is perhaps the most widely used leakage detection device in the United States This is mainly due to its very low cost and its durability.

GEOPHONE —— Cost: $275.00 (US)

This device was developed during World War I by the United States Army, which used it to detect underground tunneling by enemy forces. Since that time, it has been widely utilized in the water industry to detect and pinpoint leakage with a relatively high degree of accuracy. Localizing or pinpointing leakage using the Geophones requires considerable training and experience. The relatively low cost, its durability and the capability to both detect and pinpoint leakage, are the main reasons this instrument remains popular in the United States.

AMPLIFIED

STETHOPHONE —— Cost: $375.00 (US)

This instrument is a low cost tool utilized by field supervisors, meter readers, hydrant maintenance crews, valve maintenance crews and leak detection operators. This type of instrument has gained popularity throughout the United States because of its compact size and its ability to amplify the leak noises.

BOX TYPE DETECTOR —— Cost: $450.00 - $600.00 (US)

This Box Type Leak Detector is a medium priced instrument that has limited amplifing capabilities. It can be used to detect leakage and aid in localizing or pinpointing the leak.

AQUA-SCOPE —— Cost: $1,300.00 - 1,700.00 (US)

This instrument is perhaps the most widely used leak detector of its type in the United States. It has the ability to amplify the leak noises and can be utilized to pinpoint the leak source.

SON-I-KIT — Cost: $1,400.00 - $2,600.00 (US)

This type of instrument is widely utilized in the water industry. It is capable of amplifing the leak noises, and the operator can select a specific frequency range to aid in the detection and pinpointing of leakage.

LEAK CORRELATION INSTRUMENTS — Cost: $20,000.00 - $45,000.00 (US)

The most sophisticated and the most expensive instrument currently in use in the United States is the Leak Noise Correlator. This type of instrument utilizes computer technology to aid in the pinpointing of leakage. The operator must first determine that there is a leak (or the possibility of a leak) between point A and point B. The operator then places a microphone (connected to the amplifier) on two contact points (usually mainline valves) on either side of the leak. The leak noise is then transmitted via a cable or radio signal to the central unit (computer). The computer analyzes the data and displays a "leak picture" on an Oscilloscope, that indicates the source of the leakage and provides the operator with data such as: the leak is "X" feet from microphone A.

We have assembled a slide/tape presentation which illustrates how typical electro-sonic instruments are used to detect and pinpoint leakage in the distribution system. After we view this presentation, I will be glad to address any questions you may have.

GOOD VIBRATIONS

A POSITIVE APPROACH TO WATER LEAK DETECTION

INSTRUCTOR'S MANUAL
BY

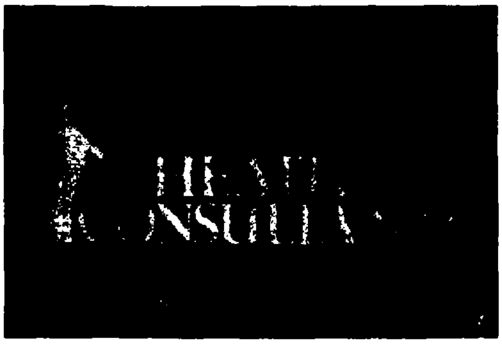
HEATH CONSULTANTS

EDUCATION DIVISION

PREFACE

This Manual is designed for use with a set of 99 slides keyed to a cassette tape on the subject of a positive approach to water leak detection utilizing electrosonic instrumentation with solid state amplifiers.

It is suggested that the instructor review this manual prior to the classroom presentation so that he can add examples from his own experience and stimulate discussion at the end of the presentation. The description of each slide is identical to the vocal tape presentation so it is simple to locate an individual slide for detailed discussion.

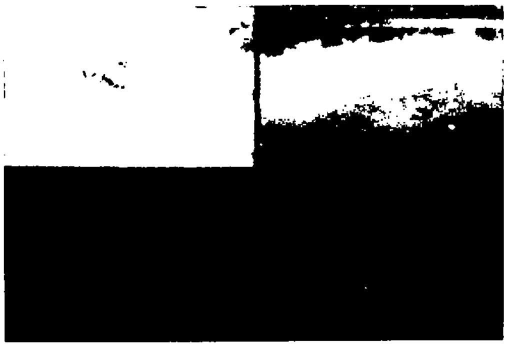


SLIDE 1 Music...

SLIDE 2 Music...

SLIDE 3 Water, mankind's most vital natural resource is fast becoming a precious and scarce commodity.

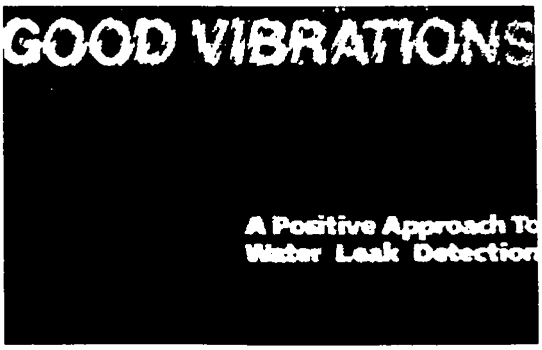
SLIDE 4 Drought,



SLIDE 5 pollution,

SLIDE 6 rising costs

SLIDE 7 and increasing consumption are all factors resulting in the effort towards conservation and more efficient use of water resources.

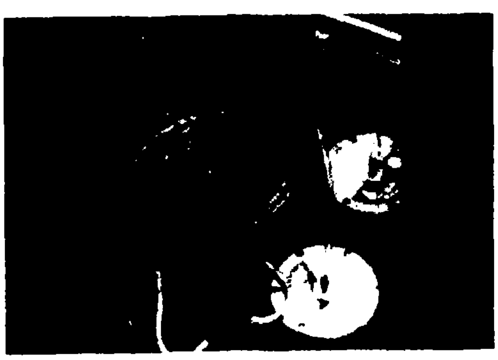


SLIDE 8 Music...

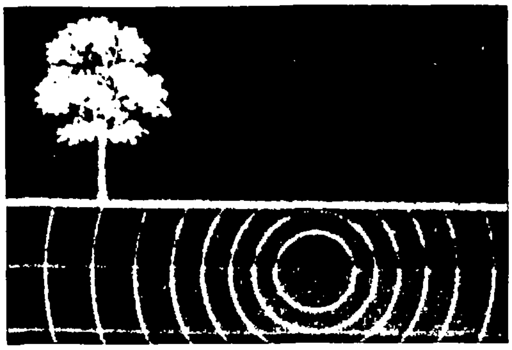
SLIDE 9 In the past, water system leakage was not necessarily considered a serious problem. But in the good old days of abundant supplies of cheap water many leaks were not economical to repair.

SLIDE 10 It has become evident that these times of practical waste are over.

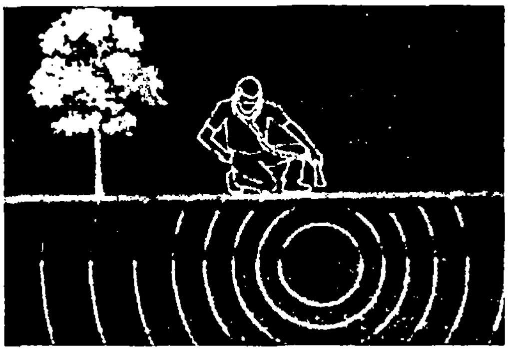
SLIDE 11 Detection of water leakage has been practiced over many years



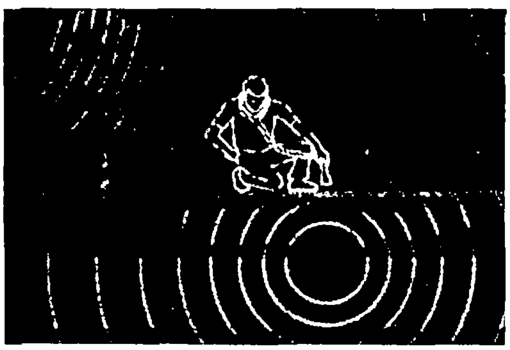
SLIDE 12 and many devices were developed to aid in their detection.



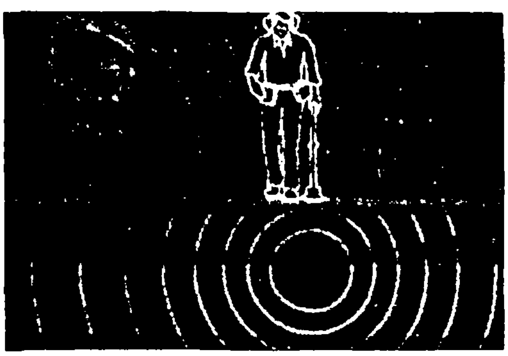
SLIDE 13 Modern instrumentation for detecting water leaks is based on the principal that leaking water and other like liquids generate sound frequencies in the audible range.



SLIDE 14 Initially, these instruments had severe limitations. It was necessary to position the devices close to the leak source to detect the leak sound.



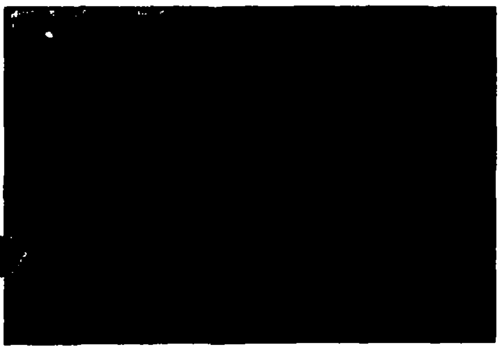
SLIDE 15 The background noises often made detection of specific leak sounds difficult. This established the need for more sophisticated technology and methods.



SLIDE 16 Electrosonic instruments with solid state amplifiers were developed for the detection of leakage on pressurized buried pipelines carrying water and other like liquids. These instruments are capable of detecting the smallest leak with a minimum of background interference.

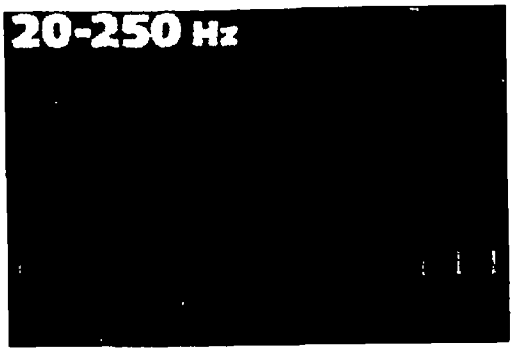
SLIDE 17 Extensive analysis of actual leaks on buried pipelines established that several distinct sound frequencies can be generated by a leak.

SLIDE 18 Test results also indicate that all leaks will produce at least one sound but that most produce two to three sound frequencies.

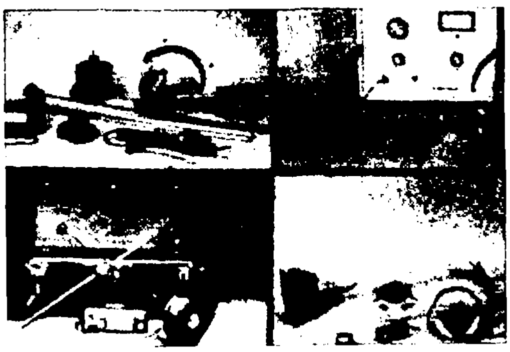


SLIDE 19 The high frequency sounds normally in the 500 to 800 hertz range usually originate as organ pipe vibration and are transmitted along the pipe wall. Sound...

SLIDE 20 The second sound, 20 to 250 hertz, is caused by the impact of water upon soil in the area of the leak. Sound...



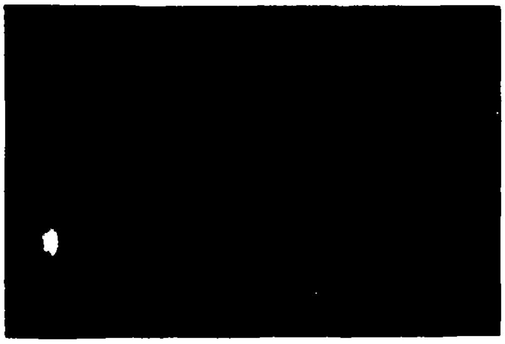
SLIDE 21 The third sound, also within the 20 to 250 hertz range, resembles the sound of a fountain. It is caused by water spraying and circulating in a cavity near the leak. Sound...



SLIDE 22 Well, now, let's look at the equipment developed by modern technology. Although the operator's equipment may be different than the instruments used in this program, the operator of any electrosonic equipment should take a similar approach.

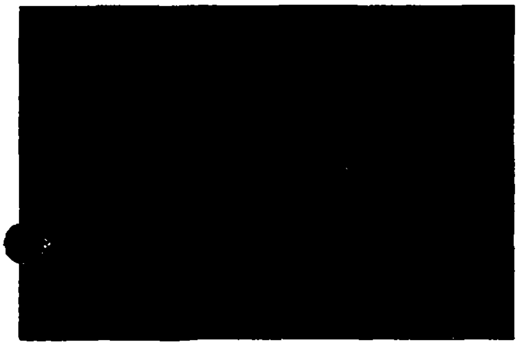
SLIDE 23 The equipment pictured incorporates all of the advantages of the latest technology and has been designed specifically for the efficient detection of leakage on underground water systems.

SLIDE 24 This instrument enables the operator to detect the complete range of leak frequencies, filter out background noises, and amplify the leak frequencies.



SLIDE 25 The pickup microphones are isolated and shielded to minimize extraneous noises such as air traffic noise, transformer humming and radio frequency.

SLIDE 26 A variety of components housing the pickup microphones are used in conjunction with the amplifiers and meter module.



SLIDE 27 The components include the direct contact microphone used to detect high frequency sounds.

SLIDE 28 The operator can select either the magnetic tip or the test rod for direct listening on exposed pipes or hydrants.

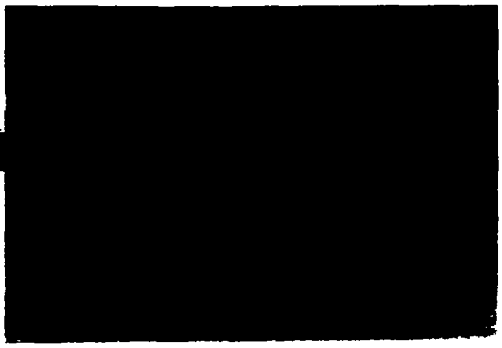
SLIDE 29 The test rod can be used on underground valves or points of exposed piping in difficult to reach locations.

SLIDE 30 The ground microphone is utilized for listening over buried mains and is designed to pickup the lower frequency sounds caused by soil impact of the fountain effect.

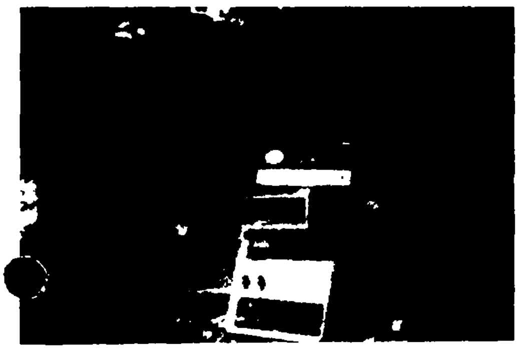
SLIDE 31 Using the combination of these components affords the operator the tools to conduct a thorough sonic leak detection survey.

SLIDE 32 It is important that the operator have accurate location of the system in order to conduct a thorough survey.

SLIDE 33 With good records and system experience the operator may read the street and refer to maps or cards for location.

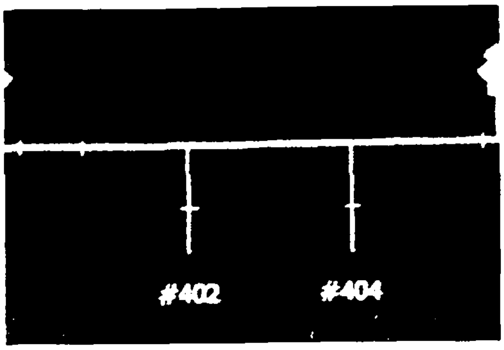


SLIDE 34 It may also be necessary to use a pipe locator to accurately locate the system.



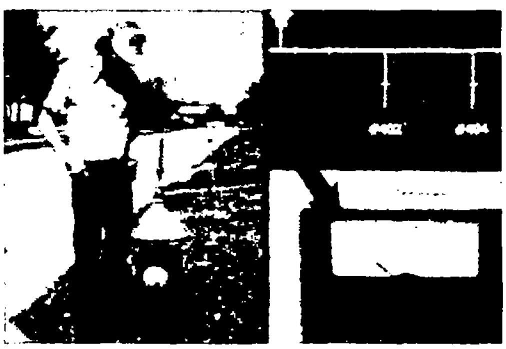
SLIDE 35 Regardless of the type of locator used, the successful operator will take the time to have accurate locations.

SLIDE 36 The system inspection requires a two person team. One person to conduct the actual leak detection and the other person to open valves and provide protection for the operator.



SLIDE 37 Now let's survey a section of the system with the operator using the comprehensive approach.

SLIDE 38 To utilize the advantages of both direct listening and surface survey, the operator will move through a section of the system plugging in the appropriate microphone at various test points.



SLIDE 39 The operator listens at a hydrant using a magnetic tip. Sound...

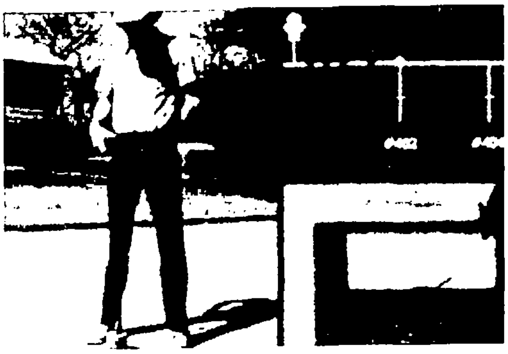
SLIDE 40 Next the operator listens at a main line valve utilizing the test rod. Sound...

SLIDE 41 Another main line valve with a test rod. Sound...

SLIDE 42 Now *utilizing the ground microphone*, the operator tests over the main near the main line valve and then moves along the main at intervals of six to ten feet.

SLIDE 43 At a point between the two main line valves, the operator hears this sound. Sound...

SLIDE 44 Down the main from the main line valves, this is the sound that is heard. Sound...



SLIDE 45 The operator listens over the service tap to house 402. Sound...

SLIDE 46 Further down the main this is the sound that the operator hears. Sound...

SLIDE 47 Back over the main this is the sound that is heard. Sound...

SLIDE 48 The operator continues to test along the main over the service tap to house 404. Sound...

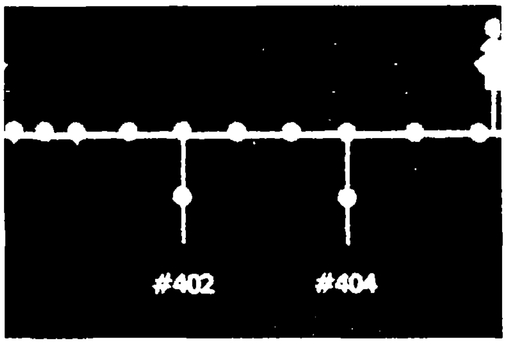
SLIDE 49 And between the tap and the main line valve. Sound...

SLIDE 50 When the operator arrives at the valve location, the operator listens using the test rod. Sound...

SLIDE 51 The operator listens at the second hydrant utilizing the magnetic tip. This is the sound that is heard. Sound...

SLIDE 52 To gain additional information for pinpointing the operator listens with the test rod at the service valve to house 402. Sound...

SLIDE 53 And the service valve to house 404. Sound...



SLIDE 54 Now let's review the leakage areas as the operator goes back to pinpoint the leak. The operator detects audible tones on both main line valves and the second hydrant.

SLIDE 55 Now with the ground microphone, the operator gets a series of audible tones and returns to listen again with the ground microphone.

SLIDE 56 Let's listen as the operator moves through the leakage area.

SLIDE 57 Sound...

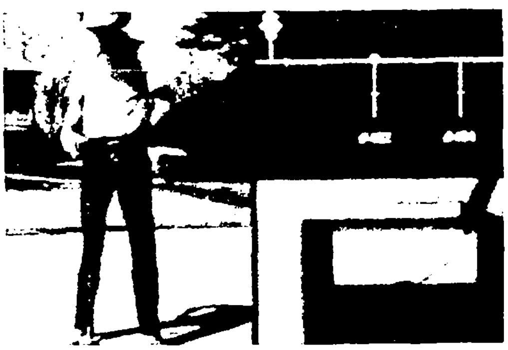
SLIDE 58 Sound...

SLIDE 59 Sound...

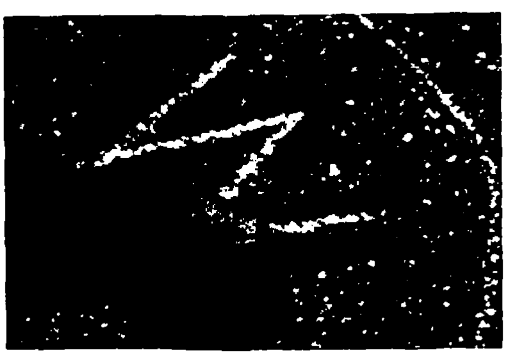
SLIDE 60 Sound...

SLIDE 61 Sound...

SLIDE 62 In this leakage area, the leak appears to be on the service tap to house 402. The operator momentarily turns off the service to 402 to determine if the leakage is on the customer's side of the service valve.



SLIDE 63 The operator listens to the service tap with the valve in the closed position. The sound of the leak is unchanged. Sound...



SLIDE 64 Going back over the main, the operator pinpoints the leak location.

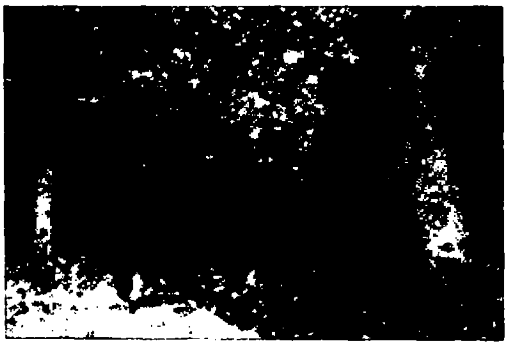
SLIDE 65 An alternative to this comprehensive survey would be for the operator to listen at only direct listening points.

SLIDE 66 This patrol type survey enables the operator to move quickly over the system.

SLIDE 67 The operator may not go back through this area with the ground microphone unless readings or audible sounds are obtained, or unless there are too few direct listening points. This method is often utilized as an initial survey to the system. The operator must keep in mind, however,

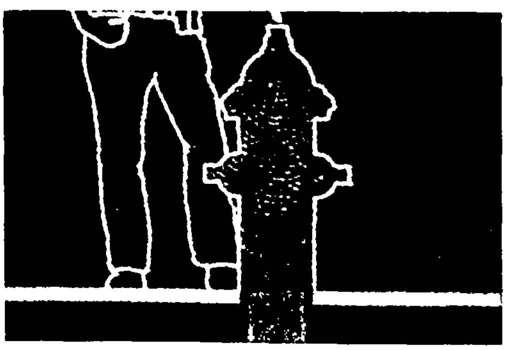
SLIDE 68 that there may be leaks.

SLIDE 69 Large volume leakage may go undetected when only the direct contact microphone is used.

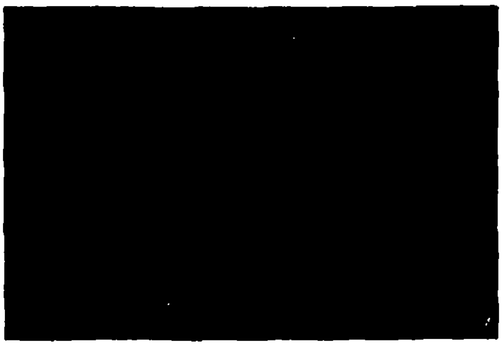


SLIDE 70 With these leaks the low frequency sounds may not be transmitted to the direct listening points due to the transmitting quality of the pipes.

SLIDE 71 In other leak locations such as hydrant leaks



SLIDE 72 most of the sound is transmitted through the hydrant and very little indication is detected with the use of the ground microphone.



SLIDE 73

The experienced operator learns that there are variables that affect the sounds and meter reading. Variables such as pressure, type of pipe, diameter of pipe, depths of pipe, contact points and type of cover.

SLIDE 74

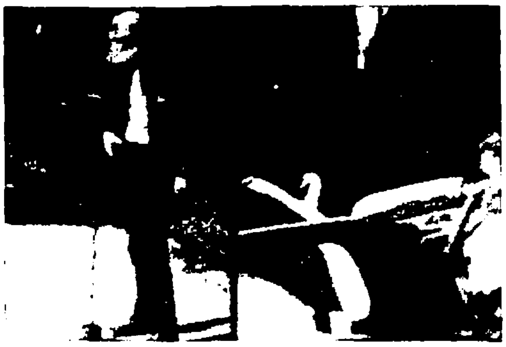
There are also sounds that will be audible that are not leak sources such as partially closed valves, electrical equipment, compressors, and lighting.

SLIDE 75

Other signals are transmitted along the pipe just like the sounds created by leaking water. The operator needs to differentiate between these sounds and readings and those created by leaks. This is a skill that is developed with experience.

SLIDE 76

Consumption will also give the operator similar sounds.

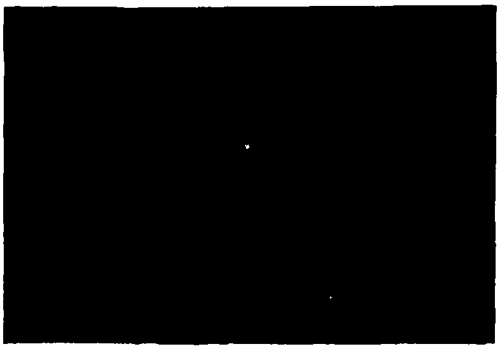


SLIDE 77 It is common practice that when the operator suspects that the readings are due to consumption to note these areas and return at another time when consumption is less apt to occur.

SLIDE 78 In some cases it is necessary to momentarily interrupt the service to differentiate between consumption and actual pipeline leakage.

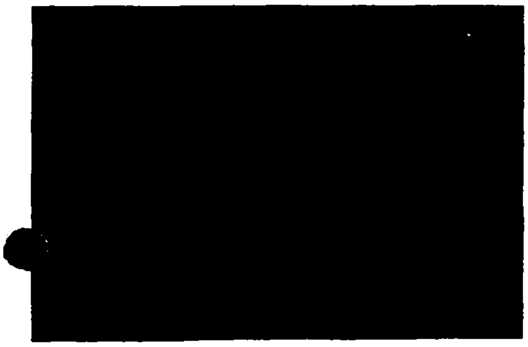
SLIDE 79 Where the main is not paved over, such as in a right-of-way or in an off country road, the approach is similar to that used for paved areas.

SLIDE 80 The operator must have accurate system location.



SLIDE 81 Here the operator may employ a probe or a T-bar to make direct contact with the pipe.

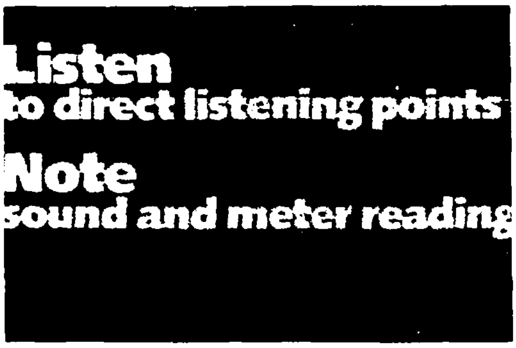
SLIDE 82 The operator then listens with a direct contact microphone.



SLIDE 83 To utilize the ground microphone, the operator may employ a resonating plate thcreby providing a surface that will transfer the sounds as the pavement did. Now let's review your approach as the operator to the system.

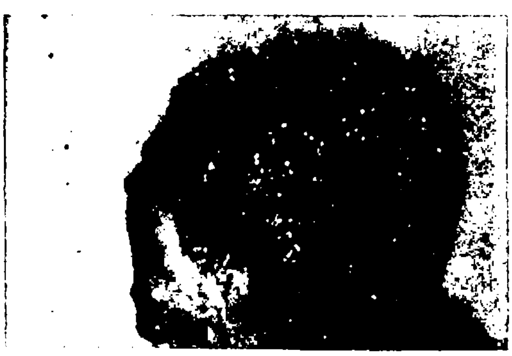
SLIDE 84 Begin with a positive attitude and thorough knowledge of the equipment.

SLIDE 85 Have an accurate system location for that portion which is about to be surveyed.



SLIDE 86 Listen to as many direct listening points as are available. And with a ground microphone over the buried structure at intervals of six to ten feet, note the sound as well as the meter readings. To be sure that you are listening to a leak sound,

SLIDE 87 you may choose to go back through the area again before actually pinpointing the leak to be certain that restrictions in the pipe due to offsets or partially closed valves are not producing the leak sounds.



SLIDE 88 Eliminate the possibility that the indications are due to consumption

SLIDE 89 rather than true leak by either interrupting the service momentarily or returning to the area when consumption is less likely to occur.

SLIDE 90 Continually look for evidence for variables that may affect sounds and meter readings such as changes in pressure, type of pipe, diametef of pipe, depth, ground cover, contact points, or a partially closed valve.

SLIDE 91 In high traffic areas or locations where unusual background noises are present such as industrial sites, it may be necessary to conduct leak surveys at night, or on days when these noises are not present.

SLIDE 92 Although it has been pointed out that leak detection utilizing electrosonic instrumentation is a developed skill and not an exact science,

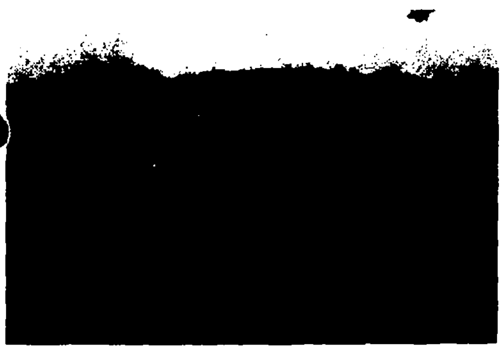
SLIDE 93 you as the well trained operator can expect to be successful in detecting and pinpointing underground leakage.

SLIDE 94 In order to ensure clean, potable water for this generation,

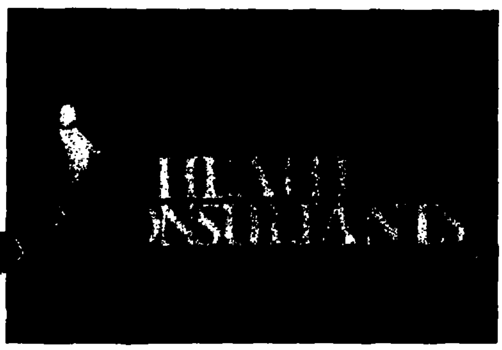
SLIDE 95 and future generations,

SLIDE 96 conservation through water leak detection has and will serve a vital role.

SLIDE 97 Music...



SLIDE 98 Music...



SLIDE 99 Music...

OBTAINMENT OF PIPELINE INFORMATION AND ITS APPLICATION IN OSAKA CITY

by :

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1. Introduction

The water works in Osaka city was inaugurated in 1895. Since then, we have implemented nine expansion works. As a result, the total distribution capacity is 2,430,000 m^3/day, and there are eleven service reservoirs and 4,909km distribution pipes. But the ninth expansion work has been shelved because of a decrease in the water demand after the oil-crisis in 1973. In recent year, the improvement and rehabilitation works of existing facilities are more of a priority than the expansion works.

The systematic approach to the pipeline rehabilitation works began in the late 1950's because of successive accidents which caused red water, leakage and breakage. Today, we have accumulated technology on the rehabilitation and improvement of old pipes.

In carrying out these rehabilitation programs, basic information on distribution pipes has played an important role. Such information has been collected through the expansion works and rehabilitation works themselves.

The objective of this paper is to state the present situation and the future plan of how to obtain and the application of pipeline information in Osaka city.

2. Pressure and flow control in distribution pipes

2-1. Current water distribution information system

There are 52 telemetry stations which measure the water pressure and the flow in distribution pipes.

The data obtained at the telemetry stations is transmitted to the distribution information center through the pumping stations. The data transmitted to the distribution information center is recorded with four recorders.

It is possible for us to monitor two water pressures, two flows and two integration flows simultaneously.

These data are utilized for pump controlling and distribution planning. The contents of the system are as follows and the data transmission network is shown in Fig.-1.

(1) Equipment
  1) Pressure telemeter
  2) Flow telemeter
  3) Transmitter
  4) Digital monitor
(2) Data of telemeter
  1) Pressures
  2) Flows
  3) Integration flows

2-2. Problems of existing system

The present system, however, has some faults. The major one is the lack of information on the purification plants and pumping stations (pressures and flows at the outlet of the plants, water levels of clean water reservoirs, the condition of pumps and valves, etc.). These can not be ignored in case of accidents in the pipeline.

Another problem is the recording system. Under the existing system we can only obtain 18 analog data and 6 digital monitor, but the rest of the data (67) is not recorded. Even if the data is recorded, it is not easily accessible because it is recorded on long roll papers.

2-3. The plan of the new information system

We have some projects to equip the new distribution information system and will begin to improve the present system from 1987. These projects are as follows:

(1) Equipment
  1) Transmitter and receiver 1 set W1300 x H2200 x D500mm
  2) Personal computer

2 computers (16 bit)
2 printers
2 operation desks

3) Location display 1 set W1500 x H2100 x D400mm

4) Improvement of display of distribution plants
The improvement for transmission of various data in distribution plants.

5) Improvement of sub-center
The improvement of terminal stations for transmission of data.

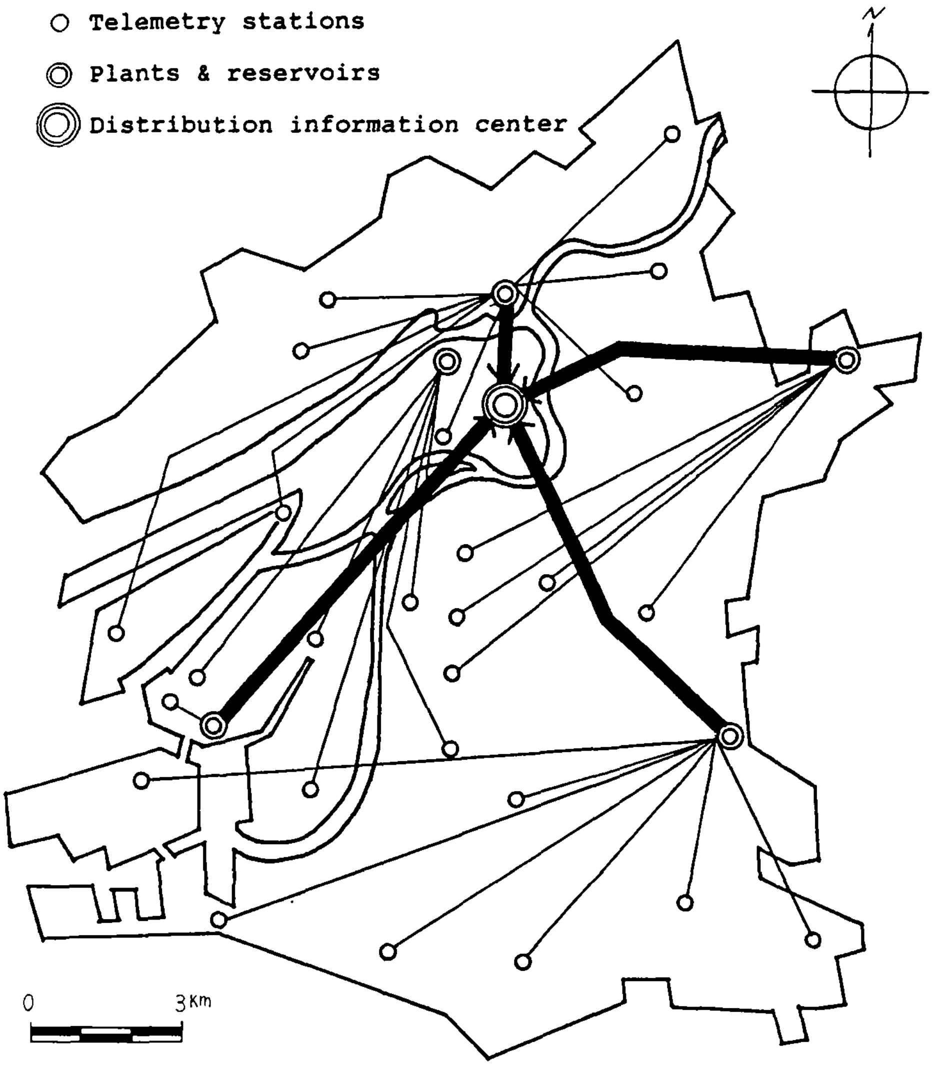


Fig.-1 Network of distribution control

(2) Classification of data (The existing number is shown in parentheses.)

1)	Pressure at telemetry stations	89 (29)
2)	Flow at telemetry stations	58 (21)
3)	Integration flow at the telemetry stations	58 (21)
4)	Flow at the inlets of clean water reservoirs	14
5)	Water levels of the clean water reservoirs	19
6)	Condition of pumps	72
7)	Flow at the outlets of the distribution plants	31
8)	Pressure at the outlet of distribution plants	31
9)	Condition of valves at outlets of distribution plants	31
10)	Quality of water at telemetry stations	34

(3) Data processing

1) Input of data

All the data is input at 10 seconds intervals.

2) Recording and keeping of data

Within the first one hour, all the data at 10 seconds intervals is kept. After the first one hour to the 48th hour, the data at one minute intervals is kept, and after 48 hours the data at one hour intervals is kept.

(4) Display of data

1) The memorized data is display in diagrams and trend graphs.
2) Daily and monthly reports are made with this data.

(5) Advantage of new system

1) We can control the water flow in case of accidents or change the flow routes more safely and rapidly with the various data from each telemetry stations.
2) We can store the basic data for a long term distribution plan, because daily and monthly reports are made and filed in computer disks with the telemetry data.
3) We can easily understand the flow condition by displaying the pressure and flow on the location display. Also the condition of the clean water reservoirs and pumps can be displayed on the CRT (Cathode Ray Tube).
4) The new system is a centralized controlling one which enables us to survey the whole distribution system and respond to accidents swiftly.

3. The basic data for maintenance of pipes and fittings

3-1. Information of pipes

(1) Records of accidents because of breakage of pipes

The records of accidents because of the breakage of pipes show that causes are mainly due to pipe materials, the strength and the surrounding condition. This is useful information in order to make some improvement projects.

This data is classified in the following three categories, and filed each year.

1) Records of accidents which have occurred

The papers for press briefings and the explanations to the related authorities.

2) Details of the accidents

Data for improvement projects

3) Examination of the pipes

Examination of the pipes and the soil condition in order to find out the causes

(2) Pipe digging investigation

We started the examination of buried pipes in 1977 and have been getting data from about 20 cases each year. This data is useful for us to estimate the condition of buried pipes , and to make some kind of improvement projects. Contents of the examination are as follows:

1) Condition of soil

Specific resistivity of soil, redox electric potential, water content percentage, sulfide, electric potential difference between pipes and soil, classification of soil, corrosion of soil

2) Extracted water from the soil, underground water

Specific resistivity, pH values, content of sulfuric acid ion, content of chloride ion, amount of consumption of potassium permanganate

3) Examination of pipes

Crushing tests, flattening tests, tensile strength tests, amount of corrosion, matrix of material, chemical analysis, lining condition of inside of pipes,etc.

4) Bolts and nuts

Appearance, matrix of material, chemical analysis, etc.

(3) Research on the pipes affixed to bridges and water pipe bridges

There are altogether about 500 water pipe bridges and bridges with pipes affixed to them in our city. We have made research on them in order to utilize data therefrom for maintenance and improvement projects.

Research is to be carried out by means of X-ray and ultra sonic inspection to investigate the degree of deterioration and estimate the life expectancy.

There are three kinds of examination.

1) Examination of the pipe condition

Corrosion of pipes, condition of flexible joints

2) Condition of the concrete of abutments and piers

Cracks, carbonation, corrosion of reinforcing bars, strength of the concrete and reinforcing bar

3) Condition of coatings

Adhesive strength and life expectancy of coating

In 1986 the above research was carried out experimentally. Also we will examine the condition of 120 bridges and research 5 bridges in detail annually from 1987. The data of this research will be sufficiently recorded in the future.

3-2. Information of fittings

(1) Files of valves

There is a lot of data on the location, the diameter, the types of valves and the data of replacement. This data is to be used for maintenance.

(2) Other files

There are also files for hydrants and air valves, data of which are filed in the same filing system as valves.

3-3. Problems

(1) It is time-consuming to use the files for several analysis since they consist of many papers.

(2) The files are arranged in order of time. Therefor, when we need data for each trunk main or on the city wards, the rearrangement of files requires a lot of time.

(3) The renewal and addition of data depends on laborious manual work.

3-4. Future plan

(1) Compiling basic data on pipelines

A lot of information, (e.g. quality of pipes, types of joints, condition of lining, the buried data, surrounding conditions, accident records etc.) has been collected for the maintenance of pipelines.

Therefore, we are going to collect basic data for pipes of 400mm diameter and larger on computer. Then if necessary, we can expand the data collection to pipes of less than 400mm diameter.

(2) Compiling basic data on water pipe bridges and pipes affixed to bridges

All of these pipes will be surveyed and the data will be recorded on computer. This data is fundamental for the planning and maintenance of the water supply system.

(3) Others

We have other plans to arrange the data with regards to conditions of pipes and records of accidents, fittings, etc.

4. Drawings for information management

4-1. Preparation of the drawings for information management

(1) Summary

It is important for us to get the correct information from our plants and equipment. From this point of view, the pipeline network drawings are a useful measure to maintain the water works. In Osaka city, we have used two types of drawings, i.e. the localized map of distribution pipes (1/3000) and the distribution system map (1/20000).

In recent years, the present maps have become insufficient for information management, because the quantity of the underground structures has been increasing, also the quality of the information and the technology has been changing and developing. Therefor we have to rearrange and use the drawings in detail for our services.

Accordingly, the preparation of new drawings with a scale of 1/500 was started in 1979. They include all the information available and are much easier to be read. They were completed at the end of 1986.

As a result of these drawings, it is possible to get detailed information such as control valves, air valves and so on, in addition to diameter, types of pipes, year buried, degree of load.

(2) Series of drawings and contents

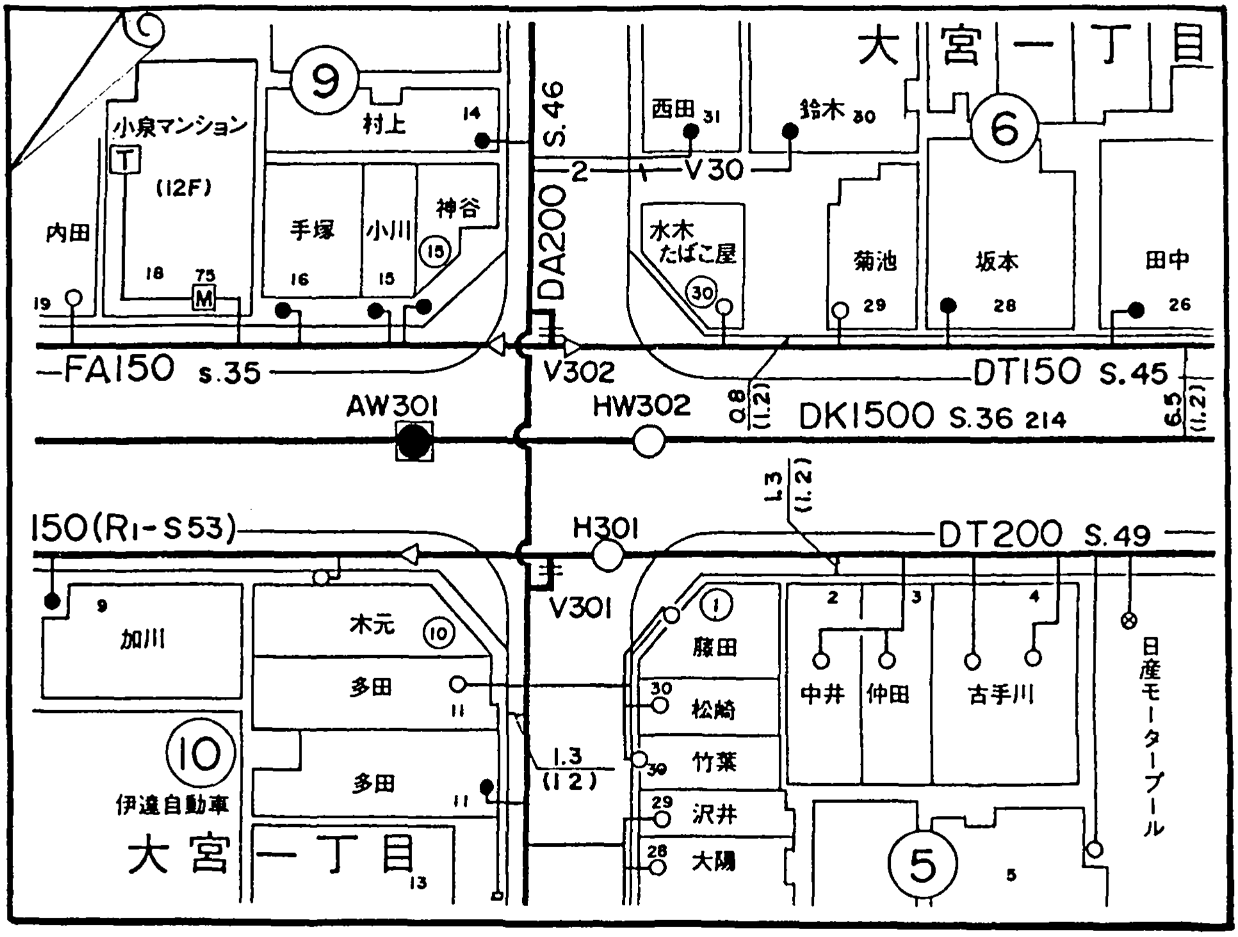
1) Drawings of distribution pipes in Osaka city (1/500, size A0, 1397 sheets)

Diameter, types of pipes, types of joints, year buried, location of pipes, overburden depth of pipes, the number of fittings, the number for management (diameter 400mm and larger)

2) Drawings for management (1/500, size A0, 1397 sheets)

Distribution pipes and service pipes (diameter, types of pipes, the points at which houses are served, diameter and location of the service meter), method of service (the size of the receiving tank), the name of the town, the number of the block, the number of the residence, the name of land marks, the user's name etc. (Because, in Japan, small streets have no name.)

An example of drawings for management is shown in Fig.-2.



(Distribution pipes)	
DT200	Types of pipes & diameter
S.49	Year buried
214 V301	Pipe number, valve & number
H301	Fire hydrant & number
AW301	Double exhaust airvalve & number
◁	Reducer
1.3 (1.2)	Location of road (Degree of road)
F=	Cast iron
D=	Ductile iron
A=	Mechanical joint
T=	Tyton joint
R1=	Epoxy resin lining

(Service pipes)	
—/—V—	Types of pipes (Lead & vinyl)
———○	13mm meter
———●	20 or 25mm meter
———⊗	40mm meter
———[M]	50mm meter or larger
V30	Types of pipes (vinyl) & diameter
Ⓣ [T]	Receiving tank
⑥	The number of block
①	The number of residence

Fig.-3 An example of drawings for management (1/500)

3) Drawings of distribution pipes (1/2500, size A1, 204 sheets)
These have still to be prepared in place of the present 1/3000 drawings of the distribution pipes, consisting of the diameter, types of pipes, and fittings.

4) Drawings of the distribution system (1/20000, covering the whole of the city)
The pipes with diameter of 300mm and larger are drawn on the map.

(3) Correction of drawings

Drawings of distribution pipes for management, and of distribution equipment are corrected within 60 days after the completion data of any construction work.

4-2. Computer mapping system

(1) Summary

We have a plan to introduce a computer mapping system instead of the present micro-films.

The computer mapping system contributes not only to the water supply system, but also to other sectors (sewage bureau, gas, telephone, electricity company etc.).

The effectiveness of this system is as follows:

1) We can store all the information of pipes, i.e, types of joints, year replaced, location, overburden depth of pipes, condition of pipes, number of operation of valves, records of rearrangement, the name of the manufactures, etc., with this system. So our service becomes more effective for making plans and designs. Therefore, we can get the latest data constantly, because this data in this system, can be renewed easily.

2) By simulation we can effectively make plans of the distribution system or predict the influence in a particular area caused by construction works.

3) When this on-line system is applied, a higher density of service, as well as a more substantial operation of the distribution information center can be expected.

(2) Future plan

We are going to start research for the introduction of a computer mapping system in 1987.

Meanwhile, the Ministry of Construction has set up a subsidiary organization which supplies information on the road structures, including buried pipes and cables, using a computer system.

Osaka City Water Works Bureau is going to join the system in 1988.

5. Grid square information of distribution pipes

5-1. Summary

(1) Concept of grid square data

We partition the city in the mesh and collect various data depending on several kinds of statistics (Population census, Industrial and commercial statistics, the survey of landuse and total floor area).

The data of each grid square in Osaka city is collected for the analysis of water consumption and water supply planning, and finally used for water demand forecasting.

Using a computer, we can analyze this data and compare it easily in the time-series.

Fig.-3 shows an example of output. (Each mesh is 500m square. There are about 900 meshes in the city.)

(2) Data of pipelines for each grid square.

The contents of the collection of grid square data for the water works are as follows:

1) The number of users
2) Quantity of water demand
3) Capacity of distribution pipes
   For each type of pipe, and each diameter of pipe
4) The length of distribution pipes
   For each type of pipe, and each diameter of pipe

5-2. Effective application of the grid square

(1) Quality control of water in pipes

Using the ratio of the quantity of water demand and the capacity of pipes (Fig.-3), we examine the detention period of water in pipes and the concentration of chlorine in the water. The decrease of chlorine is proportional to the detention period in particular grid squares. In these grid squares the residual chlorine becomes scarce. So we have to take some measures, i.e, to drain at intervals, the reduction of the capacity of pipes, etc.

(2) The reliability of assessment of pipes

We examine the proportion of aged pipes against the total length of pipes in each mesh, and make a rehabilitation program for the aged pipes. We can also forecast the occurrence of red water in areas where there are many aged pipes.

5-3. Future plan

In the future, we are going to develop a grid square data system which is more compatible to the wide range of statistics.

With these systems, the planning of the optimum allocation of water to the pumping stations and purification plants, the notification to the public of the possible occurrence of red water caused by valve handling, and more accurate water demand forecast can be attained.

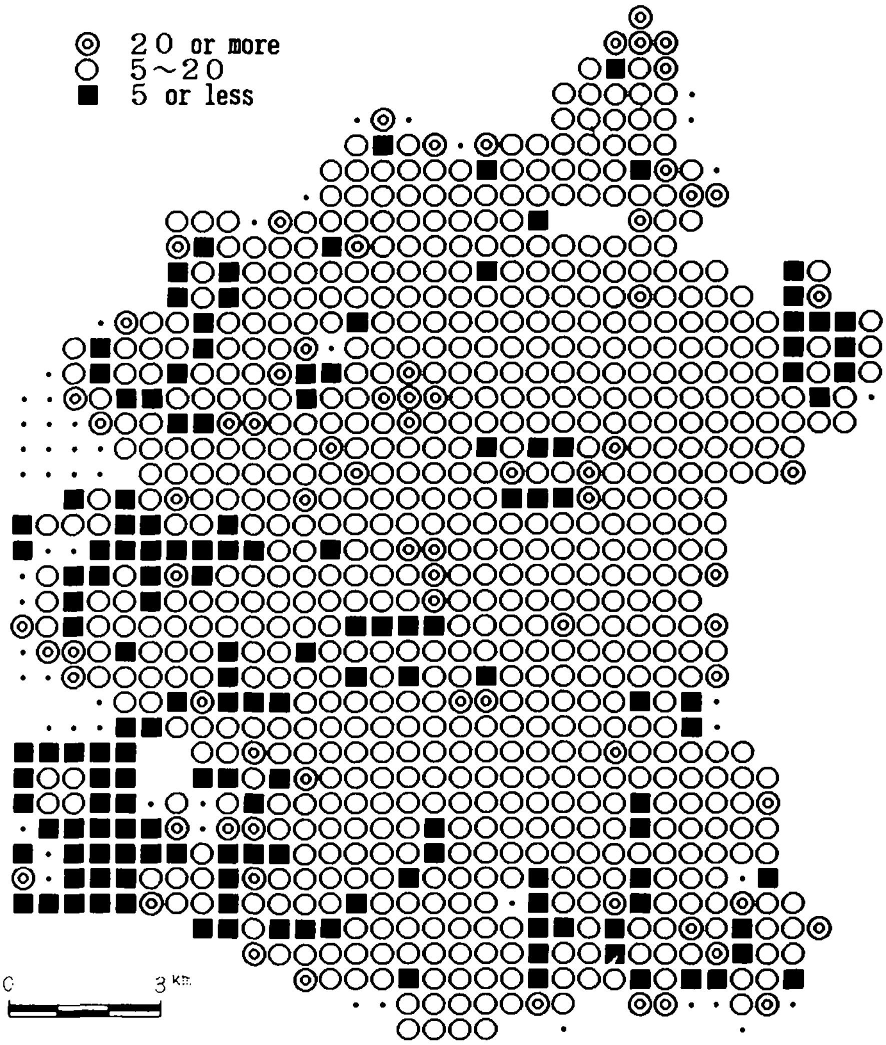


Fig.-3 An example of output (The ratio of the quantity of water demand and the capacity of pipes)

6. Conclusion

Now, the ninth expansion project has been shelved and the maintenance projects are in progress in Osaka City. We have to use the information about the pipes as basic data for making our maintenance projects more perfect. For that purpose, it is necessary to combine the basic information on pipes in the present drawings for water control, to other information, such as the surrounding conditions of pipes. Therefor this is a new issue for Osaka City; to establish "The Comprehensive Pipeline Network Information System" including other attributive data by using a computer mapping system.

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An Advanced Computer System For Charge Collection Related Business In The Tokyo Metropolitan Waterworks

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1. Water and sewage charge collection related business in Tokyo

(1) Waterworks

Tokyo Metropolis is located approximately in the middle of the Japanese Archipelago,and can be roughly divided into the following 3 areas.

① The heavily urbanized area of 23 "Ku" (special wards) districts with an area of 597 square kilometers which lies within the southern part of the Kanto Plain and borders on Tokyo Bay.

② The Tama district with an area of 1,161 square kilometers bordering the western part of the "Ku" area and is divided administratively into cities, towns and villages.

③ Islands in the Western Pacific Ocean to the south of Tokyo Bay are administrated as "towns" and "villages".

The Bureau of Waterworks of the Tokyo Metropolitan Government is responsible for management and operation of water supply in the Ku area, most of the Tama district, and industrial-water supply in some parts of the Ku area.

The Bureau, as the Local Public Corporation is making great efforts to maintain the Tokyo Waterworks which composes the essential urban infrastructure for the maintenance of human life, health, and the efficiency of urban actvities through supplying potable water stably.

(Service Area)

The service area consists of the 23 Wards, the 22 cities and three towns in the Tama district. There are a total of 32 cities,towns and villages in the Tama district. In the past, waterworks in these municipalities was addministrated by each municipal authority respectively,however,population growth and other factors have boosted demand making it increasingly difficult for these authorities to cope. As a result, municipalities began to lag behind the 23 Wards in terms of the water supply pervasion ratio and the cost burden to consumers.

In 1971 the Tokyo Metropolitan Government developed a plan to integrate the 30 waterworks systems out of these municipalities into the Tokyo Waterworks, since 1973, 25 municipal waterworks systems have been integrated into the Tokyo system. The municipalities which have not been integrated are currently supplied wholesale water from the Tokyo Waterworks under water-sharing agreements.

(The Water Demand for Tokyo)

In order to meet the rapid increase of water demand in the service area, the Bureau has planned and implemented several expansion projects for many years. As a result, the present water supply capacity is 6.63 million cubic meters per day through 11 purification plants and about 19 thousand km of water mains. The capacity is just sufficient enough for the current demand of water. The annual supplied water for 1986 amounted to more than 1.7 billion cubic meters for 4.6 million customers of an 11 million population. The future water demand in Tokyo is estimated to be constantly increasing due to the improvement of living standards and the progressive urbanization of the Tama district which will reach approximately 6.9 million cubic meters per day in the year 2000.

(2) Service Activities

The Bureau maintains direct contacts with users through the 8 branch offices and the 25 service stations located in almost all of the 23 Wards. These service stations handle meter-reading and collection of water and sewage rates, as well as providing a variety of advisory services regarding water supply systems. In the Tama district, similar services are provided through offices operated by each municipality entrusted by the Bureau.

Water consumption is determined by meter-reading. As to most of consumers in the 23 Wards, the meters are read every four months and rates are levied every two months. In the case of larger consumers, the meters are read and rates levied on a monthly or bi-monthly basis, depending on the level of consumption. In the Tama district, meters are read on a bi-monthly basis and rates are levied at the same interval.

Water rates can be paid either through bank transfer or bank payment. The Bureau is promoting the use of the bank transfer system.

• Water Rates Collection and Classification (The Ward area)

(1986)

	Clasification	Number of services	Ratio
Monthly meter reading and collction	Consumers of more than 1,000 m^3 per month	10,558	% 0.3
Bi-monthly meter reading and collection	Consumers of more than 100 m^3 per month or those who use water pipes of 30mm or more	96,519	2.7
Semiannual meter reading and bi-monthly collection	Consumers other than above (mainly general households)	3,490,925	97.0
Total		3,598,002	100

• Water Rates table (per month)

(yen)

<table>
<tr><th rowspan="2">Diameter of service pipe</th><th rowspan="2">Basic Rate</th><th colspan="7">Volume Rates (per cubic meter)</th></tr>
<tr><th>1~ 10 m^3</th><th>11~ 20 m^3</th><th>21~ 30 m^3</th><th>31~ 100 m^3</th><th>101~ 200 m^3</th><th>201~ 1000 m^3</th><th>1000 m^3 or over</th></tr>
<tr><td>13mm</td><td>800</td><td rowspan="3">0</td><td rowspan="3">120</td><td rowspan="3">160</td><td rowspan="3">195</td><td rowspan="3">270</td><td rowspan="3">335</td><td rowspan="3">375</td></tr>
<tr><td>20mm</td><td>1,070</td></tr>
<tr><td>25mm</td><td>1,320</td></tr>
<tr><td>30mm</td><td>3,000</td><td colspan="4" rowspan="2">195</td><td rowspan="2">270</td><td rowspan="2">335</td><td rowspan="2">375</td></tr>
<tr><td>40mm</td><td>6,000</td></tr>
<tr><td>50mm</td><td>18,200</td><td colspan="6" rowspan="2">335</td><td rowspan="2">375</td></tr>
<tr><td>75mm</td><td>40,000</td></tr>
<tr><td>100mm</td><td>83,000</td><td colspan="7" rowspan="5">375</td></tr>
<tr><td>150mm</td><td>140,000</td></tr>
<tr><td>200mm</td><td>300,000</td></tr>
<tr><td>250mm</td><td>410,000</td></tr>
<tr><td>300mm or over</td><td>700,000</td></tr>
<tr><td>Public Baths</td><td>As for general users (but ¥6,000 for 50mm or over)</td><td rowspan="2">0</td><td colspan="6" rowspan="2">95</td></tr>
<tr><td>Joint Use</td><td>470</td></tr>
</table>

・Sewage Rates Table (per month)

(yen)

Usage	Basic	Volume Rates (per cubic meter)						
	0~ 10㎥	11~ 20㎥	21~ 50㎥	51~ 100㎥	101~ 200㎥	201~ 500㎥	501~ 1,000㎥	1001㎥ or over
General Use	480	100	135	160	185	225	260	295
Public Baths	240	24						
Joint Use	290	29						

Notes: 1. These rates have been available since May 1st,1984.
2. Demand charges are not imposed upon mother and child or goverment subsidized households.

(3) History of the charge collection related business in Tokyo

Water rates are the fundamental revenue for activities of the Waterworks financial management. Therefore, water and sewage charge collection systems have been improved in order to decrease the unpaid charge rates.

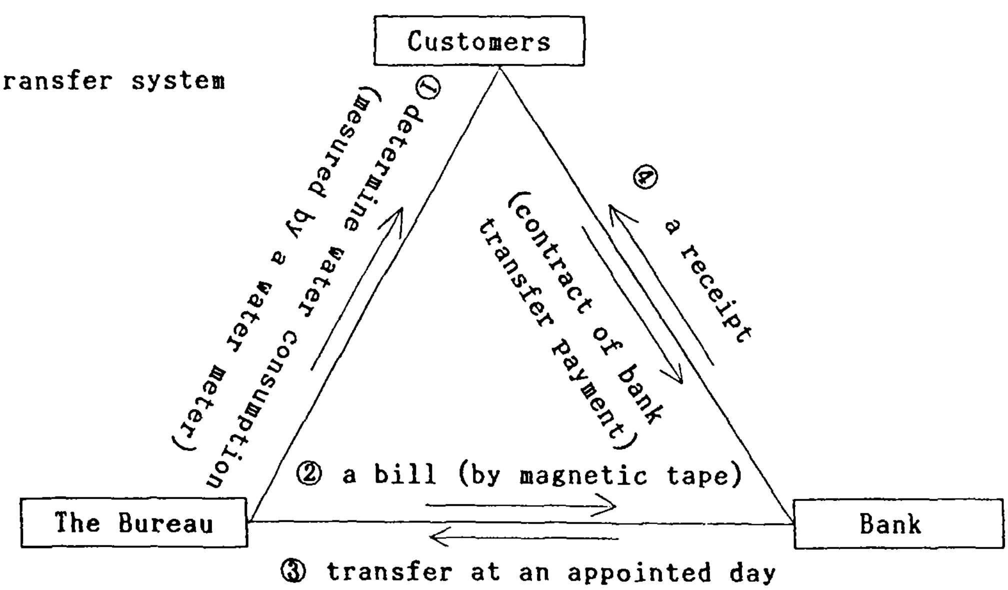
Water charges had been collected through a notification payment system dateing bank since 1898 when Tokyo started the modern water supply system. But customers had a poor sense of duty for payment in those days and the Bureau then adopted the direct charge collection system in 1933.

After World War Ⅱ, both banking system and computer systems developed rapidly. The Bureau adopted the bank transfer system in 1967,and abolished the direct charge collection system by collectors in 1974.

Nowadays,water charges can be paid either through bank transfer or bank payment. The Bureau is promoting the use of the bank transfer system.

Water charges were calculated by hand calculator at every service stations until 1962, when the Bureau adopted a computer system for the calculation of water charges by Batch Processing System at the computer center.

・The bank transfer system



Classfication of collection

(The wards area)

Way of collection	Ratio
Bank transfer	66.2
Notification payment	33.8
Total	100 %

2. Introduction of advanced computer system (on-line-real-time-processing system)

(1) The reason for the introduction

The Tokyo Waterworks Bureau has adopted a new computer system for water and sewage charge collection related business since December 1986. The system, "on-line-real-time-processing-system" can deal with various information concerning water and sewage customers in 32 service stations, which are on-line to the computer center, on a realtime basis.

Since 1962, the Bureau has introduced electronic computers into various works in order to realize further prompt and efficient works. For instance, water purification, construction designing, overall control of water from sources to taps, personnel management, financial management and so on.

As for the charge collection related business in paticular, computers have also been introduced as batch processing system that is directly related to the vast customers of 3.59 million, so we have to respond to any inquiries and applications from them promptly and accurately.

This system, however,had become unconvenient and troublesome due to the following reasons;

① The system produced vast amount of papers, such as meter reading books and slips, so it often interrupted quick responce to the inquiries and applications from consumers.

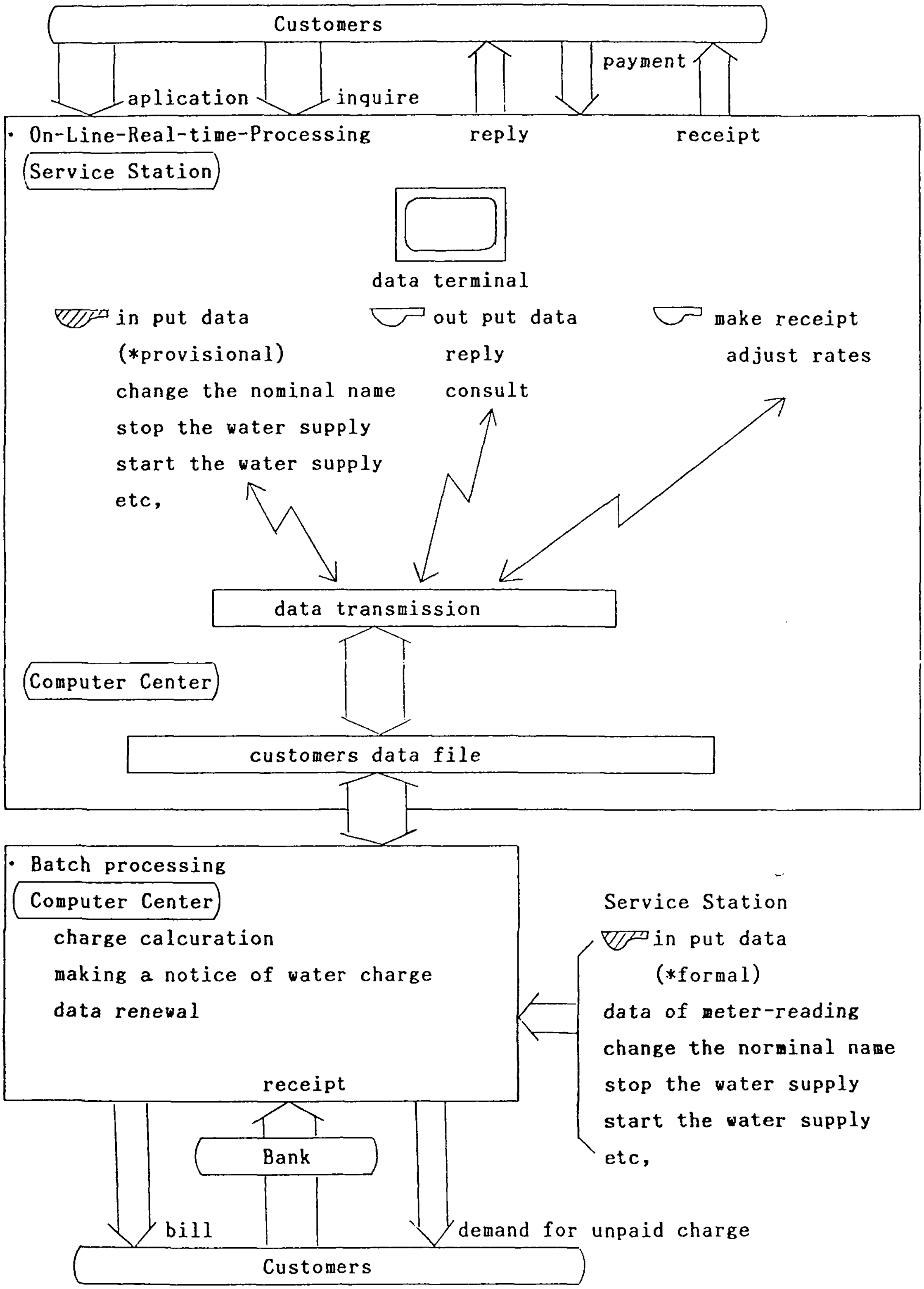
② The informations made by the system took a long time to reach each service station, so we couldn't access to the current condition of the consumer.

③ The inquiries or applications from the customers in other service station area couldn't be dealt with.

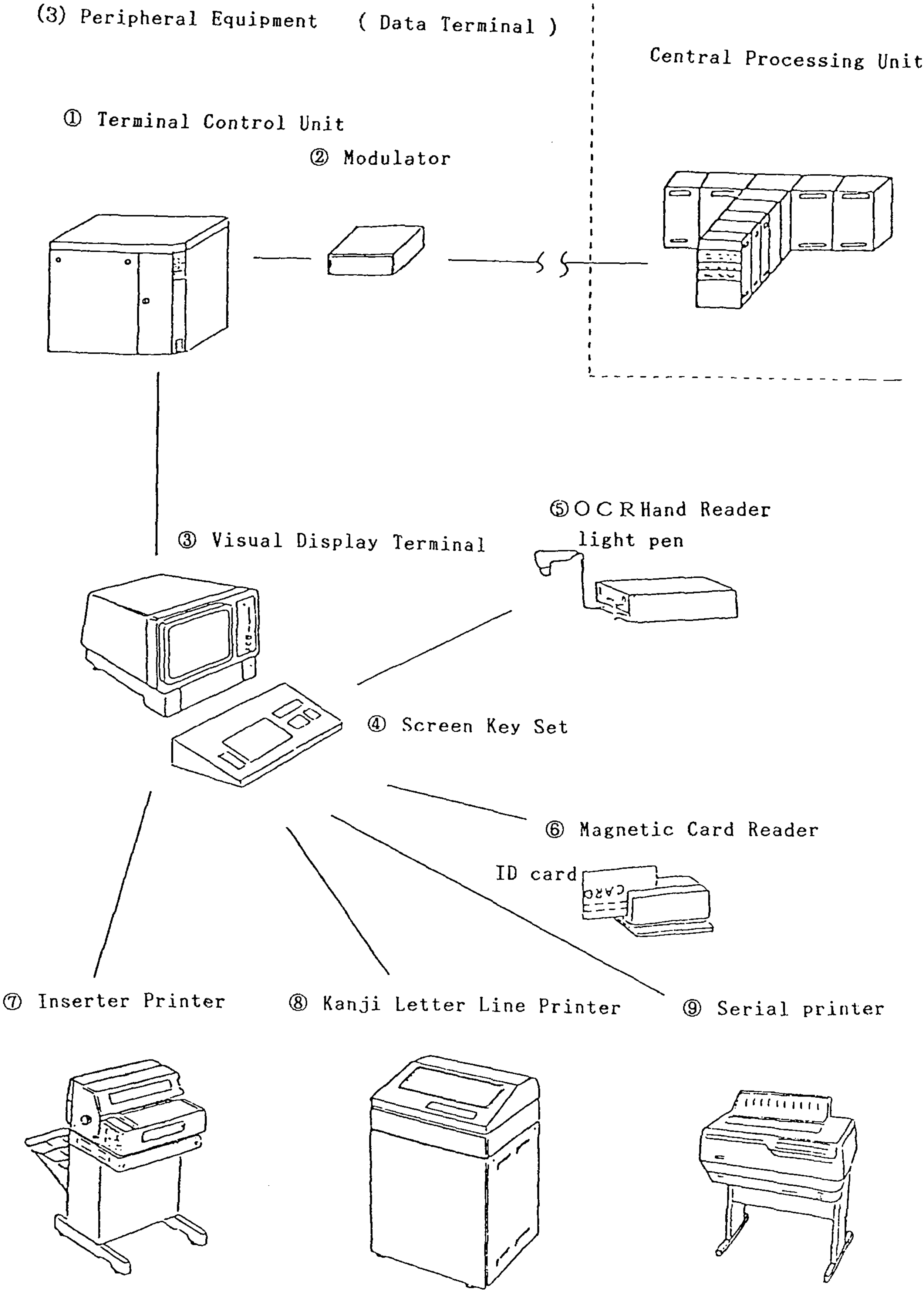
And it was inevitable for us to shorten the time of charge collection related business. Therefore,we introduced the new system equipped with the advanced software in the central computer and with visual display terminals in all service stations.

It becomes possible for us, by introducing this system, to make quick responces to any contact from any customer in any area. And the number of service stations and staffs can be reduced.

(2) On-Line-Real-Time-Processing-System



(3) Peripheral Equipment (Data Terminal)



② Explanation of Data Terminal

No.	N A M E	E X P L A N A T I O N
①	Modulator and Demodulator	modulate and demodulate the signal for transmission and reception use
②	Terminal Control Equipment	controls the Data Terminals, and transmits and receives data from the Computer Center
③	Visual Display Terminal	display the data from the Computer Center and in-put-data at the Service Station
④	Screen Key Set	in put data and transfer to the Computer Center
⑤	Optical character Hand Reader	reads the customers number on bills and other papers, automatically
⑥	Magnetic Card Reader	reads the Magnetic Card (Identification card) when the staff is doing the special work *mainly, money treatment
⑦	Inserter Printer	printing various slips
⑧	Kanji Letter Line Printer	printing various lists
⑨	Serial Printer	makes a receipt at the counter of Service Station

(4) Some notices of the new system

① Data protection

A. Protection of customers data

The Bureau instituted the" Electronic Data Protection Regulation " to protect customers privacy.

B. Electronic data processing through the on-line-system is processed by contract with The Public Utilities Computing Center (P.U.C.). The Bureau assigns the duties of data protection to the P.U.C. under the following conditions

a. prohibition of retrust

b. protection of customer data

c. prohibition of the use of data for another object

d. provision of staff of the Bureau to access and check to the PUC.

C. We protect customers privacy from the system as follows;

a. printing an abbreviated word, for receiver of social welfair allowance.

b. non-indication of the individual bank transfer number on a receipt by mail

② Computer Security

Computer Security means protection of the Hardware, Software, data, staff of computer system and facilites from to lose a property and life,to delay and disorder an economic and social activity, to invade privacy, to misuse a computer and computer crime by the mistake of data management, interference of data and destruction of computer systems.

In accordance with the development of the computer society,computer security has been become more and more important. The national administrative agencies and the Tokyo Metropolitan Goverment try every possible means.

The Bureau adopts the safest measure in operating the on-line system for charge collection related business.

③ Measures to obstruction

a. The computer center has two computers which compose of a dual system,main computer and sub computer. If one computer is stopped, another computer is operating.

b. Every service station has 5 ~ 8 data terminals, so even if one data terminal occured obstruction, another data terminal is operating.

c. Communications circuits which are connected to the central computer and data terminals at every service station have two circuits. Even if one circuit stopped, another circuit is available.

d. The computers are designed to shut-off automaticaly when the electric current is shut off or voltage is unstable,the computer center located in Shinjuku Urban Sub-center, transmits electricity from 3 different systems. Even if one system stopps supplying electricity another system can supply electricity continuously. So the on-line-system is seldom affected by an electrical accident.

④ Measures to safety and health of workers

By technical innovation centering micro-electronics, office automation is developed at every firm. Therefore the work of VDT (Video or Visual Display Terminals)has advanced widly and quickly in offices

Work of VDT consists of making documents,in-puting data,and performing information retrievals. Scholars of every country tackle the problems of medical sciences, human engineering, and management engineering. Also in Japan,all sections examine and research the problems for suitable answers.

This result is reflected in the improvements of hardware and utilization for the safety and health of workers. However, it will take time to resolve some of the problems of the VDT.

Safety and health of workers, who work with the VDT at the on-line-system is not that of long hours and continual work, therefore it is difficult to suppose that the workers will be injured. We will take all possible measures to realize safety and health for workers according to the Government guide-line.

Main measurs for the safety and health of workers

A. Enviromental control
   a. adequate lighting
   b. prevention of glare on the VDT
B. Operations management
   a. take an easy data terminal to operate
   b. set a desk and chair set for the staff to operate the data terminal in confortable position
   c. operate the VDT in shifts to preclude fatigue
C. Check the health
   a. take a medical examination
   b. hold a workshop gymnastics

In the end

Tokyo Metropolis is an area of about 2,000 ㎢, and about 12,000,000 residents. Of these areas, the Waterworks Bureau is responsible to supply water.

Today I explained the on-line-system which is used in the special wards, that serves a population of 8,350,000 (water supply receipents are about 3,600,000 units). In the near future, we must introduce the on-line-system in the Tama district. We have only one year experience with the on-line-system started last December,so we have several problems to be solved yet. For example, improvement of the computer software for ease of use by all workers.

We can't avoid the use of the computer in the modernization of Japan. The computer has now found its way into almost every company. Today its use spans from office areas and factory automation to home automation. The hardware has improved very well along with the software. Now, I think, in future, our people must make friends with computer to work toward improved human happiness.

MATERIAL MANAGEMENT ADOPTED IN TAIPEI WATER DEPARTMENT

by :

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ABSTRACT

The main research method adopted in this paper is to apply an inventory model to material management for satisfying the demand of materials and minimizing the cost of inventory. Firstly this paper describes the function of warehouse of Taipei Water Department (TWD) and determines various kinds of materials used in analysis. It also probes into the actual inventory operation of the warehouse, and uses a forecasting model to estimate demands for the future, and analyzes some cost parameters of inventory model, and try to get the information in the field of inventory. Finally this paper discusses the results and the conclusions of inventory management.

I. PREFACE

People gradually notice living quality and environment, and notice the health and safety of the public. Under these requirements, the quality of water has been paid more attention by them. TWD has adopted some available policy for promoting the quality, but this has caused a tremendous expenditure which forces TWD to use some methods for decreasing cost. This paper discusses from the field of management, especially from the study of inventory control, to achieve the goal of reducing inventory cost. The final purpose is to provide better and cheaper services for the residents of using water.

The construction of laying water pipe needs various kinds of materials which are large in quantity and different in type. It is impossible to get the best effective usage of these waterials, unless TWD uses scientific management method and system to handle the materials stored in the warehouse. Material Management, in the field of inventory management, is the theory and method for getting the purpose. From the viewpoint of inventory control, there are many models can be utilized, but which one is the best adapted for TWD that completely depends on the judgement in the characteristics of demand and the limits of inventory which are occurred in TWD.

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II WAREHOUSE FOR MATERIAL INVENTORY

The warehouse where the materials flow in and out has the function of controlling the amount of material. It is necessary for the materials to be ordered before shortage. They cann't be ordered while being still abundant. Such an effective management, it is impossible to result in the idleness of capital and the increase of cost.

The warehouse of TWD has some characteristics described as follows:

1. The warehouse orders the materials which are finished-products and can be provided for the usage of construction at any time. Therefore, it is a station of gathering and delivering.

2. The important mission of the warehouse is to match the demand of material for engineering construction and to purchase the materials under the condition at appropriate time, quality and price.

3. The warehouse has the responsibility for holding and checking the materials. This can keep their quality and prevent them from loss and break.

4. To take out the material from the warehouse, there is a rule which is first in-first out. This can keep the materials which are stored to be renewed.

The warehouse is the center in the whole process of material management shown in Fig. 1.

The accurate results acquired from forecasting and inventory model depends completely on the reliable data which can drive to the most appropriote model in getting significant information.

The effective control of inventory is critically based on two kinds of data. One is the data of material demand which is discussed in this paragraph, the other is the data of material cost which is shown in paragraph V.

The materials used in the construction of water pipe have many kinds of type and size. Some representative kinds of materials are chosen and listed in Table 1. For these materials, three years (from year 1983 to 1985) data of demand which are utilized for the operation of forecasting and inventory model have been collected in Table 2.

A important task of inventory operation is to account the actual amount of materials which flow in and out from the warehouse; especially the latter which is called material demand must be calculated accurately. In general speaking, the task of inventory operation maybe encounter in two limits. One is the cost for purchasing materials, the other is the lot for storing materials. However, there are no limits for the actual inventory operation in TWD. Thus, this gives a better condition for choosing inventory model.

The existence of inventory is due to be necessary for storing some materials which can match the flunctuation of demand for engineering construction. In the aspects of storing appropriate inventory level, There are maximum and minimum inventory levels which are described as follows.

a). minimum inventory level: monthly average demand.
b). maximum inventory level: three times of monthly average demand.

According to the levels described above, estimating level for year 1985 can be gotten from the demand of year 1984, it is in Table 3.

III FORECASTING SYSTEM

The following characterictics will be assumed for demand forecasting.

1. Forecasts are for demands of single-echelon inventories i.e. independent demands.

2. The time span covered by the forecast is middle term span (a few months to a year). This span is general enough for planning single-echelon inventory levels for a company whose demand is already determined.

3. The stable demands come from the construction of laying material pipe.

4. The forecast will be stated as a single value.

Approaches to demand forecasting may be classified in a variety of ways. As a basic of inventory, the statistical and intrinsic type holds greater promise as an effective aid to routine controlling. The study adopts this type of forecast for demand forecasting.

A forecasting approach requires a model which accepts imput data and generate forecasts. The input data typically includes a sequence of previously observed demand values, usually representing demands for equally spacious periods of time, which are referred to as a time series. By observing the demands (as a time series) used in this paper,the characteristics are identified as:

1. trend effect which is a linear

2. seasonal effect which is only once per year.

It is important to find a model which includes the characteristics observed from the past data of demand. In this paper, Winters method is used as a forecasting model whose formula is expressed as follows:

$$d_t = (a_1 + b_2 t)\, c_t + e_t \qquad (1)$$

Where d_t : demand for the period t.
t : time period
a_1 : the base signal, usually called the permanent component.
b_2 : a linear trend component
c_t : a multiplicative seasonal factor in period t.
e_t : the usual random error component.

The length of the season is L periods, and the seasonal factors are defined so that their sums are equal to the length of the season, that is

$$\sum_{t=1}^{L} C_t = L \qquad (2)$$

From equation 1, there are many coefficients which need be estimated.

$$a_{1e}(T) = \alpha d_T / C_{Te}(T-L) + (1-\alpha)[a_{1e}(T-1) + b_{2e}(T-1)] \quad (3)$$

Where $a_{1e}(T)$ the estimate of the permanent component for period T.

$0 < \alpha < 1$ is a smoothing constant.

T is any time period.

$$b_{2e}(T) = \beta[a_{1e}(T) - a_{1e}(T-1)] + (1-\beta) b_{2e}(T-1) \quad (4)$$

Where $b_{2e}(T)$ the estimate of the trend component for period T

$0 < \beta < 1$ is a smoothing constant.

$$C_{Te}(T) = \gamma d_T / a_{1e}(T) + (1-\gamma) C_{Te}(T-L) \quad (5)$$

Where $C_{Te}(T)$ the estimate of the seasonal factor for period T.

$0 < \gamma < 1$ is a smoothing constant.

These three smoothing constants, α, β and γ are specified by the user, or its optimum can be calculated. The optimum combination of smoothing constants are those values which result in a minimum forecast error sum of squares for the first n_1 ($< n$) periods which are length of time series to be used in model for initialization phase, n is the total periods used in the model, The last $n - n_1$ observations are used in forecast simulation.

The optimum (α, β, γ) appears, when

$$\sum_{i=1}^{n_1} (d_i - d_{ie})^2 \quad \text{is the minimum}$$

Where d_i is actual data in i-period
d_{ie} is forecasted data in i-period
α, β, γ change from 0.1 to 0.9 in step size 0.4
i is from 1 to n_1

Now, to forecast the observation by using the optimum value of α, β and γ in any future period $T+\tau$, compute

$$d_{(T+\tau)e}(T) = [a_{1e}(T) + b_{2e}(T)\tau] C_{(T+\tau)e}(T+\tau-L) \quad (6)$$

Where τ lead time

$C_{(T+\tau)e}(T+\tau+L)$ refers to forecast period $T+\tau$ for which seasonal factor was computed in period $T+\tau-L$, i.e. the previous season.

Heuristic algorithm has been devised to utilize the past data for initial parameter estimation i.e. $a_{1e}(0)$, $b_{2e}(0)$ and $C_{te}(0)$ for t=1,2,... ....,L. the trend component at the start of the first period is estimated by

$$b_{2e}(0) = (d_{me} - d_{1e}) / (m-1)L \quad (7)$$

Assume that the data for m seasons are available, let d_j, j=1,2,....m denote for average of the observations during the jth season.

The permanent component at the start of the first period is estimated by

$$a_{1e}(0) = d_{1a} - L/2 \times b_{2e}(0) \qquad (8)$$

Seasonal factors are computed for each time period t=1,2,....mL, as the ratio of the actual observation to the average seasonally adjusted value for that season, further adjusted by the trend; that is

$$C_{te} = d_t / \{d_{ia} - [(L+1)/2 - J] \times b_{2e}(0)\} \quad t = 1,2 \cdots L \qquad (9)$$

Where d_{ia} is the average for a season corresponding to the t index, and J is the position of period t within the season. Equation 9. will give the estimated value of the seasonal factor for each period. These should be averaged to produce a single estimate of the seasonal factor for each period within the season. This is accomplished

$$C_{ta} = 1/m \times \sum_{K=0}^{m-1} C_{(t+KL)} \quad t = 1, 2 \cdots\cdots L \qquad (10)$$

Finally, the seasonal factors should be normalized so that they add to L, this produces the initial estimates of the seasonal factors as:

$$C_{te}(0) = C_{ta} L / \sum_{t=1}^{L} C_{ta} \quad t = 1,2,\cdots\cdots L \qquad (11)$$

There are 36 observations that mean 36 periods of time series.

Other conditions used in this study are described below.

1. Optimum smoothing constants are calculated from the data. for α, β and γ, the lower limit is 0.1, the step size is 0.4 and the upper limit is 0.9.

2. The initial values of the model parameters are also estimated from the data.

3. Length of one season is divided into 12 equal periods (one year).

4. Forecast lead time is one month.

5. n is equal to 36, n_1 is equal to 24.

The whole procedure used for forecasting by Winters method has been programed in Fortran Language. The forecasted and actual demand of materials for year 1985 is listed in Table 4.

IV ANALYSIS OF COST PARAMETERS:

Inventory Model includes some cost parameters, such as ordering cost (set-up cost,) holding cost (carrying cost), unit cost (purchasing cost) and shortage cost (penalty cost). Inventory cost is a functional value of these cost parameters which will be estimated and discussed below.

1. Ordering Cost

Set-up cost which is independent of the amount of ordering is always a fixed cost, it includes a). the cost for the procedure of ordering. b). the cost for mo ing-in of material. c). the cost for checking material. From the viewpoint of simplification, the paper considers only the ordering cost which results from the salary for the workers related to the inventory. These workers are 10 persons. The average salary per month is 500$ and the average number of ordering material is 42 times, and every ordering commonly includes 10 kinds of materials, therefore the average ordering cost is about 12$ per time for each kind of material.

2. Unit Cost

Unit cost is dependent on the amount of ordering under this condition, it becomes an important element in the inventory model. Table 5 collects the unit cost of each kind of material.

3. Holding Cost

The holding cost represents the cost of holding inventory in stock, and it directly increase with the level of inventory. It is divided into four categories (1) capital cost (2) storage cost (3) service cost (4) risk cost. Total holding cost is about 14% to 43% of inventory value, the average is 29% . The unit of material has two kinds, kind A named "piece" and kind B named "meter", so the holding cost is also divided into two parts to calculate. This paper adopts the minimum inventory amount of materials to calculate the cost of materials, and the interest for the cost is counted by 1.5% per month. The value of materials is 268,270$ for kind A materials and the value of inventory is 4,024$, The value of materials is 94,340$ for kind B materials and the vlaue of inventory is 1,415$. The total holding cost for kind A materials is 1167$, and for kind B materials is 410$. The unit cost of material no.1 is used as the basis for kind A materials, and the unit cost of material no.5 is used as the basis for kind B materials. So the value ratio and the equivalent minimum inventory level for each kind of materials can be obtained, seeing Table 6.

The holding cost for material no.1 is equal to the total holding cost for kind A material divided by the sum of equivalent minimum inventory level for each of kind A materials, it is 0.0225$. The holdign cost for material no.5 is equal to the total holding cost for kind B materials divided by the sum of equivalent minimum inventory level for each of kind B materials, it is 0.0025$. The holding cost for the other kind of material is listed in Table 6.

4. Shortage Cost

No shortage cost occurrs for TWD, because people will not cease the desire to use water for the sake of TWD being temporarily short of materials. Therefore, the shortage will not result in any loss for TWD.

V. INVENTORY MODEL

There are large varieties of inventory model whose methods of solutions range from the use of simple calculous to sophisticated application of mathematical and dynamic programming respectively, depending upon as to whether the demand of materials is deterministic or probabilistic.

The demand, known with certainty, may vary from one period to the next. This causes a deterministic dynamic model adoptabe to the present study.

The storage capacity is infinite, because the warehouse is rather large. At the same condition, there is no restraint among each kind of materials which is treated as individual one.

Also, the inventory level has been reviewed periodically, because ordering programme is also required to be reviewed periodically so as to meet the variable demand. The periodicity of one month has been considered appropriate because the time for ordering modified quantity of materials commensurate with changed inventory level has been taken to the coincident with the end of each time interval i.e. the end of every month.

The inventory level studyed in this paper is only the inventory level occurred in the warehouse. So this is a single eachelon inventory.

According to the above discussion, the inventory model can be called as "Single-item Single-echelon Periodic Review Dynamic Model".

The main purpose of inventory model is to get the answer for two problems followed.

1. When to order
2. How much to order

These two problems have only one goal,that is to minimige the total cost.

Dynamic model, adopted in this study, was developed by Wagner and Whitin. It is a quantative tool for analyzing the problems in which decisons have to be made sequentially over time. One way to recognize a situation which can be formulated as a dynamic programming problem is to notice that its basic structure is analogous to the basic features which characterize dynamic programming problem as follows:

1. The problem can be divided into stages(periods), i, with a policy decision required at each stage about the amount of ordering during each stage (Say Z_i), so as to meet the demand(say D_i) during the period.
2. Each stage i has a state (say X_i) associated with it.
3. The effect of the policy decision at each stage is to transform the current state into a state associated with the next stage X_{i+1} is a function of (X_i, Z_i, D_i) or mathermatically $X_{i+1}=F(X_i, Z_i, D_i)$.
4. The solution procedure begins by finding the optimal policy for each state of the last stage.
5. Using this recursive relationship, the solution procedure moves backward stage by stage, and finds the optimal policy for each state under the stage.

A simple diagram can depict the development of the dynamic programming model, as shown in Fig. 2.

For stage i, 2 elements flow in and 2 elements flow out. They can be expressed in the following formula.

$$X_{i+1} = X_i + Z_i - D_i \qquad (12)$$

Where, X_{i+1} is the inventory level left at end of ith period which carried to (i+1)th period. X_i is the inventory level at beginning of ith period. The important point that is the holding cost is proportional to X_{i+1}, which is charged at the end of the time period. A purchasing cost based on unit cost C is considered to be charged at the beginning of the time period. However, the set-up cost K is considered to be charged at the beginning of the time period for obvious reasons.

Thus, if $B_i(X_i, Z_i)$ indicates the total cost incurred in period i, given the entering inveatory X_i, and the quantity Z_i ordered then

$$B_i(X_i, Z_i) = \begin{cases} K + CZ_i + H\times(X_i + Z_i - D_i) & \text{if } Z_i > 0 \\ H\times(X_i - D_i) & \text{if } Z_i = 0 \end{cases} \qquad (13)$$

Notice that K is equal to zero when Z_i is equal to zero. If $A_i(X_i, Z_i)$ denotes the total cost of the best overall policy from the beginning of period i to the end of the planning horizon, given that the inventory level entering period i is X_i and Z_i is chosen to be produced, then, the corresponding minimum value of $A_i(X_i, Z_i)$, subject to the constraints that $Z_i \geqslant 0$ and that the requirements for the periods are met, can be expressed mathematically as.

$$A_{im}(X_i) = \text{minimum } B_i(X_i, Z_i) + A_{(i+1)m}(X_i + Z_i - D_i)$$

$$\text{subject to constraints} \quad Z_{i+1} \geqslant 0 \qquad (14)$$
$$Z_i \geqslant D_i - X_i$$
$$\text{for } i = 1, 2 \cdots\cdots n \qquad (n = 12)$$

Where $A_{im}(X_i)$ denotes the corresponding minimum value of $A_i(X_i, Z_i)$ and such $A_{(n+1)_m}(\cdot)$ is defined to be zero.

The development of deterministic dynamic model requires the use of the dynamic programming technique which warrants the manipulation of a great amount of information. Now, a computer Fortran program which can be used in the model has to be developed to get the answer to the two main inventory problems that are when to order and how much to order.

Some input data for the deterministic model are listed as follows.
1. a fixed number of time period T, equal to 13.
2. ordering cost K
3. unit cost C
4. holding cost H
5. demand for each period

Some output data for the deterministic modes are listed as follows and shown in Table 7.
1. amount of ordering
2. inventory level and cumulative inventory level.
3. inventory cost and cumulative inventory cost.

VI CONCLUSIONS

Some conclusions can be drawn from the inventory completion of the dynamic inventory model.

1. The amount of demand doesn't exceed the maximum inventory level i.e. the maximum inventory level is a safety inventory level.
2. For the purpose of minimizing inventory level and cost, it is suitable to order every month for the materials whose unit cost is higher, and to adopt the policy of frequent ordering for the materials whose holding cost is higher.
3. The inventories for each kind of materials shown in Table 7 haven't the shortage occurred, this is a characteristic of the inventory model adopted in this paper.
4. The difference between the ordering amount and the demand amount is not large for the materials whose unit cost is higher. Thus the result not only satisfies the demand but decreases the inventory level. On the contrary, the difference is large for the materials whose unit cost is lower. But, the result may result in the decrease of ordering number, this also can achieve the goal of minimizing inventory cost.

Inventory control is an important step for material management, it matches the demand as well as decreases the inventory cost. The purpose of this paper is to provide an available direction for TWD in the field of material management which, described above, is not a negligible task for TWD. Inventory control has two functions for TWD. One is to decrease the total cost for itself, the other is to promote the quality of service for the public. As a general rule, it is of great advantage to TWD that the employers engage in the more profound researches in the field of management.

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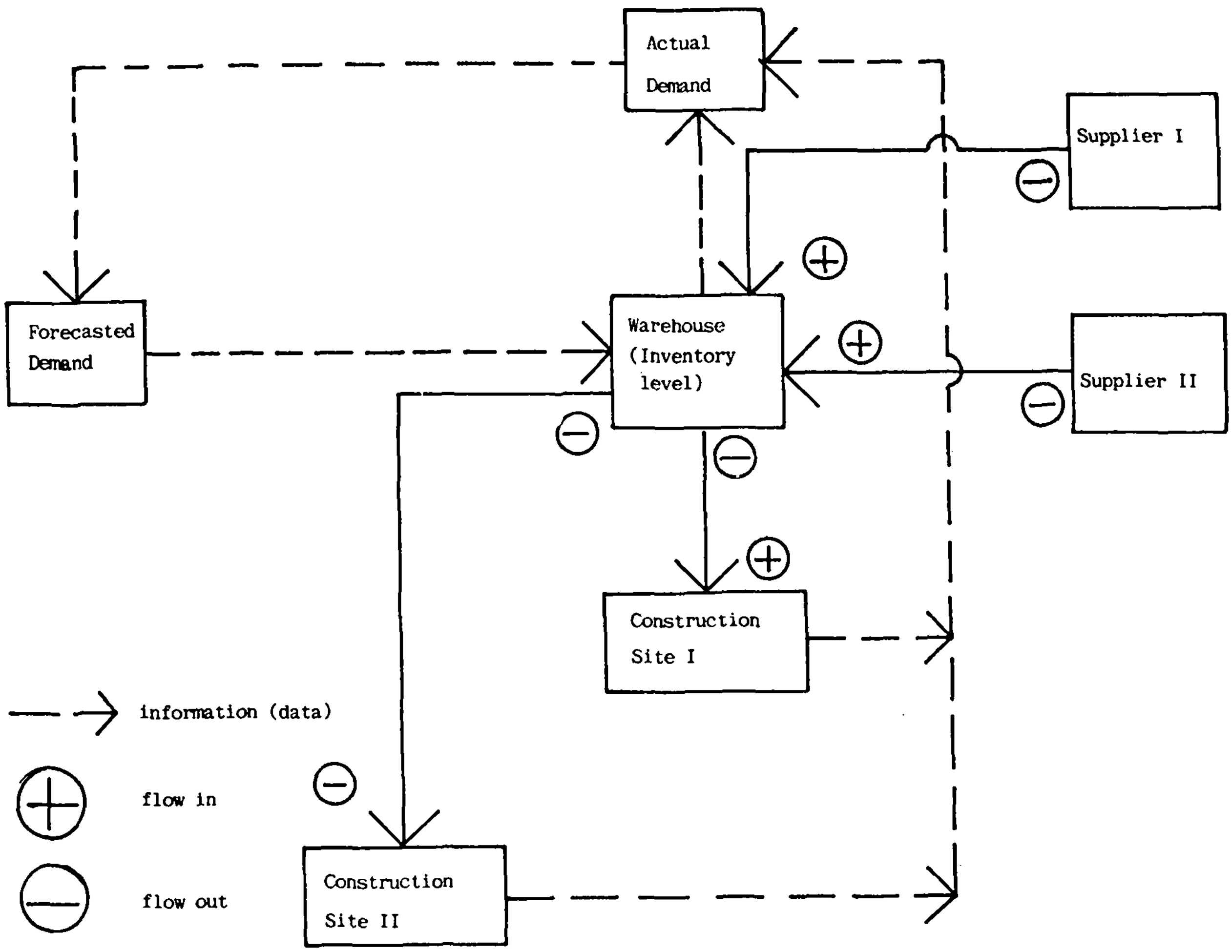

Fig. 1 Simplified Forecast-Demand-Inventory System

Table 1 Material Type and Size[1]

Material number	1	2	3	4	5	6	7	8	9
Material type	expansion union	corpation cock	water guage	water guage	PVC	PB	PVC	DIP	DIP collar
Size	13–40mm	13–40mm	13–20mm	25–40mm	13–50mm	13–50mm	75–100mm	100–250mm	75–250mm

1 TWD's Rules for Material Management

Table 2 Actual Material Demand (from year 1983 to year 1985)[2]

material number	month / year	1	2	3	4	5	6	7	8	9	10	11	12
1	'83	5,300	3,795	3,981	3,820	3,327	5,282	5,484	5,312	6,357	4,336	4,092	5,115
	'84	6,434	2,097	4,695	5,282	3,955	3,220	4,918	5,205	3,663	5,280	5,170	6,488
	'85	8,417	6,941	5,105	4,007	4,763	3,731	4,089	4,029	3,804	3,554	2,508	4,710
2	'83	1,134	816	1,212	1,723	1,669	926	1,777	1,259	1,239	831	1,395	1,946
	'84	1,277	1,103	1,375	1,939	2,016	1,777	1,777	1,214	1,677	796	2,414	2,799
	'85	1,723	1,015	1,803	1,546	2,080	1,713	1,642	1,188	1,830	548	1,795	1,578
3	'83	3,927	5,495	7,958	6,857	7,696	6,490	7,043	7,327	7,574	5,825	7,214	4,679
	'84	6,360	2,636	2,188	8,539	8,827	4,189	13,605	7,018	6,904	6,310	6,856	5,469
	'85	7,883	4,564	1,557	1,750	8,465	3,857	2,808	7,045	3,086	5,179	4,461	4,082
4	'83	3,648	2,900	2,925	3,969	3,694	4,271	5,535	3,015	5,578	3,263	4,971	5,386
	'84	6,749	3,817	11,207	10,262	5,627	4,082	3,669	4,766	2,719	3,782	5,042	6,117
	'85	7,349	4,554	4,087	4,044	2,781	3,521	4,086	2,915	3,528	2,174	2,900	4,183
5	'83	9,125	5,929	6,634	8,425	9,766	7,304	13,944	8,629	8,877	3,784	9,468	8,513
	'84	7,989	4,232	7,451	7,112	7,769	7,799	9,683	8,577	9,344	5,256	10,453	9,306
	'85	9,276	4,980	8,780	9,088	10,590	15,605	9,239	7,658	7,599	5,702	10,530	10,248
6	'83	6,162	1,573	3,069	4,588	6,977	4,032	6,227	5,672	5,151	1,601	5,387	4,763
	'84	4,884	2,685	4,686	4,796	3,990	4,295	4,299	3,149	6,632	2,211	5,495	6,203
	'85	5,895	4,208	4,990	2,831	4,766	4,365	3,209	2,936	3,744	1,897	2,916	4,288
7	'83	2,048	2,480	1,711	3,551	2,382	2,265	2,600	2,059	2,656	999	2,884	3,119
	'84	2,520	1,126	2,075	1,519	2,704	2,352	2,357	1,954	4,407	1,757	2,374	3,237
	'85	3,130	1,464	2,012	1,517	2,358	2,841	2,559	886	1,612	1,410	2,330	2,035
8	'83	5,154	2,043	4,344	4,705	5,343	4,279	4,339	3,675	2,690	1,475	4,708	4,203
	'84	2,654	3,644	6,962	6,865	4,123	4,198	5,069	6,672	6,307	4,584	7,066	5,341
	'85	4,753	2,335	12,137	5,255	5,568	10,704	7,872	6,369	6,034	2,200	5,051	9,602
9	'83	223	161	253	265	353	364	224	80	166	571	268	299
	'84	222	142	310	252	184	237	588	149	353	326	401	342
	'85	455	241	372	239	222	589	199	285	472	121	336	468

2 TWD's Mouthly Statistical Lists for Material from year 1983 to year 1985
unit for material no. 1, 2, 3, 4, and 9 : piece
unit for material no. 5, 6, 7 and 8 : meter

Table 3 Maximum and Minimum Inventory Level of Materials (year 1985)

Material number	1	2	3	4	5	6	7	8	9
Minimum inventory level	4,700	1,680	6,575	5,653	7,914	4,444	2,365	5,290	292
Maximum inventory level	14,100	5,040	19,725	16,959	23,742	13,332	7,095	15,870	876

Table 4 Forecasted and Actual Demand of Materials for year 1985

No.	M	1	2	3	4	5	6	7	8	9	10	11	12
1	F	7,712	4,012	5,323	6,347	4,416	4,039	4,325	5,001	4,974	5,992	5,300	6,821
	A	8,417	6,941	5,105	4,007	4,763	3,731	4,089	4,029	3,804	3,554	2,508	4,710
	E	-705	-2,929	218	2,340	-347	308	236	972	1,170	2,438	2,792	2,111
2	F	1,425	1,376	1,408	2,013	2,276	2,136	1,794	1,101	1,935	810	2,857	3,015
	A	1,723	1,015	1,803	1,546	2,080	1,713	1,642	1,188	1,830	548	1,795	1,578
	E	-298	361	-323	467	+196	+423	+152	-87	105	262	1,062	1,437
3	F	6,630	3,817	4,314	6,179	8,329	4,011	8,003	7,055	7,014	6,400	6,217	6,012
	A	7,883	4,564	1,557	1,750	8,465	3,857	2,808	7,045	3,086	5,179	4,461	4,082
	E	-1,253	-747	+2,757	4,429	-136	154	5,195	10	3,928	1,221	1,756	1,930
4	F	7,311	4,328	6,203	6,107	6,083	3,488	3,972	4,113	2,929	3,812	5,032	5,979
	A	7,349	4,554	4,087	4,044	2,781	3,521	4,086	2,915	3,528	2,174	2,900	4,183
	E	-38	-226	2,116	2,063	3,302	-33	-114	1,198	-599	1,638	2,132	1,796
5	F	7,022	3,225	8,279	7,836	8,678	8,789	7,923	8,341	9,617	6,133	10,938	9,924
	A	9,276	4,980	8,780	9,088	10,590	15,605	9,238	7,658	7,599	5,702	10,530	10,248
	E	-2,254	-1,755	-501	-1,252	1,912	-6,816	-1,315	683	2,018	431	408	-324
6	F	5,257	3,426	5,117	4,989	5,423	4,435	2,829	2,058	5,712	2,819	5,587	5,938
	A	5,895	4,208	4,990	2,831	4,766	4,365	3,209	2,936	3,744	1,897	2,916	4,288
	E	-638	-782	127	2,158	657	70	-380	-878	1,968	922	2,671	1,650
7	F	3,057	1,588	2,379	2,356	2,569	2,624	2,236	1,814	3,562	1,869	2,068	2,873
	A	3,130	1,464	2,012	1,517	2,358	2,841	2,559	886	1,612	1,410	2,330	2,035
	E	-73	124	367	8,839	211	-217	323	928	1,950	459	-262	838
8	F	3,934	4,136	8,725	7,321	4,478	4,036	6,183	7,681	7,314	6,287	9,781	6,537
	A	4,753	2,335	12,137	5,255	5,568	10,704	7,872	6,369	6,034	2,200	5,051	9,602
	E	-819	1,801	-3,412	3,066	-1,090	-6,668	-1,689	1,312	1,280	4,087	4,730	-3,065
9	F	216	139	340	243	143	250	316	212	383	346	381	432
	A	455	241	372	239	222	589	199	285	472	121	336	468
	E	-239	-102	-32	4	-79	-339	117	-73	-89	225	45	-36

F: Forecasted ; A: Actual ; E: Error

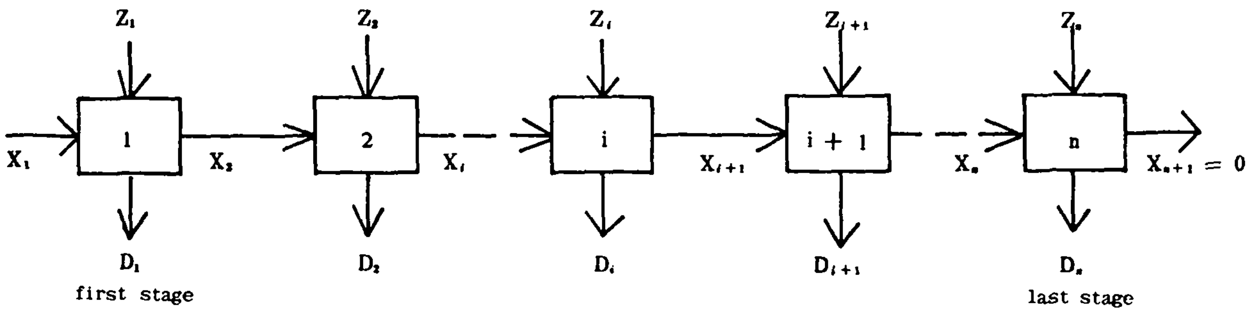

Fig. 2. Diagram for the Development of Dynamic Model

Table 5 Unit Cost

Material number	1	2	3	4	5	6	7	8	9
Unit	piece	piece	piece	piece	meter	meter	meter	meter	piece
Unit cost	206	291	573	929	24	38	113	595	872

Table 6 Holding Cost ($/piece/month, or $/meter/month)

Material number	1	2	3	4	5	6	7	8	9
Value ratio	1.0	1.4	2.8	4.5	1.0	1.6	4.7	24.8	4.2
Minimum inventory	4,700	1,680	6,575	5,653	7,914	4,444	2,365	5,290	292
Equivalent Minimum inventory	4,700	2,352	18,410	25,439	7,914	7,110	11,116	131,192	1,226
Holding cost	0.9	1.2	2.5	4.0	0.1	0.2	0.5	2.6	3.7

Table 7 Results of Dynamic Inventory Model

m. No.	mon	ordering amount	demand	inventory	cumulative inventory	current inventory cost ($)	cumulative inventory cost ($)
1	1	8,460	8,417	43	43	43,582	43,582
	2	6,947	6,941	6	49	35,789	79,371
	3	5,056	5,105	0	0	26,050	105,421
	4	4,211	4,007	204	204	21,703	127,124
	5	4,789	4,763	26	230	24,680	151,805
	6	3,856	3,731	125	355	19,878	171,683
	7	3,734	4,089	0	0	19,247	190,925
	8	4,931	4,029	902	902	25,427	216,352
	9	4,326	3,804	522	1,424	22,323	238,675
	10	4,638	3,554	1,084	2,508	23,954	262,629
	11	0	2,508	0	0	0	262,729
	12	4,710	4,710	0	0	24,268	186,897
2	1	1,835	1,723	112	112	13,365	13,365
	2	903	1,015	0	0	6,581	19,946
	3	1,836	1,803	33	33	13,370	33,316
	4	1,589	1,546	43	76	11,574	44,890
	5	2,183	2,080	103	179	15,899	60,789
	6	1,765	1,713	52	231	12,859	73,648
	7	1,712	1,642	70	301	12,464	86,112
	8	1,257	1,188	69	370	9,168	95,279
	9	2,008	1,830	178	548	14,637	109,916
	10	0	548	0	0	0	109,916
	11	1,863	1,795	68	68	13,567	123,483
	12	1,510	1,578	0	0	10,997	134,480
3	1	8,175	7,883	292	292	117,137	117,137
	2	4,589	4,564	35	327	65,770	182,907
	3	1,230	1,557	0	0	17,632	200,538
	4	1,863	1,750	113	113	26,706	227,245
	5	8,573	8,465	108	221	122,834	350,079
	6	4,001	3,857	144	365	57,349	407,428
	7	2,443	2,808	0	0	35,008	442,436
	8	7,314	7,045	269	269	104,802	547,238
	9	2,817	3,086	0	0	40,365	587,603
	10	5,250	5,179	71	71	75,223	662,826
	11	4,687	4,461	226	297	67,172	729,997
	12	3,785	4,082	0	0	54,232	784,229

4	1	7,383	7,349	34	34	171,485	171,485
	2	4,520	4,554	0	0	104,989	276,474
	3	4,099	4,087	12	12	75,212	371,687
	4	4,065	4,044	21	33	74,425	466,112
	5	2,748	2,781	0	0	63,834	529,946
	6	3,547	3,521	26	26	82,394	612,340
	7	4,114	4,086	28	54	95,565	707,904
	8	2,861	2,915	0	0	66,459	774,363
	9	3,541	3,528	13	13	82,253	856,616
	10	2,161	2,174	0	0	50,189	906,805
	11	2,925	2,900	25	25	67,948	947,753
	12	4,158	4,183	0	0	96,581	1,071,334
5	1	10,523	9,276	1,247	1,247	6,329	6,329
	2	7,226	4,980	2,136	3,383	4,290	10,619
	3	10,013	8,780	1,233	4,616	6,031	16,650
	4	4,472	9,008	0	0	2,695	19,345
	5	11,760	10,590	1,170	1,170	7,071	26,416
	6	17,289	15,605	1,684	2,854	10,392	36,808
	7	6,384	9,238	0	0	3,842	40,651
	8	9,821	7,658	2,163	2,163	5,910	46,561
	9	11,138	7,599	3,539	5,702	6,709	53,270
	10	0	5,702	0	0	0	53,270
	11	13,512	10,530	2,982	2,982	8,126	61,396
	12	7,266	10,248	0	0	4,371	65,768
6	1	7,111	5,895	1,216	1,216	6,773	6,773
	2	5,124	4,208	916	2,132	4,890	11,664
	3	5,689	4,990	699	2,831	5,431	17,094
	4	0	2,831	0	0	5,431	22,525
	5	5,689	4,766	923	923	5,421	27,946
	6	5,412	4,365	1,047	1,970	5,163	33,109
	7	4,175	3,209	966	2,936	3,993	37,102
	8	0	2,936	0	0	0	37,102
	9	5,641	3,744	1,897	1,897	5,380	42,482
	10	0	1,897	0	0	0	42,482
	11	4,126	2,916	1,210	1,210	3,938	296,420
	12	3,078	4,288	0	0	2,936	49,356

7	1	4,080	3,130	950	960	11,550	11,550
	2	2,064	1,464	600	1,550	5,862	17,412
	3	1,979	2,012	0	1,517	5,622	23,033
	4	0	1,517	0	0	0	23,033
	5	2,632	2,358	274	274	7,451	30,484
	6	3,089	2,841	248	522	8,745	39,229
	7	2,923	2,559	364	886	8,280	47,509
	8	0	886	0	0	0	47,509
	9	2,127	1,612	515	515	6,027	53,537
	10	2,069	1,410	659	1,174	5,872	59,408
	11	3,191	2,330	861	2,035	9,052	68,460
	12	0	2,035	0	0	9,052	77,512
8	1	4,789	4,753	36	36	71,251	71,251
	2	2,512	2,335	177	213	37,392	108,642
	3	11,927	12,137	0	0	177,426	286,068
	4	5,411	5,255	156	156	80,511	366,579
	5	5,783	5,568	215	371	86,103	452,682
	6	10,333	10,704	0	0	153,715	606,397
	7	7,908	7,872	36	36	117,646	724,043
	8	6,512	6,369	143	179	96,890	820,932
	9	6,212	6,034	178	357	92,439	913,371
	10	1,843	2,200	0	0	27,427	940,798
	11	5,149	5,051	98	98	76,610	1,017,407
	12	9,504	9,602	0	0	141,384	1,158,791
9	1	483	455	28	28	10,544	10,544
	2	256	241	15	43	5,597	16,141
	3	389	372	17	60	8,498	24,638
	4	259	239	20	80	5,666	30,304
	5	264	222	42	122	5,778	36,082
	6	666	589	77	199	14,549	50,631
	7	0	199	0	0	0	50,631
	8	364	285	79	79	7,954	58,586
	9	514	472	42	121	11,228	69,814
	10	0	121	0	0	0	69,814
	11	392	336	56	56	8,563	78,377
	12	412	468	0	0	8,994	87,370

ADVANCING MEASURES FOR STABLE WATER SUPPLY – A CASE OF YOKOSUKA WATERWORKS

by :

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1. INTRODUCTION

Current service ratio of potable water supply in Japan is 93 percent and reaches 100 percent in Yokosuka City. Thus, the role of water supply is of vital importance for municipal life and industrial activities, necessitating provision of a higher degree of reliability.

When the present supply facilities and management are reviewed, there are found many aspects requiring improvement in securing stability in water supply and maintaining water quality. Upgrading the distribution system is directly related to the use of clients, being one of the most important themes in water services.

So far, the city administration has been implementing provisions for anti-seismic facilities and distribution blocks, renewal of pipelines and leakage prevention by providing basic pipeline maps of 1/500 scale and lists of isolating valves. Facility management has been performed through standardization of maintenance procedures by manuals. However, establishment of innovative measures is still to be implemented including development of advanced technology in order to provide ungraded tap water supply with stable quality, volume and pressures.

Introduced hereunder is the representative example being promoted by Yokosuka City Waterworks Bureau for advancement in reliable water supply. Table 1 shows summary of water service operations.

Table 1

Benefited Area	99.5 Km^2
Inhabitants Supplied	430,000
Service Ratio	99.9 %
Fee Charged Ratio	88 %
Average Daily Volume	210,000 m^3
Maximum Daily Volume	265,000 m^3
Resource Storage	342,900 m^3
No. of Distribution Ponds	27
No. of Pump Stations	19

as of April 1987

2. Distribution Block

The distribution pipe network has been divided into 5 blocks according to administrative boundaries and further divided into each reservoir network. However, because the size of blocks was so large and the piping in each block was so complicated, it was difficult to determine the exact condition of the pipeline, thus preventing efficient and economic maintenance and replacement planning.

To solve this problem, the following measures were taken

(1) to simplify the pipeline configuration

(2) to divide the network further into smaller blocks to increase the number of blocks (see Table 2)

(3) to classify pipelines according to sizes and functions (see Fig 1)

(4) to branch at two points to make a small block (to make a loop)

Division of the pipe network into smaller blocks has proved to be effective.

2.1 Division into small blocks

(1) Element to be considered

Topography, geography, roads, area characteristics and population were evaluated in order to determine the size and boundaries of these blocks. With these divisions, leveling of pressure, improvement of maintainability, and recognition of demand patterns were obtained.

(2) Size of block

(a) Population in a block ; about 3,000

(b) Head loss within a block ; less than 10 m

(c) Available supply head ; more than 15 m

(3) Other considerations

(a) Connections for a portable flow meter were installed at each branch point to small blocks, which could be used for leak detection when necessary.

(b) 60 blocks of the total of 186 were identified as requiring reduction of pressure.

2.2 Effect of making small blocks

(1) Routine maintenance of distribution network has become effective.

(a) Areas where the pressure can be reduced were clearly defined. This was useful for leakage prevention.

(b) Influence of valve operation upstream and downstream became definable thus enabling accurate control of maintenance work.

(c) Leakage detection was more effectivelly carried out.

(2) Pipeline improvements were more resonably planned,

(a) By determining hydraulic data (flow rate pressure, flow direction)

(b) Pipe sizes could be more economically selected and replaced.

(3) Emergency response is improved

(a) Influence of trouble in distribution system can be minimized.

(b) Counter measures can be reasonably planned based on reliable assessment.

In Yokosuka city, dividing stand in 1986 from the area which had a higher population concentration and has gradually spread all over the city, aiming at improvement of water supply service and of leakage prevention.

Table 2 Arrangement of Distribution Blocks

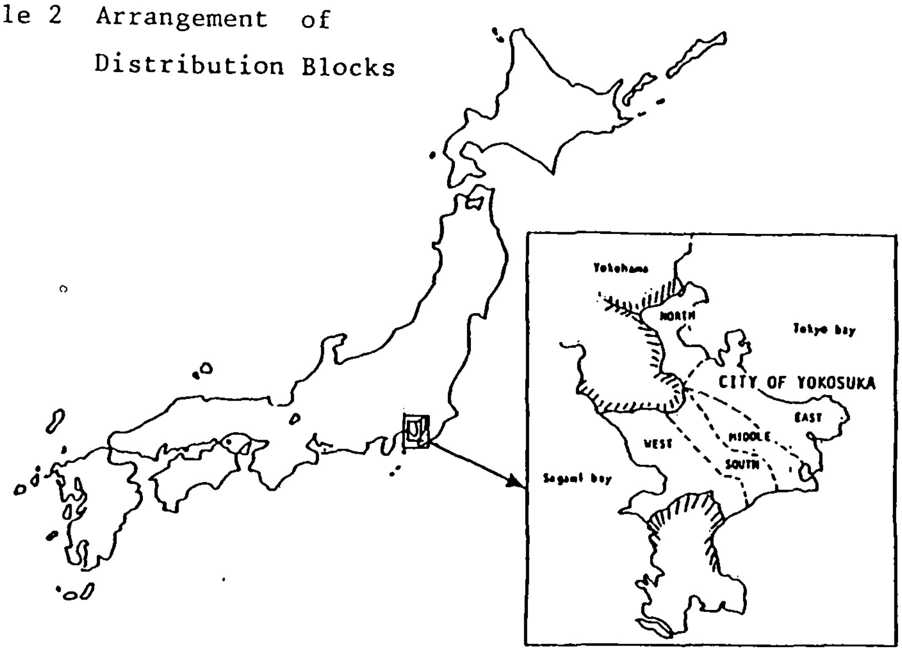
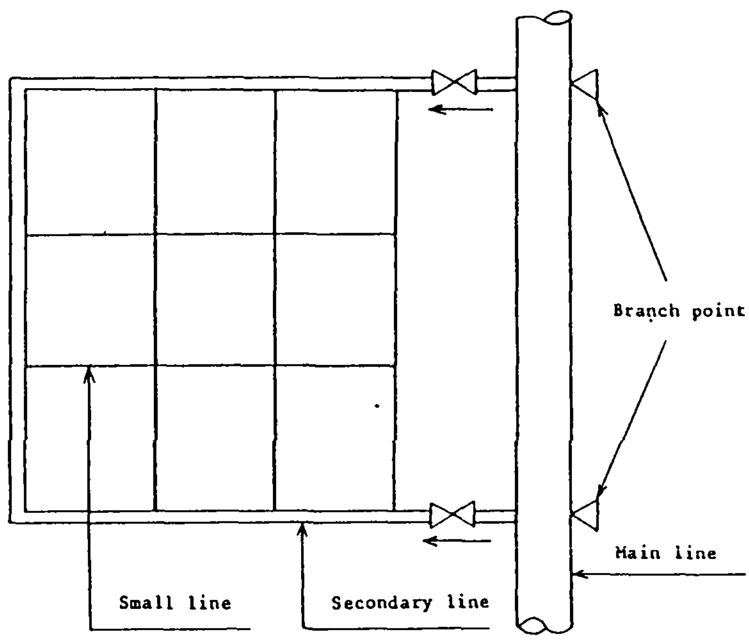


Table 2

Large block	Medium block (reservoir)	Small block
North	5	34
East	7	79
Middle	2	21
South	4	21
West	4	31
5	22	186

Fig 1 Distribution Block



3. Adoptation of Computerized Mapping System

It is said that 80 % of information required for the water supply business could be found in drawings. A majority of the facility is underground piping and the volume of piping drawings we must maintain are huge.

It is therefore of vital importance how promptly and exactly the necessary information from the drawing can be obtained.

In the city of Yokosuka, drawings which have a scale of one to 500 and which were based on an aerial survey have been used in the Waterworks Bureau.

In order to improve the efficiency of revisions and updating of drawings required at every pipeline replacement and maintenance, the adoptation of a computerized mapping system was determined.

3.1 Input data

Basic input data includes all the one to 500 piping drawings which had been completed, isolating valve list, pipeline maintenance history, graphic data from leakage/repair distribution map and as-built drawings, plus other attributal and character numerical data included in the these drawings.

Attributal data for pipelines includes pipe diameter, pipe material, year of completion and data for lining while data for each house, includes number of residents and existence of reservoirs.

3.2 Function of mapping system

Function of the system is divided into basic and applied functions. Basic function is the function to control databases while the applied function is the function to perform various applied calculations such as hydraulic analysis (See Fig 2).

(1) Basic function

(a) Mapping

- Basic function relating to maps including input, editing, retrieval and output of geo data.
- Statistics, word processing, graphic editing function

(b) Water service common function
Registration, retrieval and revision of master client list and drawings.

(c) Specialized function
Function to communicate with other computer systems and exchange such data as meter reading-invoicing system and water service management system.

(2) Applied function

(a) Generation of skeleton (network) drawing

(b) Hydraulic analysis

(c) Water ingredient analysis (color, residual chlorine etc)

(d) Leakage detection support

(e) Analysis of cause of leakage

These applied functions are used in combination with the basic functions so that extraction of maximum performance is contemplated. That is, data in the applied system are analysed together with geographical data and the results are displayed on the map.

3.3 Effect of computerized mapping

By adopting the computerized mapping system the integration of various attributal data with geographical data and the management using all such data at one terminal becomes possible. More specifically, the following results are expected,

(a) Time, efforts and frustration which was required for searching, storing drawings and other necessary documents can be almost completely saved.

(b) Any map or piping drawing can be quickly displayed on a screen for viewing and editing.

(c) Revision, addition and deletion can be effectively and accurately accomplished on display and the database is automatically revised at the same time, thus making constantly updated drawings available.

(d) Network simulation and other useful data processing can be performed and displayed in connection with geographic information.

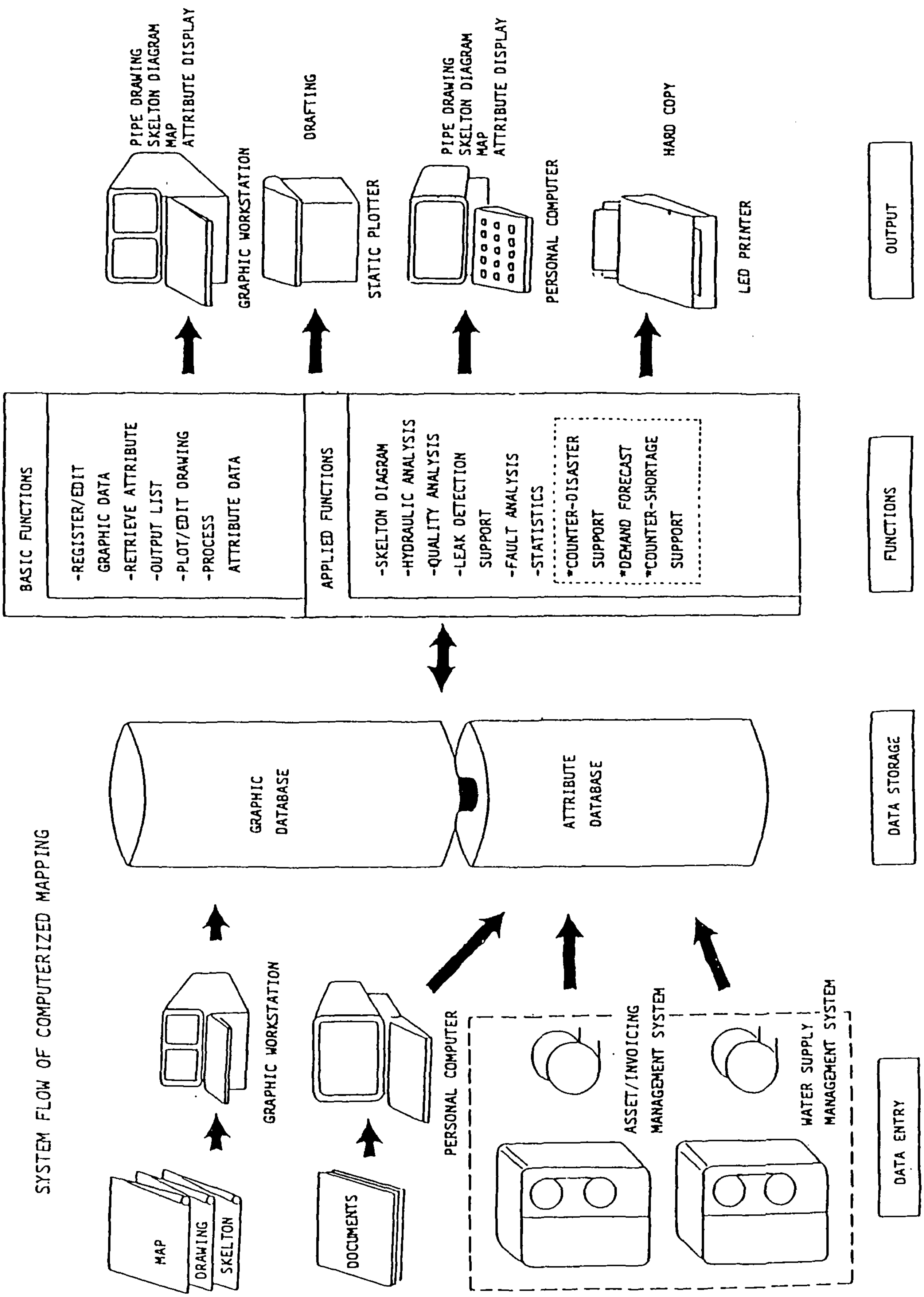


Fig 2 System Flow of COMPUTERIZED MAPPING

4. INTRODUCTION OF ADVANCE WATER SUPPLY MANAGEMENT SYSTEM

Water resources of Yokosuka city are taken from rivers several tens of kilometers away from the city center and the length of the three delivery mains from the resources is as long as 110 Km.

As the city is hilly there are nineteen booster pump stations and twenty seven reservoirs in the city. The optimum control of these individual facilities is essential for reliable water supply and efficient management.

Implementation of advanced water supply management system is now scheduled to start from next year in the Yokosuka Waterworks Burean, and is outlined as below,

4.1 Basic requirement for the system

(1) Water supply management under normal operating conditions

This system aims to provide optimum control of the total water supply system by integrating water intakes, treatment works, pump stations and the distribution system.

For example,

(a) Water allocation based on the forcast of demand, in distribution side

(b) Distribution control

(c) Optimum operation of pumps enabling the maximum use of the reservoir capacity and absorbing the variations of daily demand

(d) Effective operation of water intake and treatment works by leveling the throughput to the treatment works

(e) Establishment of a water quality control system which copes with the change of the intake water quality

(2) Quick and proper water supply control to cope with emergency conditions

(a) This system assisted by the Mapping System, is programmed to minimize the damage caused by disasters, power failures or facility failures.

(3) Improvement of maintenance management

(a) Improvement of maintenance by using the computerized integrated facility information

(b) Improvement of facility reliability and rationalization of the maintenance work

(4) Integration of the information from water resorces through to delivery and effective application of the information

(a) All the information from individual systems is integrated and processed to assist human judgement.

4.2 Concept of system functioning

System function is classified into four subfunctions (see Fig. 3) according to the control level (classified by the character of control) and control cycle (period of human decision for the control) as explained below.

(1) Function 1

(a) Control of equipment such as pumps, valves and water treatment works

(b) Monitoring and sampling process values such as water level, flow rate, water quality, power consumption

With this control and monitoring function, necessary human decisions are made in the terms of seconds or minutes.

This function covers water treatment works, pump stations, distribution reservoirs, delivery mains and local telemetering stations.

(2) Function 2

(a) Planning of water supply under normal conditions based on the short term water demand forecast

(b) Planning of water supply under emergency conditions based on the hydraulic analysis and emergency planning of treatment works operation

This function enables various statistical analysis of the data and simulations for the optimum operation of the system. With this planning function, necessary human decisious will be made within hours or days.

(3) Function 3

includes the following functions,

(a) Total management of the facility information, maintenance work and equipment fault history

(b) Statistical tendancy analysis of equipment faults

(c) Spare parts stock control

This function helps improve the reliability of the facility and optimization of maintenance work.

(4) Function 4

This function provides information necessary for a long term management program such as future planning for water demand / supply, rehabilitation of the facilities and budget planning.

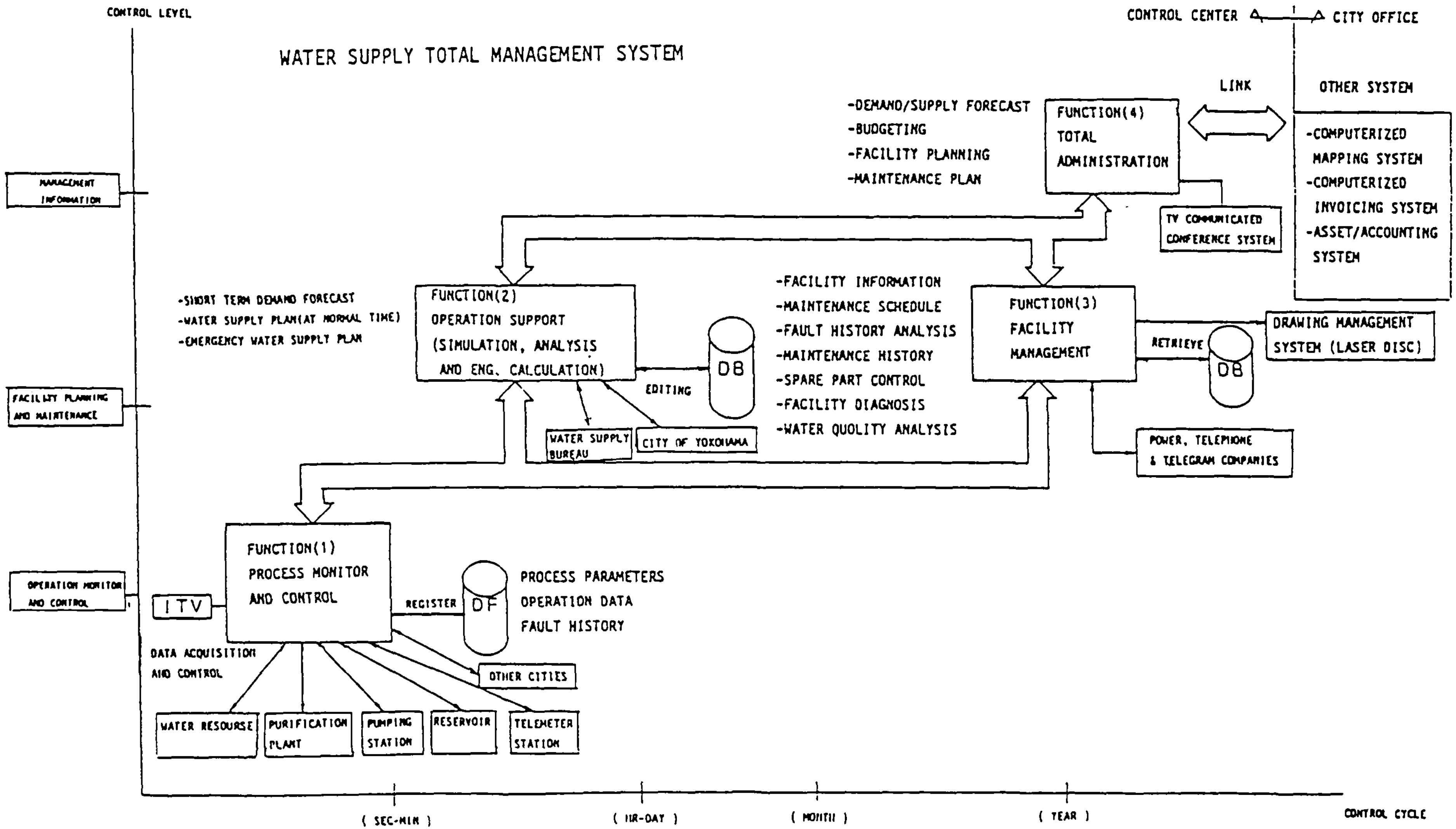


Fig 3 Water Supply Total Management System

5. CONCLUSION

The distribution block system, mapping system and advanced water supply management system currently all positively promoted by Yokosuka City are closely co-related and assist each other. Accordingly, promotion should proceed collectively by identifying the role of each system. On the other hand, respective systems are technical means to finally provide the most efficient water supply management.

Now, in Yokosuka City, some functions of the three systems are planned to be proeessed through an on-line real time basis. It is expected further advancement in reliable water supply will be promoted effectively.

MANAGEMENT OF DISTRIBUTION WATER MAINS DRAWINGS

by :

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1. INTRODUCTION

The Yokohama Waterworks, established in 1887, celebrated its 100th anniversary this year. Ever since we have successfully completed eight expansion projects including the laying of 7,600 km of water mains. These mains have been maintained and managed based on a water mains drawing management system, which was renovated in 1970.

Up to 1970, individual staff members were responsible for recording and maintenance of mains drawings and for operation of water distribution facilities including operation of valves for construction and maintenance. Hence systematic management of water mains was an extremely difficult task. In 1969, for example, a serious error was made of cross-connection of a drinking water main with an industrial water main. Next year another accident occurred - in Osaka this time - a gas explosion at a subway construction site due to a failure of a gas main. This accident could be prevented if the drawings management system of underground facilities had been complete.

To facilitate functional construction and management of water mains, which also aims at preventing the recurrence of such accidents, a new mains drawings management system was adopted in 1970-- a system based on 1:500-scale mains maps. This renovation project was completed in 1983.

The successful completion of this project has resulted in the attainment of comprehensive water mains information of both old and new water mains, and enabled the proper management of various distribution facilities.

2. SITUATION IN JAPAN

At present about 17,500 water supply utilities exist in Japan, most of which are small. There are only about 2,000 public water supply utilities each with more than 5,000 people served. Among them there are only a small number of water supply utilities which maintain a roster of accurate mains drawings. Among these water supply utilities, their mains drawings management systems vary rather widely.

Even in those water supply utilities, which had less need to maintain an advanced mains drawing system, the desire to establish such a system has become stronger due to the progressive congestion of underground facilities including water mains.

3. THE MAINS DRAWINGS MANAGEMENT SYSTEM

Japan has adopted a system of the 1:2,500-scale National Land Base Map System (1.5 km north-south and 2 km east-west) prepared in conformity with the National Land Survey Act.

Since 1971, for recording water mains information, we have been using the "Yokohama City Standard Mesh", a 250m X 250m square, dividing the National Land Base Map into 48 equal meshes.

Our system maintains project completion drawings and three different categories of mains maps, i.e., (a) basic mains maps, (b) district mains maps and (c) general mains maps. (see 3. (1)-(4)) These maps are closely related to each other and based on standard mesh numbers.

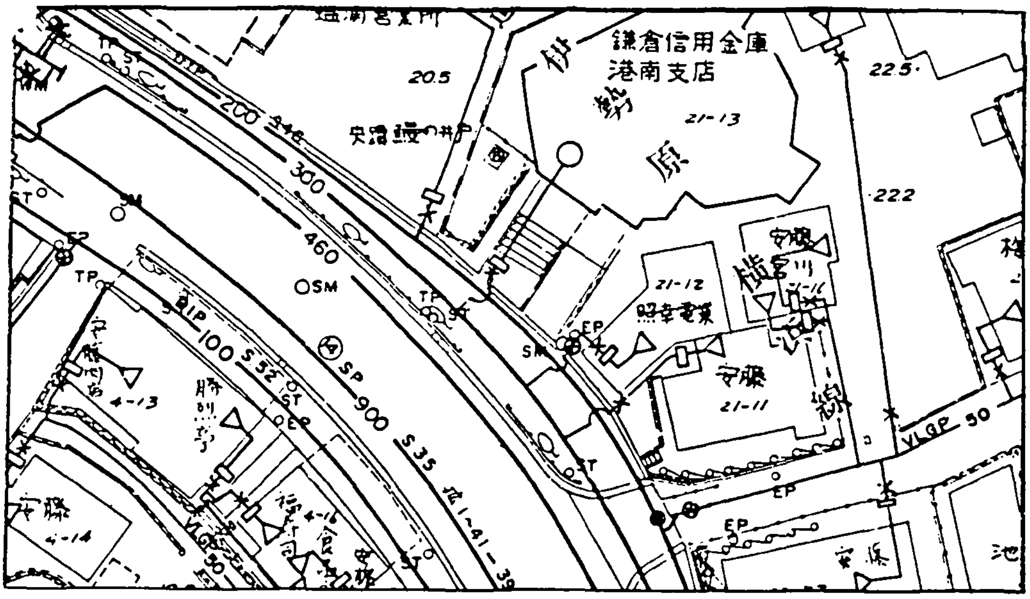
The details and usages of each category of maps are as follows:

(1) The basic mains map uses the largest scale (1:500-scale) in the system. This map is used as a basic reference giving almost all information about the city's water supply facilities. (see Fig. 1)

This map is used for checking the location of valves and mains for the maintenance and management of water distribution facilities, counting the number of households suffering from the breakdown of water supply, and preparing both water service management programs and facility improvement plans.

As illustrated in Fig. 2, the basic mains map is based on (A) the topographical map, (B) the distribution mains drawing (mains of 75 mm in diameter or larger), (C) the service connections drawing (mains of 50 mm in diameter or smaller), and

A Sample of 1:500-scale Map (Reduced Scale)



1/500-scale (Actual Scale)

Fig. 1 Basic Mains Map

(D) the industrial water mains drawing. The basic mains map is overlaid by these map and drawings A to D by tracing on a polyester base-film.

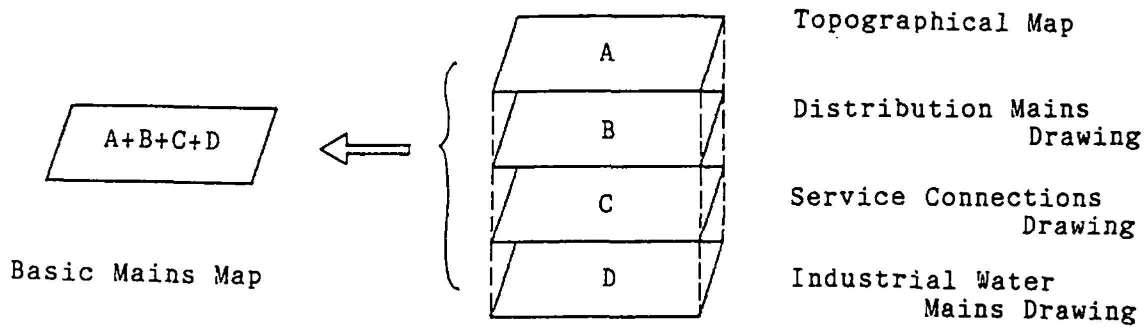


Fig. 2 Composition of Basic Pipeline Map

(2) The district mains map is prepared in two different scales of 1:2,500 and 1:5,000. The 1:2,500-scale district mains map, covering the large mains only, is based on the topographical map, the distribution mains drawing, and the industrial water mains drawing.

The 1:5,000-scale district mains maps, based on 1:2,500 maps, color-printed and bound in volumes, service disconnection during construction, are used mainly for designing a plan for checking the location of mains, and preparing the indexes of basic mains maps.

(3) The general mains map is prepared in two different scales of 1:10,000 and 1:30,000. Both types are a transcription of the 1:2,500-scale district mains map, with some omittions, and used for preparing various programs and as a general map giving various information or guidance.

(4) The completion drawings are prepared in various scales after the laying of water mains is completed. These drawings are used for revising the basic mains maps. Sometimes the completion drawings are used to indicate detailed information which can not be described on the basic mains maps. All the completion drawings are then transferred to micro-films, the originals being disposed of as a rule. The completion drawings and the basic mains maps are closely cross-referred to each other as the former carries the standard mesh numbers and the latter carries the pipe laying construction numbers.

Table 1 shows the relationship between maps and the standard mesh as well as the shape and number of maps prepared.

It took ten years(1974-83) to prepare the 1:500-scale basic mains maps, and the total cost is approximately 1,000 million yen.

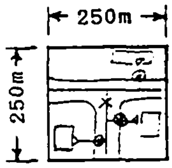
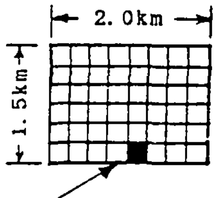
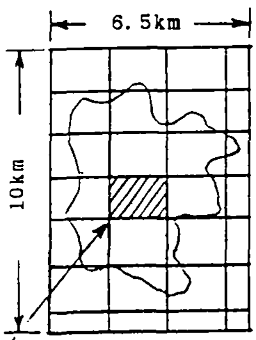
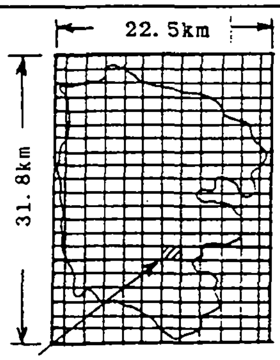
	MAP		The Relation-ship Between Map and Standard Mesh	Shape of Map	Number of Map	Term of Revision
	Name	Scale		width(mm) X length(mm)	(sheets)	
1	Basic Mains Map	1:500		500X500	7,000	every month
2	District Mains Map	1:2,500	 basic mains m. 250m x 250m	600X800	188	every year
		1:5,000	scale down from the 1:2,500 district m. map	300X400	188	
3	General Mains Map	1:10,000	 district m. map 1.5km X 2km	650X1,000	17	every two years
		1:30,000	 district m. map 1.5km X 2km	750X1,060	1	

Table 1 The Relationship between Maps and Standard Mesh

4. REVISION OF THE MAPS

It is indispensable for us to revise mains maps whenever the environment of water mains changes. The city's Water Distribution Department is staffed with personnel responsible for such revision works conducted centrally.

At the outset four staff members were responsible for preparation of mains drawings and management (including revisions) of maps, but gradually the staff size has expanded to eight due to the increasing need for such an activity.

The method of revision is as follows:

(1) The basic mains map, comprising the topographical map and the mains drawings is revised separately.

* The topographical map is revised by contracted drafting firms, when noticeable topographical changes take place as a result of housing land development or the like.
* The distribution mains drawing is reviced by contracted drafting firms every month based on the completion drawings.
* The water service connection drawing and the industrial water mains drawing are revised by the Department's staff whenever any significant changes take place.

(2) The district mains map (1:2,500-scale) is revised by contracted drafting firms every year based on the basic mains maps.

(3) The general mains map is revised based on the 1:2,500-scale district mains maps by contracted drafting firms every two years.

The average annual cost, incurred by the revision of maps amounts to about 53 million yen, which includes printing and binding costs, as well as expenditures for revising originals due to the contracted drafting firms.

5. HOW TO USE THE MAPS

The three categories of maps are closely inter related among them. Therefore, the completion drawings can easily be referred to by the mesh numbers indicated in all the categories of maps.

These maps are used in the following ways:

(1) The staff in charge of repairing damaged water mains take with them a set of the 1:5,000-scale district mains maps to the site of pipe bursting. If they can not find the alleged valves and pipes on the site, they get in touch with the office staff by radio. According to the standard mesh numbers printed on the maps, the office staff consult with the basic mains maps or the completion drawings in the office and then give their findings to the staff on the site.

(2) Taking advantage of the standard mesh numbers, the office staff can also send appropriate instructions to the site by radio.

(3) Communications are also possible with other branch offices by referring to the standard mesh numbers of these maps by telephone in response to their inquiries.

6. COMPUTER-CONTROLLED MAPPING SYSTEM

As an enormous volume of information on our system has been compiled mannually, our system has a problem, i.e., information on water mains can not easily be gathered quickly from any area of our city when needed.

Recently in Japan, a computer-controlled mapping system was developed and put into practical application for the management of mains drawings and information on water mains.

A computer-controlled mapping system gives us such outputs as topographical maps and mains drawings with additional data such as the types of pipe, pipe diameters and the dates of construction in relation to the drawings. It also builds up a data base, revises drawings, output data and analyzes statistics constructed from the input data of drawings and other data which are supporting, but not shown on the drawings. This system provides the data requested by users in an easy-to-understand way.

As illustrated in Fig. 3, the data on drawings are accumulated in the data base in layers as is the case of topographical maps and mains drawings. By doing this, the drawings can be displayed or revised individually on each layer.

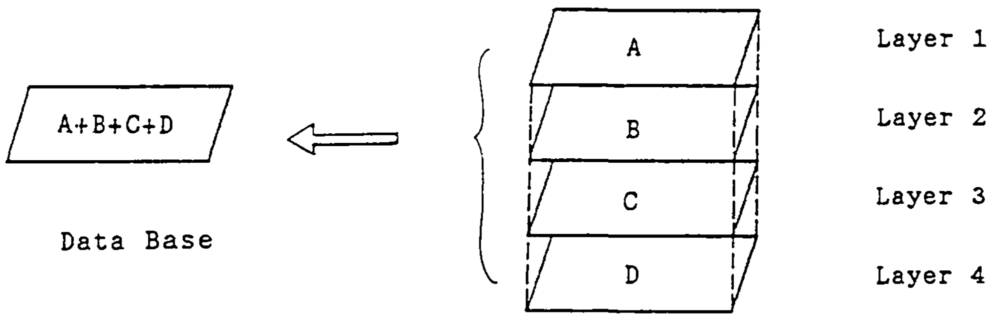


Fig. 3 Illustration of Each Layer

Fig. 4 shows a schematic of the computer-controlled mapping system.

For improving the level and speed of control over data on roads and underground structures, the Ministry of Construction has been studying a Road Control System utilizing the computer-controlled mapping technique since 1985 toward its completion scheduled for 1989. The Ministry requested road-occupying enterprises to submit the computer-processed 1:500-scale drawings of their facilities installed in the roads.

For this reason, we are also planning to introduce a computer-controlled mapping system. For this purpose, about 7,000 sheets of the 1:500-scale basic mains maps will need to be computer-processed, and new procedures will be required for application and authorization (by the Regional Construction Bureau) of road-occupying projects and facilities. It is estimated that about 800 million yen will be required for computer-processing of the basic mains maps alone.

Through the introduction of the computer-controlled mapping system, it will be possible to attain prompt access to

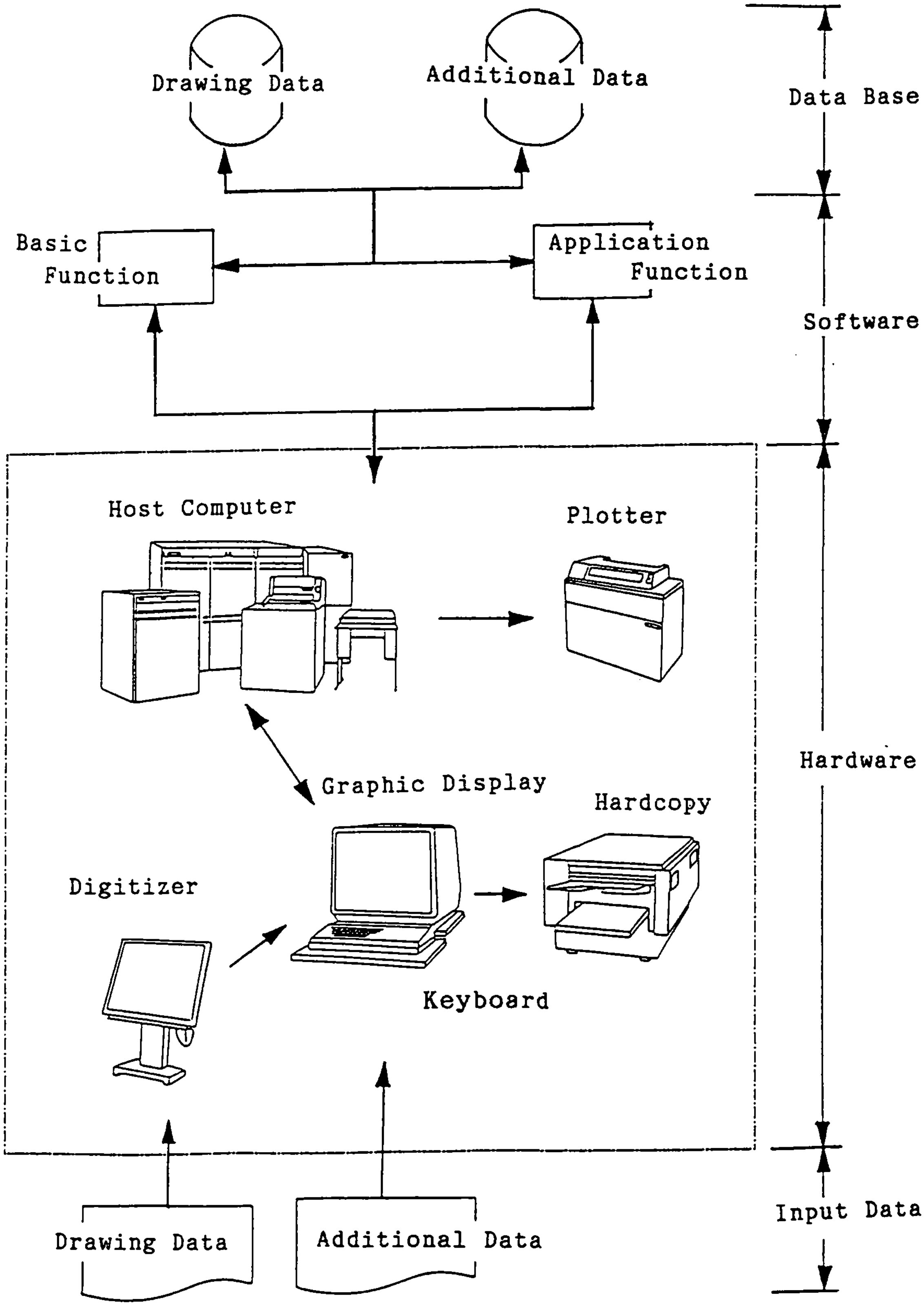


Fig. 4 Schematic of the Mapping System

various information on water mains. Furthermore, it is expected that the procedures for application of road occupation will be simplified.

For the application of the mapping system to water supply, the possibilities are as follows:

(1) It can facilitate maintaining updated drawings, because revision and production of the 1:500-scale basic mains maps can be made at a higher speed.

(2) In the event of water leakage or bursting of a main, appropriate countermeasures can be taken towards public relations activities in the neighborhood of the accident and in tank-truck water supply activities because the number of households under service suspension can be counted in a short time.

(3) In the aspect of controlling of mains ledgers, it can benefit the maintenance and management of water supply facilities since the ledgers on valves and fire hydrants can be controlled integrally and facilitate statistical processing of data, and furthermore quicken the output of the data of mains by the conditions (type of pipe, pipe diameter, the date of construction, etc) within specific blocks.

(4) The appropriate pipeline replacement plans and emergency water distribution plans in the event of disasters and droughts can be drafted up by using a variety of data accumulated on the data base.

(5) Information on water mains can be provided quickly on demand by general public.

In addition, it is expected that, following the advancement in mapping technique, various additional functions will be developed for various water supply operations.

7. FUTURE DEVELOPMENT

Since the survey of old water mains would not be perfect, continuous revision of drawings is required to maintain the accuracy of drawings whenever mains are repaired or old mains are replaced. For this purpose, it is necessary that all staff assist the staff responsible for revising mains drawings. In order to properly maintain mains drawings in the future, it is required to provide mains drawings in such a way that the systems functionalize the maintenance and management of water distribution facilities.

In addition, continuous study of the future trend of technology is also necessary to make easy revision and upgrading of the systems drawings. Also it is necessary to establish a new mains drawings management system so that the mains drawings can be revised periodically and quickly.

8. CONCLUSIONS

This year the Yokohama Waterworks celebrated its centenary. After eight expansion projects, it has 7,600km of distribution mains in addition to water intake, treatment, and transmission facilities. To functionally maintain these water mains, an advanced mains drawing management system has been used since 1970. The system consists of project completion drawings and three categories of maps: (1) basic mains maps;

(2) district mains maps; and (3) general mains maps. Each basic mains map covers a square of 250m by 250m in 1:500-scale. The district mains map is composed of 48 basic mains maps covering an area of 3 sq km (1.5km x 2.0km) in 1:2,500 or 1:5,000. The general mains map comprises about 12 district mains maps covering an area of about 30 sq km (6.5km x 10km) in 1:10,000 scale; or 188 district mains maps covering the entire service area of 430.8 sq km (22.5km x 31km) in a 1:30,000 scale. The basic mains maps are supported by and produced from four categories of basic mains maps and drawings, namely, (A) topografical maps, (B) distribution mains drawings, (C) service connections drawings, and (D) industrial water mains drawings.

These maps and drawings are regularly revised and updated by either contracted drafting firms or Waterworks Bureau staff. The Bureau is currently in the process of developing a computer-controlled mains drawings management system. The new computerized system will make the revision and register of maps much quicker, more accurate and systematic; and make quicker and easier the reference and sccess to map ledgers by staff in charge of maintenance of distribution mains.

TRAINING AND EDUCATION
An Integral Part of the Philippines Rural Water Supply Program

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I. INTRODUCTION

A. Physical Characteristics

The Philippines is a country composed of 7,100 islands. It has a total land area of 300,720 sq. km. where more than two-thirds of the country is within the island of Luzon in the north and the island of Mindanao in the south. The islands stretch more than 1,932 km. from Batanes (near Taiwan) in the north to the Sulu Islands (near Borneo) in the south.

The islands of the Philippines are the higher portions of a partly submerged mountain chain, and the terrain is generally mountainous. The highest point among the islands is Mt. Apo in Southern Mindanao with an altitude of 2,955 m. Among the main areas of level land area are the Cagayan Valley in northern Luzon, the Central plains of Luzon and the Agusan Plain in Mindanao. Most of the Visayan islands have narrow coastal plains.

The Philippines by nature is endowed with many rivers and tributaries. Among the more important ones are the Cagayan River, Pampanga River, Agusan River and the Pasig River which flows through the heart of Manila. The large lakes are Taal Lake, Laguna de Bay, and the Lanao Lake.

B. Climate

The climate of the country is mild, tropical throughout the year. The average annual temperature varies from a maximum of 32 degrees to a minimum of 22 degrees C. Relative humidity varies from a low 76 percent to a high 83 percent.

C. Demographic Data

The population of the country is estimated at 53.4 million as of 1980, having an annual growth rate 2.49 percent. Of this, about 21.2 million reside in the urban areas and 32.2 million in the rural areas.

The Philippines is divided into 13 regions with a total of 75 provinces. The number of towns or municipalities total 1,563, within which are 39,107 barangays or villages. The rural areas far exceed the urban, both in number of towns as well as in population.

D. Hydrogeologic Characteristics

The Philippines has abundant water resources, having an annual average precipitation of 2,269 mm., an average annual run-off of about 256,980 million cu.m. It has large reservoirs of ground water covering some 50,000 sq. km., concentrated mostly beneath its major river basins. The distribution of these water resources varies widely with time and location to the archipelagic nature of the country's geography and climate conditions.

The geologic formations present in the country are classified as follows: littoral and alluvial deposits, corraline limestones, volcanic breccia and agglomerates, bedded volcanic tuff, tertiary sedementaries, massive igneous rocks and metamorphic rock.

II. THE RURAL WATER SUPPLY AND SANITATION PROGRAM

A. The National Scenario

In order to bring the benefits of improved water supply facilities to the entire archipelago, the national government rationalized the water sector in the late 1970s and divided the country into "areas of responsibilities" for three government agencies.

Just early this year, however, the new government reorganized the water sector once again to make it more responsive to the needs of the rural populace.

The new institutional arrangements are as follows:

o - The Metropolitan Waterworks and Sewerage System (MWSS) is to serve the requirements of Metro Manila where the bulk of urban population is concentrated. It is a public corporation which has control and responsibility for the planning, design, construction, operation and maintenance of water supply and liquid waste disposal system of towns within its jurisdiction. The MWSS operates and develops the system out of revenue, borrowed funds and government capital subscriptions.

o - The Local Water Utilities Administration (LWUA) is to serve cities and municipalities outside of the MWSS jurisdiction by establishing Level III water service (Water Works Systems) through the Water District (WD). LWUA is a government corporation for the promotion development and financing of local water utilities. In the recent reorganization, however, its responsibilities have been expanded to include the formation of level II water service (Communal Faucet Systems) through the Rural Waterworks and Sanitation Association (RWSA).

o - The Department of Public Works and Highways (DPWH) through its Project Management Office for Rural Water Supply or PMO-RWS is to be mainly responsible for Level I water service (Point Sources) in the rural areas of the country. It undertakes the drilling of wells, development of springs and the improvement of water systems that fall outside the responsibilities of both MWSS and LWUA.

B. The Program Targets

To meet the water supply and sanitation needs in the rural area, the government embarked on a nationwide Rural Water Supply and Sanitation Program. The basic objective of the program is to install safe and reliable water supply and sanitation facilities within easy access of the rural households at the most affordable terms. For this purpose, a Rural

Water Supply and Sanitation Master Plan was prepared. This plan provided specific policies, targets and action programs for the provision of water supply and excreta disposal facilities to service the rural communities where the need for these basic services has been identified to be urgent.

Furthermore, a Planning and Implementation Inter-Agency Committee (PIIC) was organized to carry out the necessary planning and implementation functions to meet the program objective. PIIC was to orchestrate the entire Rural Water Supply and Sanitation Program as well as to monitor the progress of the program/projects and periodically update the Rural Water Supply and Sanitation Master Plan.

Recently, because of changes in the development conditions in the country, the PIIC was restructured to assess the requirements and policies of the sector to make them more responsive and realistic to economic and social changes. The result was the updated Integrated Water Supply Program (1986-1990) that presents a new program of implementation, a corresponding financing plan, as well as a number of recommendations on how best to carry out these programs institutionally, financially and technically.

Coordinated by the PIIC are the following agencies: Department of Public Works and Highways (DPWH), Local Water Utilities Administration (LWUA), Department of Health (DOH), Department of Local Government (DLG) and the National Water Resources Board (NWRB) which all have functions related to rural water supply.

The target of the Integrated Water Supply Program is to provide dependable, accessible and safe water supplies to the people in the fastest time possible and in a cost effective manner. In figures, by the year 2000, the total population will have a Level I service; 20% of the rural villages will have a minimum of Level II service; and almost all poblaciones or urban centers will have Level III service.

C. Institutional Development

From the above, it can be gleaned that there is a clear delineation of responsibilities, tasks and functions for those involved in the entire national water development sector, including the rural program. Institutional linkages among the agencies are present in order to better coordinate and more effectively implement the activities of the program. This is particularly true in the rural program where the linkages transcend from the national level to the provincial level, to the municipal then down to the barangay level.

In order to appreciate better the institutional linkages present in the rural program, consider the past arrangement.

In the past, waterworks systems were locally controlled by the municipal or provincial governments. As such, there was not much institutional development activity to speak of as these waterworks systems were operated and maintained by the local governments. Because of this arrangement, the systems, as water supply institutions, were poorly managed, technically weak, provided unreliable service and inadequate supply of water to its consumers. Its facilities, likewise, were poorly maintained that they became so badly deteriorated.

The situation prompted the government to change the concept of water supply development and management in both the urban provincial centers and in the rural areas. New government agencies were created to administer the needs of the local water works systems. It called for the establishment of Water Districts as the organization that would service the water needs of the local urban communities.

As for the rural communities, the establishment of a Rural Waterworks and Sanitation Association was the answer to better water facilities' management and operation. The improvement of existing water and sanitation facilities or the construction of new facilities became the responsibility of both the government and the community, such that the communities' involvement and participation had to be solicited.

The RWSA as an Institution

The RWSA is an organization of users of a water supply system. It is composed of the community members residing in the town or area where the water system is located. As a non-stock, non-profit organization, it operates as a cooperative, that is, it owns, operates, provides sanitation services and maintains the community's water supply system. It is the basic group entitled to the financial, technical and institutional assistance from the PMO-RWS for Level I water systems.

The RWSA organization consists of two functional section: finance member services section and the operation and maintenance section.

The finance and member service section takes charge of accounting, collection and member relations functions. The operation and maintenance section takes care of the proper operation and maintenance of the system involving acquisition of spare parts, repairs of distribution or service lines and other parts of the system.

It is the Board of Directors of the RWSA who actually runs the business of the association through a systems manager. The Board is composed of members duly elected by the association members.

Institutional Development Activities

In institutional development, the capability of the organizations that will build and later operate and maintain the existing and expanded water supply systems is very important. And for each organization, the following variables have been taken into consideration in strengthening the present institutions that either give government assistance or the institutions that are recipient of this assistance:

o - management activities, including strategic planning and management control; operational planning and control;

o - organizational functions or systems

o - decision-making process and management information systems that support them;

o - support activities such as training and public education.

A lot of emphasis now is put into training and education, including information programs to ensure adequate, cohesive and regular community participation.

III TRAINING

For the water supply program, training, as part of institutional development, has been put in equal footing with technical activities. It has been defined as the "systematic development of attitudes, skills and knowledge of all personnel involved in water supply (and sanitation) necessary for their adequate performance and participation in the implementation of the rural water supply program."

Thus training is aimed at improving the job of program personnel and at accomplishing program goals. The ultimate aim of training is to develop the capability of all program personnel, at various levels, to effectively plan, operate, and maintain water and sanitation systems.

The government's policy of self-reliance has made basic social services such as water supply not only the responsibility of government alone but also that of the project beneficiaries. As the new caretaker of the water facilities, the community has to be trained in water system operation and maintenance. On the other hand, training is likewise urgent for the personnel of the water districts or the RWSA in every aspect of water supply management and operation. This is necessary to upgrade the quality of service these utilities offer to its consumers.

The target groups for manpower development programs are the following:

a. Technical personnel at the program level belonging to the participating agencies and local government units including the task forces both on the provincial and municipal levels;

b. Systems operators who are actually officers of the RWSA responsible for the operation and maintenance of the system; and

c. End-users or the direct beneficiaries of the rural water supply projects.

There are various courses that have been identified and developed to equip each of the target group to accomplish the required tasks. These courses run from institutional, management, technical, financial, and the like. There is also the trainors' training to ensure that training can be more effectively be carried to more participants at a faster pace.

The thrusts of the training programs are:

a. Creation of a pool of trainors for courses relative to the implementation of the rural water supply program.

b. Upgrading of the knowledge of the government involve in the program and the regional/ district offices on feasibility study preparation, design and construction of water systems, and water quality analysis.

c. Improvement of skills of technical personnel of the regional and district levels of the construction, operation and maintenance of water systems.

d. Development of skills of technical personnel from the district offices in the proper dissemination of information and techniques to the RWSA caretakers/operators on the operation and maintenance of water systems.

e. Strengthening of the capability of the institution-building officers and their counterpart personnel on the formation and /or registration of RWSAs.

f. Training of RWSA officers on basic management, accounting, record keeping, and operation and maintenance.

To give you an idea of some of the training programs being conducted for the rural water program, consider the following:

COURSE TITLE/DESCRIPTION	PARTICIPANTS
1. RWSA Formation	
It is an assembly attended by the prospective water users and personnel from the regional and district offices, and the PMO-RWS in order to facilitate the organization of the association. Likewise, taken up are the procedures and required documents for registration.	Barangay Officials, and representatives water users.
2. Skills Training for Operators of Level II Rural Water Supply Projects	
This is hands-on training that will develop competence of the RWSA operators to operated, maintain and repair their respective water supply systems.	Operators/Technicians of an operational RWSA.

3. Training for Caretakers of Level I Systems	
This is hands-on training that will develop the ability of Level I caretakers in the proper use, maintenance, and repair of the water supply system.	Caretaker of operational RWSA Level I systems.
4. Project Preparation Course	
A non-residential seminar-workshop aimed to provide the participants with knowledge and skills on planning, construction of water supply structures, operation and maintenance and RWSA formation.	Personnel of the District Offices who are directly involved in the program.
5. Water Quality Analysis and Treatment	
It enables the trainees to conduct water quality analysis and surveillance following the standard methods and procedures using portable water quality analysis kit, and disinfection using granular or tabletized chlorine.	Engineers/personnel directly involved in the conduct of water quality analysis and treatment.
6. Workshop on the Operation and Maintenance of Various Water Supply Equipment and tools	
This is a hands-on training for the project implementators of the RWSA program on the proper operation and maintenance of various equipment and tools to ensure a more efficient and effective implementation of the program.	Engineers, district well drilling supervisors and other concerned individuals.

IV. EDUCATION

For a successful rural water supply program, education activities are crucial from the time the project is incepted. They are necessary if the project is to proceed along until the physical facilities are ready to be operated for the community by the community. For once the technical inputs are available, the institutional phase of the development process begins. The proposed project is presented to the community and a series of dialogues are made between the Government and the proposed RWSA. It is when an agreement is reached that the proposed RWSA submits registration documents and eventually, the RWSA is duly formed. And only upon approval of the RWSA, can the construction of the water supply system starts. Meanwhile, the RWSA members are trained on how to operate and maintain such system. Following the completion of the construction of the project, this is turned over to the RWSA for operation and maintenance.

The RWSA is the community structure that operates and maintains the water supply system. The RWSA can only efficiently operate and maintain the system if it is strong, functional and viable. To be so, it must have the full support of all the members and be ran by competent and dedicated officials. The RWSA formation process is therefore the first step in the development of a strong, functional and viable RWSA.

For the RWSA formation process to take root, relevant information should be imparted to the would-be RWSA members during its organization. These members should be educated on the concepts behind the rural water supply program, as well as on the importance of ensuring community participation and cooperation in operating and maintaining the system's newly built facilities. Public information and education are therefore basic to the development of an enlightened, cohesive and supportive membership.

The existence of an efficient water supply system that can adequately meet the community's need for domestic water supply is only one part of the program. It is the existence of an educated community's participation and involvement on all aspects of the water supply development process that assures the rural program's success.

To show you the seriousness of the educational program for water supply, a parallel educational program for the nation's schools has been developed in the early 1980s. Called Project WATER (Water Awareness Through Educational Recourse), this program integrates education in the curriculum of the schools from Grade I to high school. This program was approved by the Department of Education, Culture and Sports (DECS) as an enrichment to the regular school curriculum specifically in the following Subject areas: Math, Science, Social Studies, Language, Practical Arts, Reading and Pilipino. Integrated into the curriculum are water concepts such as water conservation, water cycle, computation of water consumption, protection of watershed areas, soil erosion, responsibility of citizens/community in water development programs and the like. It is hoped that through this program, the youth of today who will become tomorrow's citizens, be made more aware and therefore be more involved in the water supply development plans of the government.

Another important component of education is public information and public relations. A planned and sustained public information and public relations program utilizing the various media of communication, such as print, radio and TV, is now underway. Never before has a "media blitz" been conducted so as to make sure that the beneficiaries of the water supply development program are aware, do understand and will support their own communities' programs.

Some of these info programs are: person to person information dialogues with the grassroots, local officials, national agencies; placement of news and feature articles in newspapers and magazines of both national and community-based circulation; placement of dramatized radio plugs in stations with wide network reach; development of audio-visual presentations for various audiences; utilization of TV, through direct ads and talk shows, to explain programs and concepts.

To be effective however, the info and educational programs have to be sustained both on a national and local level. It must have adequate funding support in order to ensure that the ultimate aims of getting community involvement and participation are reached. Community participation, however, integrates the actions taken at all levels - from the community to the national organization. The educational approach adapts to the needs of the communities and includes information on the content and extent of such participation.

V. PROBLEMS

The reorganization of the water sector was borne out of necessity considering the problems that befell the entire water supply sector particularly the rural water supply development program.

Much of the problems on institutional development for rural water supply systems were on the institutions or agencies themselves that provide assistance to th RWSA. There seemed to be a lack of coordination among the agencies involved in the rural water supply program despite a clear delineation of functions and responsibilities. This lack of or weak coordination could be seen when comparing the 1986 status of RWSA formation vs. RWSA with constructed facilities.

Theoretically, a RWSA must be formed and registered before even a rural water system is constructed therein. But apparently, figures show otherwise. Water systems were being constructed even in areas not organized into a RWSA.

It is hoped that this situation be corrected with the recent reorganization where only two agencies, namely LWUA and PMO-RWS, are now fully responsible for the rural water supply program.

Training in itself must be increased in scope as well as reach. Although the programs presently being conducted are good, they can definitely be improved. A regular staff development course should be developed for the local levels for it is in this level that training is needed.

Training, however, must be made continuous to be truly effective. Its funding and logistical requirements must be made available so that planned training activities are supported. This means that management support, too, has to be firm and unwavering.

Weak community participation in the formed RWSA is also a problem. There is a need to seriously involve the community in RWSA activities, especially during formation. This can be done by developing a regular information and education program designed to impart to the community-beneficiaries timely and relevant information on the rural water program and RWSA policies. Such an information and education endeavor should be sustained and maintained if the RWSA is to be successful.

VI. CONCLUSION

The concept behind the rural water supply program is sound. The objectives that are aimed to be reached are reasonable. However, the problem on institutional development has stunted the success of the program. Most RWSA are not functional as members have not been properly motivated to support their own association. Many do not even pay their water bill. And if the RWSA cannot collect its fees, it faces a problem in operating and maintaining the system. Thus, water service remains inadequate and unreliable.

If functioning, many RWSA systems are poorly maintained. This is largely attributed to the improper formation of the RWSA or to the lack of training of the end-users.

But all is not hopeless with institutional development, particularly the support activities of training and education. This is so if the "support activities" are made to stand as independent activities in the category of the engineering function. There is a need to emphasize now that the key to the success of the rural water supply program is training and education. Because it is people that build systems to make them work for people.

The broadly recommended solutions in dealing with the institutional development problems are:

1. Strengthen further the agencies that provide institutional assistance by streamlining their operations to remove gaps and overlaps.

2. Strengthen the institution, in this case the RWSA, that receives the assistance.

3. Develop more effective trainor's training programs especially for the local level.

4. Develop an honest-to-goodness information and education program to get community support to the RWSA and its activities.

N O T E : As this paper was being written, the public water supply sector was reorganized to make it more responsive to the present development needs. In fact, the structures of the agencies involved in the rural water supply program were reviewed in detail prior to the final implementation of the reorganization plan. It is hoped that with the reorganization, the sector will be streamlined so that the ultimate objective of providing the entire population with safe, adequate and affordable water will soon become a reality.

Renovation and Durability Estimation of Water Mains

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1. Purpose of the Paper

It is main purpose of this paper to report a method to estimate the durability of water mains. The method is one of the results of a series of investigation sponsored by the Ministry of Health and Welfare to prepare some materials for the Ministry to provide the guidelines for water mains renovation.

2. Importance of Maintenance in Distribution Network

2.1 Future policies of water supply in Japan

Presently, more than 93.3 percent of the whole inhabitants in Japan enjoy public water service. It means the heavy responsibility of water suppliers that 113 million people could not have any measure to get water other than relying upon water supply. Urban life-lines, including water, electricity, gas, tele-communication, etc., are not only important by themselves, but cooperative and also interfering each other.

Besides, along with pervasive water service, citizens have shown more interest in water quality as well as in taste, and their apprehensions about environmental pollution has built up the concern.

Reflecting these circumstances, the Advisory Committee on the Living Environment has proposed a recommendation to the Minister of Health and Welfare in March 1984 under the title of "Future Policies for Administration of Water Supply in the Age of High Diffusion." The recommendation, composed of following five targets, has pointed up remaining problems and newly aroused ones, which water suppliers are now tackling with, and clearly indicated the course that the water supply in Japan should pursue for the near future.

(1) Arrangement and operation of water supply system
(2) Security of the water supply system as a life-line of the society
(3) Safe and palatable quality of water
(4) Equalization of water charge
(5) Promotion of technical cooperation with developing countries

From the Target (2) and (3) arise some important problems concerning both physical stability and quality control in the distribution network, e.g.,

(i) More effective leakage prevention

(ii) Preventing turbid water troubles

(iii) Besides (ii), maintaining good quality and palatability of water and minimizing residual chlorine

(iv) Securing safety again disasters, such as earthquake

These requirements lead us to establish a reasonable methodology for systematic renovation system of aged mains. However, pipe renovation has not necessarily been carried out on a specific criterion, and in fact, mains renewal service is often conducted merely as ex post facto measures after leakage or some trouble had been occurred.

2.2 Objective of the Investigation

According to the unsystematic current practice of mains renovation as stated above, we should be under the apprehension that it would be not easy to improve the effectiveness ratio, a valuable index for estimating the results of leakage control works, and to minimize the damage caused by earthquakes and other disasters.

Consequently, any points in the network of mains which may be subject to leakage or turbid water trouble should be predicted based upon a more logical and systematic method before they develop into hazards. Then, the related pipes should be renovated or improved according to their priority.

The examination had it as an object to grasp the requirements which specify the durable limits of pipelines affected by several factors such as the order of their installation date or piping materials. It is also one of the main objectives to develop a proper prediction method about the durable limit of pipeline as well as a pipeline renovation system by which the order of pipe renovation can be determined more logically with particular attention placed on the priority of a part of pipelines.

3. General features of water mains renovation in Japan

Japanese waterworks is now celebrating the one hundredth anniversary of its first inauguration of modernized water supply in Yokohama City. Although about two thirds of the whole mains were constructed within these 40 years, some pipes are much aged and subject to leakage and even breakdown or occurrence of turbid water trouble.

Mains renovation is now regarded as the inevitable link in the assurance of safe and stable water supply, the most important one of the lifelines.

An inquiry to waterworks of 19 larger cities proved that about 1,000 - 1,200 km of mains within total length of 63,000 km have been annually renovated these years as shown in Fig. 1. Most of the water suppliers employ the age, or lapse of time, as the criterion for renovation, and also specific pipe materials, such as asbestos cement, are given priority to be renovated.

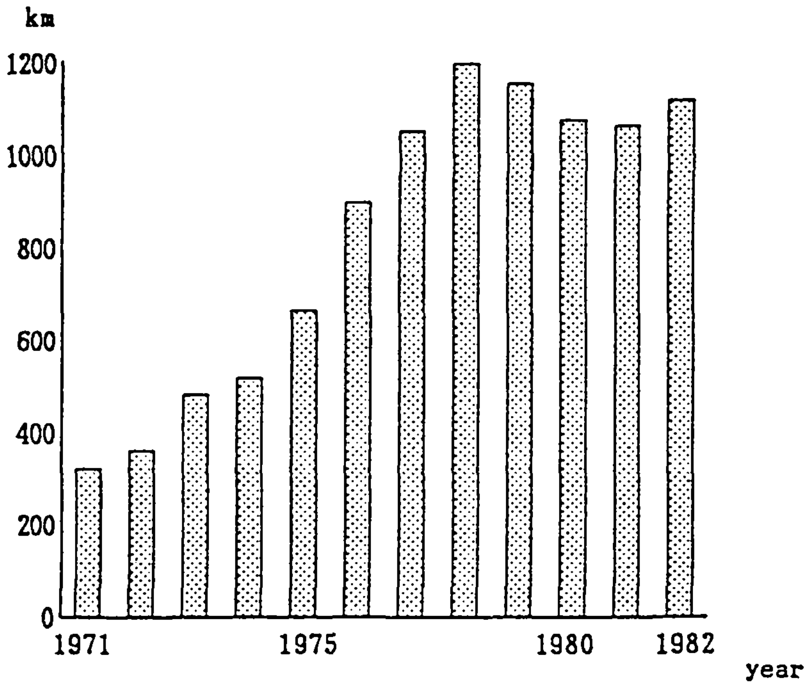


Fig. 1 Progress in mains renovation in Japan

The term "pipe renovation," as applied hereupon, includes "replacement" and "rehabilitation." For the rehabilitation, several in situ methods have been developed and adopted by water suppliers. These include, e.g. "pipe-in-pipe" method," using ductile cast iron pipe and steel pipe, "polyethylene pipe insertion method", "hose lining method" and "cleaning followed by lining method", etc. The last method applies scrapers, water jet, sand blasting, etc. for cleaning inside of pipe, and then adopts epoxy resin or cement mortar as lining material.

Obviously, the cost needed for pipe replacement is more expensive than that of rehabilitation. On the other hand, the expected life is naturally shorter in case of rehabilitation. Here is a relationship of trade-off, regarding the interest on a loan. For example, a life of 20 years should be expected by a rehabilitation with an interest at six percent, then an average cost for rehabilitation would be 70 percent of replacement.

Table 1 shows the tendency of pipe rehabilitation according to four representative rehabilitating methods and pipe diameters.

Table 1 Progress of Pipe Rehabilitation

Year	Diameter(mm)	Types* and rehabilitated length (km) PIP	PL	HL	CL
Before 1974	< 250		6.0		212.5
	300 - 600		1.6		
	600 <	6.2			
1975 - 1979	< 250		8.4		1,038.5
	300 - 600	1.7	21.6		
	600 <	6.1	0.9		
1980 - 1984	< 250		20.6	4.4	3,722.1
	300 - 600	5.8	18.2	12.8	0.3
	600 <	41.3	3.3		

* Types of pipe rehabilitation:

PIP: Pipe-in-pipe method
PL: Polyethylene pipe insertion method
HL: Hose lining method
CL: Cleaning followed by lining method

4. Durability estimation of water mains by a statistical analysis

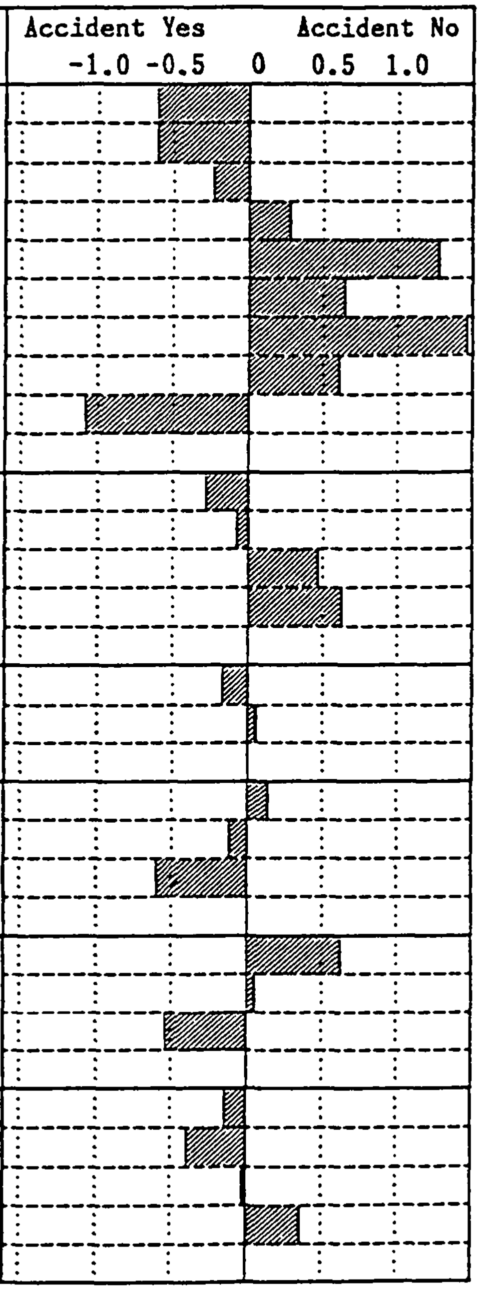
An examination about conditions including histories and hazards concerning distribution pipes were conducted for 20 water suppliers in representative cities in Japan. The number of samples reached to 10,313 pipe elements, of total length at 1,567,340 m. 729 damages were included in the data. They consisted of crack fractures at 75 percent, relaxation in joints at 20 percent and corrosion at five percent.

Durability against pipe accident could be estimated through each of the statistical method based on maintenance data of mains, analytical method by physical and chemical properties of pipe materials, and/or direct diagnostic method.

In this chapter a tentative statistical estimation model will be presented. The Quantification Theory of Class II, a multivariate statistics for non-metric variables, brought the most practical results among the trials.

Sample scores of the categories of chief items were calculated for the existence of accident (yes or no), according to whose values, "Hazard ranking" of each pipe element can be evaluated. Fig. 2 illustrates one of the set of examples, collected from the said examination.

Item	Category	Score	Range
Pipe materials	ACP-CA-G	-0.6339	
	ACP-G-G	-0.6316	
	CIP-SO	-0.2717	
	CIP-M	0.2683	
	DCIP-M	1.2451	
	SP-SO	0.6187	
	SP-W	1.4339	
	SP-SC	0.6031	
	PVC-TS	-1.0872	
			2.5211
Diameter (mm)	50～ 75	-0.2835	
	100～150	-0.0800	
	200～300	0.4778	
	400 and larger	0.6175	
			0.9010
Earth covering (m)	0.9 and smaller	-0.1728	
	1.0 and larger	0.0407	
			0.2135
Trafic of large vehicle	None	0.1270	
	Light trafic	-0.1214	
	Heavy trafic	-0.6004	
			0.7274
Max. hydraulic Press. (kg/cm^2)	0～2.0	0.6087	
	2.1～6.0	0.0459	
	6.1 and higher	-0.5448	
			1.1535
Lapse (year)	40 and larger	-0.1612	
	30～39	-0.4240	
	20～29	-0.0265	
	10～19	0.3128	
			0.7368



Hazard Ranking	Sample Score	Accident Ratio (%)
1	Below −1.2275	34.9
2	−1.2275 ～	17.1
3	−0.8105 ～	7.6
4	0.7147 ～	1.1
5	Above 2.0479	0.0

Fig. 2 Estimation model on water mains accident

5. Index of Pipe Damage Occurrence Ratio

Durability against pipe accident might be estimated in another way, on the basis of the index of accident occurrence ratio calculated according to the data obtained from the examination on the asctual condition.

Table 2 shows the indices of accident occurrence ratio for different pipe materials and type of joints. Although the pipe length of each sample is different each other, we can understand the vulnerable conditions of pipes at a glance of it. The legends for pipe materials and types of joints are illustrated in Table 6.

According to Table 2, the indices of accident occurrence ratio for crack and fracture and relaxation in joints are larger in case of ACP, CIP-SO and PVC-TS. Therefore, their indices of accident occurrence ratio with regard to pipe conditions are arranged in Tables 3, 4 and 5.

These tables are conveniently used to estimate a regarded pipe roughly, but quickly.

Table 2 Indices of Accident Occurrence Ratio Based on the Classification of Pipe Material and Joint Types

Hazard /Accident Pipe material /Pipe Joint	Index of accident occurence ratio				Extension of samples (km)
	Crack Fracture and Relaxation in Pipe Joints				
	Crack Fracture	Relaxation in Pipe Joints	Total	Corrosion	
ACP	100	18	83	0	121.51
CIP-SO	79	11	62	3	439.22
CIP-M	24	1	17	2	200.09
DCIP	4	0	3	0	741.13
SP-SO	10	7	13	100	10.32
SP-W	0	0	0	0	11.67
SP-SC	50	13	44	39	12.29
PVC-TS	17	100	100	0	30.75

Table 3 Indices of Accident Occurrence Ratio per Items (ACP)

Item	Category	Occurence Index
Diameter (mm)	50	100
	75	35
	100~150	24
	200 and larger	16
Installation Date	Before 1944	100
	1945~1954	85
	1955~1964	32
	1965~1974	26
	After 1975	15
Earth Covering (m)	0.9 and smaller	100
	1.0 and larger	50
Max. hydraulic Press. (kg/cm²)	2.0 and lower	44
	2.1~6.0	70
	6.1 and higher	100

Table 4 Indices of Accident Occurrence Ratio per Items (CIP-SO)

Item	Category	Occurence Index
Diameter (mm)	100 and smaller	100
	150~200	62
	250~300	37
	350 and larger	15
Installation Date	Before 1944	100
	1945~1954	68
	1955~1964	63
	After 1965	16
Earth Covering (m)	0.9 and smaller	100
	1.0 and larger	46
Max. hydraulic Press. (kg/cm²)	2.0 and lower	22
	2.1~6.0	29
	6.1 and higher	100

Table 5 Indices of Accident Occurrence Ratio per Items (PVC-TS)

Item	Category	Occurence Index
Diameter (mm)	50	47
	75	84
	100 and larger	100
Installation Date	Before 1974	100
	After 1975	16
Earth Covering (m)	0.9 and smaller	100
	1.0 and larger	55
Max. hydraulic Press. (kg/cm²)	3.0 and lower	14
	3.1~4.0	27
	4.1 and higher	100
Fluctuation in Hydraulic Press. (kg/cm²)	1.0 and lower	26
	1.1~2.0	33
	2.1 and higher	100

Table 6 Legends for Pipe Materials and Joint Types

Pipe materials		Joint	
ACP	Asbestos cement pipe	CA	Asbestos cement joint
		CS	Steel plate joint
		G	Cast iron joint
CIP	Cast iron pipe	SO	Socket joint
		M	Mechanical joint
DCIP	Dctile cast iron pipe	SO	Socket joint
		M	Mechanical joint
SP	Steel pipe	SO	Socket joint
		W	Welding joint
		SC	Threaded(Screwed) joint
PVC	Unplasticized polyvinyl chroride pipe	TS	Adhesion joint
		RR	Rubber ring joint

6. Evaluation of Other Pipe Hazard Occurrence

Hazards in water mains that sets limits to the durability of a pipe are classified into three chief categories: damage, turbid water occurrence and decrease of water conductivity.

To evaluate turbid water troubles, there may be two indirect methods available. One is the method to evaluate based on the precedent of a typical water supply authority.

The other is the method to evaluate on the basis of the calculation of the distribution of rust concentration within the pipe network.

For insufficient water conductivity, a method to estimate according to an analysis of hydraulic characteristics in the pipe network could tentatively be clarified in this investigation. It requires an experimental work to measure the flow coefficient of the regarding pipe, which may bring some difficulties.

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COMPUTER APPLICATIONS FOR DESIGN, OPERATION AND MANAGEMENT OF WATER SUPPLY AND DISTRIBUTION SYSTEMS TWO CASE STUDIES : THE MACAU WATER SUPPLY COMPANY AND THE PARIS WATER SUPPLY COMPANY

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INTRODUCTION

Ever-increasing requirements of water supply systems operators and customers in terms of quantity, quality, efficiency, security, together with the tremendous development of the potential offered by computer science and industry, have led the various actors in Water Industry and Services - Consulting Engineers, Water Supply Authorities or Companies - to design and implement more and more efficient and complete computer applications in the fields of design, operation and management of water utilities (production and supply, treatment, distribution).

These various computer applications tend more and more frequently to integrate previously disconnected functions, such as :

- Automation of water works (treatment plants, pumping stations),
- Supervisory control and data acquisition (SCADA) systems,
- Modelling and simulation of supply and distribution systems (modelling of groundwater or surface resources, modelling of distribution networks, ...),

- Data base management systems for technical data related to water systems description and operation (for example : network description and evolution, laboratory data management, ...)

- Digital mapping of network and related urban environments,

- Expert systems for aid to decision making in water systems design and operation.

Numerous examples of such integrations of systems and functions can be quoted, which have been tested or implemented in the previous years, such as :

- integration of a computer model and a SCADA system for real-time pipe breakage detection on a distribution system,

- integration of an optimization software and a SCADA system for real-time optimization of a large multi-resources supply and distribution scheme,

- integration of a groundwater model and an optimization algorithm for optimal prevision of groundwater recharge.

Such integration can nowadays be analyzed and framed within the concept of "Technical computerization schemes" to be progressively implemented according to operational priorities, financial capabilities and manpower abilities.

The following paragraphs highlight some specific aspects of the development of such computerization schemes in two contrasted case studies : MACAU and PARIS.

I - MACAU Case study : development and operation of a network simulation model. Further automation and computerization projects.

The MACAU Water Supply Company (Sociedad de Abastecimento de Aguas de Macau) is in charge, under agreement with the MACAU TERRITORY GOVERNORATE, of water supply, treatment and distribution on the Territory. The Company serves a present population of circa 400.000, bound to a rapid growth in the future.

In 1985, SAAM commissioned SAFEGE and HO TIN Associates, Consulting Engineers to prepare a Master Plan for the improvement and development of the water supply of the Territory of MACAO. This Master Plan targeted a maximum daily production requirement of 130.000 m3/day at year 1993, and recommended corresponding schemes for water supply and treatment. It also outlined that, in order to properly route and distribute this expected production at the year 1993, extension and improvements of the distribution system had to be analyzed and planned. Therefore, the MACAU Water Supply Company required, in 1986, SAFEGE's services in order to carry out a detailed hydraulic analysis of the supply and distribution system. This analysis was conducted in 1986-1987 through three stages :

- Updating the water demand projection, taking into account the changes in the geographical distribution of population growth and the new development as mentioned by the MACAU Government;

- Evaluating the network data, including pipeline information (size, length, condition) and preparing a detailed breakdown of consumption by sub-area and the location of the major consumers, with a view to determining the water demand to be allocated to each node;

- Conducting a network hydraulic analysis, with SAFEGE's simulation model software PICCOLO.

Regarding particularly the third stage of the study, main features were :

a) The software used in the simulation.

The software used for model design and operation is SAFEGE's PICCOLO software. This software offers a fast algorithm for computations, a wide dynamic process, particularly regarding the input parameters, a large, precise and easy inter-active graphics capability, all factors which render the software highly user-friendly and multi-purpose in terms of analytical, operational and managerial capabilities.

b) The objectives of the hydraulic analysis.

The main objectives of the hydraulic analysis were defined as follows :

- analyze present operating conditions (5 distribution zones),
- identify hydraulic problems at pumping stations, storage reservoirs or distribution mains in present and future peak conditions,
- define optimal pumping works in future operating conditions,
- define optimal distribution conditions (zones, mains structures, ...),
- analyze emergency situations.

c) The design of the model

The model was built considering the main structure of supply and distribution, composed of :

- two pumping stations,
- five storage reservoirs (existing and projected),
- supply mains with diameters over 200 mm (up to 800 mm) representing circa 60 km,
- over 130 existing valves.

This led to a model of roughly 300 nodes and 500 sections.

The model went through preliminary calibration using existing pressure records on a limited number of nodes on the network.

The model was built under dynamic conditions, allowing for simulations over a 24 hr period.

d) Operation of the model

Once the model built, over 150 simulations were carried out for analytical purposes, with variation of the following parameters :

- volumes and invert levels of reservoirs,

- 24 hr demand evolution,

- demand allocation,

- valve positions,

- extension of distribution zones,

- dynamic pumping conditions.

PICCOLO's interactivity and user friendliness proved, within this intensive simulation sessions, to be of invaluable help to the water Engineer in charge of the study in terms of :

- "real time" display and interpretation of dynamic computations,
- interactive modification of computation parameters,
- extreme rapidity in computation stages (roughly 20 seconds for each computation).

e) Main conclusions of the analysis

Main conclusions drawn from the simulation stage of the study were as follows :

- a considerable simplification and improvement of network operating conditions can be obtained through reduction of operating zones from 5 to 2 :
    * upper zone linking all the high points of the island (elevation 20 m and above),
    * lower zone connecting the remaining parts of the network.
- this simplification leads to a far-better pressure balance of the networks,
- a new design of hydraulic characteristics of the pumping stations leads to a significant reduction in pumping costs,
- invert levels and capacities of projected storage tanks have been optimized, together with a definition of their localization compatible with Governmental requirements on land use,
- bottle-necks on the network were identified and corresponding reinforcements of networks or supplementary loops were defined.

Furthermore, three emergency situations were analyzed and corresponding improvements in operating conditions defined :

- supplementary supply to the near-by islands of COLOANE and TAIPA (10,000 cum/day),
- fire fighting simulation at the extreme southern part of the network,
- other zoning requirements in case of equipment breakdown.

It can be seen that, through this analysis, a very valuable information was

drawn, instantly convertible into design features for projected works (pumping stations, reservoirs, mains extension or replacement) and operational features (valves position,...).
Further calibration and update of the model shall undeniably lead to supplementary information that will help the Company in defining ever-improved design features or operating conditions.

Confidence gained by the Company in the application of computer science in its design and operation challenges, and gradual implementation of major projects derived from the Master Plan and the Hydraulic Analysis have led the Company, with the assistance of LYONNAISE des EAUX and SAFEGE, to formulate an integrated computerization scheme involving :

- automation of treatment plants, pumping stations and related utilities (Diesel generators),

- Supervisory Control and Data Acquisition System (SCADA) for remote operation and control of treatment plants, pumping stations, reservoirs and control points on the network,

- Technical data base management system for storage, retrieval and management of data issued from the SCADA System as well as external data (climatology, ...),

- On-site implementation and operation of PICCOLO network model,

- Implementation of a consumption prediction model linked with the PICCOLO model,

- Digital mapping and technical data base management system for the distribution network, using the RESAPIC software developped by SAFEGE.

All these gradually inter-related applications shall be supported by a network of 2 Micro-VAX (DEC) computers with fully compatible graphic and non-graphic peripherals.

Progressive implementation of this complete scheme shall be carried out by the Company in the years 1988 - 1989.

II - The PARIS Case Study. Implementation of a digital mapping and technical data base management system : a major stage in the computerization scheme

The PARIS Water Supply Company (Société Parisienne des Eaux) was commissioned in 1985 by the City of PARIS to take over operation and management of the water distribution networks (potable water and service water) of the Left Bank of PARIS.
This area shelters a population of circa 900.000 inhabitants and the main characteristics of the network are :

- length of pipes : 1,000 km
- Number of valves : 12,000
- Number of house connections : 35,000
- other appurtenances (washouts, air releases, ...) : 12000
- public connections (hydrants, street washing, ...) : 8000.

When the Company took over the management, information on the network handed over by the City's Services was fairly limited and inaccurate : maps at 1/5000 scale, outdated and incomplete. This was obviously inadequate in terms of basic technical information required for :

- an efficient daily operation of a large and complex network

- an optimal policy for network rehabilitation and renewal, in which the Company was to be deeply committed under its agreements with the City.

Therefore, together with other actions which will be briefly described here-under, the Company decided, in early 1986, to launch a program aiming at the implementation of a "digital mapping and technical data base management system". The two main components of this program were :

- information acquisition through field surveys and records data collection,

- design and implementation of a computer system.

Information acquisition

Information acquisition was made easier by the fact that, in inner PARIS, most of the water distribution networks (both potable and service) are located in the main sewers and technical galleries, thus allowing for :

- thorough and precise identification and localization of all network components : pipes, valves, other devices, house connections, ...

- a precise evaluation of the various components present condition : corrosion, leaks at joints,...
  Six teams of service men and draughtsmen carried out, during a 12 month period, a complete survey of the networks whose results were recorded :

  - on 1/500 maps to be further digitized,

  - on special forms for pipes, valves, and devices recording alphanumerical information to be further loaded into the data base.

System design and implementation

Main objectives and features that the system had to match were the following :

- enable the creation, updating, edition, and distribution of maps at any scale,

- constitute a complete data base used in daily operation, in emergency situations, in assessment of rehabilitation and renewal requirements,...

- be accessible to all operational levels of the Company to serve their information needs : servicemen, draughtsmen, engineers, management.

Following a competitive bidding held in mid 1986, the Company chose the solution proposed by SAFEGE, based upon its "RESAPIC" software, and SAFEGE was committed to implement the system on a turnkey basis (design, implementation, maps digitization, personel training, system maintenance), with a completion date fixed at November 1987.

Main characteristics of the "RESAPIC" Software that led to its choice by the Company were the following :

- its remarkable efficiency in data base management : the software is object-oriented, fully relational, and graphic and non-graphic data are stored and processed on the same level;

- its efficient graphic functions; though it is not a CAD software, RESAPIC has the major functions used in two-dimensional mapping;

- the continuity in the base map and related networks, which are not treated on a sheet basis;

- its powerful query langage, mixing graphic and non graphic inputs;

- its flexibility, openness and evolutivity in terms of future applications or connections with other technical or commercial computer applications;

- its efficiency in terms of remote operation through specialized transmission lines, without degradation in response time;

- its independence of the hardware.

In terms of system architecture, the main features are :

- a VAX 8200 computer, hosting the software and managing communications with local or remote peripheral equipment,

- two TEKTRONIX 4125 graphic stations at the Company's headquarters,

- one AO digitizer and one AO plotter at Company's HQs,

- various alphanumeric terminals and printers at HQs,

- three sets of peripherals in the three remote operational Centers located in various parts of PARIS, each set comprising :

  * one TEKTRONIX 4125 graphic station with digitizing tablet,

  * one A3 plotter for field drawings requirements,

  * one alphanumeric query terminal and one printer.

As an example of the functions implemented on the system, the "emergency valve shut-down" will be descrited hereafter.
When a problem is reported at a given address (pipe breakage, incident on a connection,...), the sequence of interactive interventions with the system is as follows :

- the man-in-charge types address where the incident is signalled;

- the system displays on the VDU a map of the area centered on the given address;

- the man in charge then points on screen exact location of the incident;

- the system finds out the various valves to be shut down in order to isolate the pipes around the breakage point and :

  * gives details on the valves (type, shut-down procedures, ...),

  * gives detailed drawings where necessary (triangulation of surface boxes if any),

* gives list of priority customers to be warned;

- finally, user decides which informations or drawings he needs to be printed or plotted on paper before leaving for field intervention and repair.

When in full operation at the Company, the system will be of extended and valuable help to the various levels of operation of the Company, which is already considering, through feasibility studies, its extension towards such directions as :

- input and processing of data collected through regular leak detection surveys carried out on the network. These data will be captured by field operators on micro-computers which will "discharge" information into the system, thus helping in network rehabilitation programs implementation;

- connections between the technical data base and customer management computer system, in order to transfer valuable information from one system to another;

- implementation of an expert system for aid to decision making in network maintenance and rehabilitation, using the technical data base as one of the components of the system.

Moreover, all these actions are integrated into a thorough computerization scheme also comprising :

- implementation of a SCADA System to collect and treat data on network flows and pressures,

- simulation of the various distribution zones with PICCOLO software, to be further coupled with the SCADA System on the one hand (in particular for leak or breakage detection purposes, this is of particular importance for the Company as, at present, major leaks breakages may remain undetected for several hours or even days as leaked water flows into the sewers), and on the other hand with the technical data-base, from which they will draw accurate and permanently updated information.
  Integration or coupling of these various applications should be completed by the end of 1988.

CONCLUSION

Through a brief examination of these two case studies, the authors wish to point out that, due to advances in computer science and technology and improved adequation of softwares or systems proposed by specialized firms to the specific requirements of the Water Industry throughout the world, computer applications for design and operation of water supply and distribution systems must not be considered as the uttermost stage in technical and operational developpement, as they were considered a few years ago. They are nowadays a basic tool dedicated to instantly serve the needs of the Water Authorities and Companies, at any stage of their institutional, organizational and technical development. In order to preserve medium term evolution, they should be identified and designed within the frame of global computerization schemes, and implemented progressively with priority patterns specific to each situation.

PIPELINES NEED PROPER PROTECTION

Vandervelde Protection

Rijswijk, The Netherlands

INTRODUCTION

Quoting from an article recently published in one of the Dutch newspapers : The costs of corrosion are almost 10 cents (1.3 Bhat) per citizen per hour. Imagine the costs per day or per year.
It is therefore no use to argue about the necessity of prevention of and fight against corrosion.

Cathodic protection is one of the methods of corrosion prevention of metal structures in contact with soil or water.

Protection against corrosion of underground pipelines

As for the distribution of gas, water, oil and all other kinds of products an underground piping system, mainly consisting of steel pipelines, is being built throughout the years. The total length of all underground pipelines in Thailand will be a considerable amount of km's. In the Netherlands, for example,several tenthousands of km's steel pipelines are installed and buried in the soil.

This piping system is constantly being threatened by damages due to digging and corrosion. It is of course a must that investments in pipe transport systems has to be protected sufficiently against corrosion.

The corrosion attack can be either from the inside through the medium to be transported as well as from the outside through the soils surrounding the pipelines. In this article we will only concentrate on the corrosion damages on the outside surface of the pipelines that might occur and the measures to be taken against it; such as the application of a suitable coating and in addition a cathodic protection system (CP) The possibilities to maintain and safeguard the condition of the buried pipelines are also described.

Corrosion

Corrosion of metals is an electrochemical process, in which the metal surface is in contact with an electrolyte. The electrolyte may be a film of moisture containing dissolved salts, e.g. as in the case of corrosion in the atmosphere, or may constitute the whole or part of the surrounding medium, e.g. when metal is immersed in fresh water, sea water or buried in the soil.

In the last case the electrolyte is the soil water, containing dissolved salts.

At the surface of a metal corroding in an electrolyte there are active electro-chemical cells in which current flows between anodic and cathodic areas.

The distribution of the anodic and cathodic areas depends on the metal surface and also on the nature of the surrounding medium.

Owing to the potential differences existing between the anodic and cathodic areas, positively charged metal ions leave the metal surface at the anodes while electrons leave the surface at the cathodes. Thus corrosion takes place at the anodic areas where metal ions react with the electrolyte to form the typical corrosion products. At the cathodic areas dissolution of metal does not take place, but reactions occur in the electrolyte.

Principle of cathodic protection

The principle of cathodic protection is to make the potential of the whole surface of the steel structure sufficiently negative with respect to the surrounding medium to ensure that no current flows from the metal into the medium. This is done by forcing an electric current to flow through the electrolyte toward the surface of the metal to be protected, thereby eliminating the anodic areas. The current may be obtained from any convenient external source, such as a battery, rectified alternating-current supply, direct-current generator or by galvanic action.
The principle of cathodic protection illustrated showes the use of both impressed current and galvanic anode system. The auxiliary anode is arranged to be at a higher potential than the metal structure to be protected, so that current will flow from the former to the latter.

Corrosion of steel normally can be entirely prevented if the steel is maintained at a potential not more than minus 0.85 V (-0.85 V) with respect to a copper/copper sulphate half-cell. Under anaerobic conditions when sulphate-reducing bacteria are present, it is necessary to depress the potential a further hundred millivolts, to minus 0.95 V (-0.95 V) with respect to a copper/copper sulphate half-cell.

For the system to work properly the structure to be protected shall be electrically continuous. Therefore, before installing a cathodic protection system, this continuity shall be ensured between all parts of the structure. for example, with an existing underground pipeline fitted with Viking Johnson couplings, it is necessary to provide electrical bonds.

Furthermore the structure to be protected should be insulated from other structures. Thus for underground pipelines insulation should be installed at locations where the lines continue overground, at buildings and other concrete structures. This to avoid current losses to the structures not intended to be protected.

Methods

The following two methods of applying cathodic protection to buried surfaces of metallic structures and pipelines are used :

a. Sacrificial anode

With the sacrificial anode method, use is made of galvanic action to provide the cathodic protection current. The surface of the structure is made cathodic by connecting it electrically to a mass of less noble metal buried or immersed in the common electrolyte, the less noble metal is then the anode. Magnesium , and in some cases zinc, is used for this purpose. The anodes are referred to as sacrificial anodes because protection of the structure is accomplished by the simultaneous consumption of the anodes by electrochemical corrosion.

b. Impressed direct current

With the impressed direct current method the structure is placed in an electric circuit with a direct power supply and an earth system or groundbed. The groundbed consist of high silicon iron anodes.
The groundbed materials used should show a relatively low consumption rate if they are to be used for long periods.

In general one will choose for the impressed current system since this is an active and fully controllable method however technical and economical reasons may lead to the choice of a sacrificial anode system.

Coating

Application of cathodic protection necessitates a suitable coating, which is to be applied to the structure. Such a coating must be inert, possess sufficient electrically insulating properties, and its bonding to the material must be good to avoid water penetrating between coating and material.
The following materials are in common used on pipelines in soil or in water.

Asphalt bitumen

Asphalt bitumen (average thickness 4-5.5 mm) is usually reinforced by impregnated wrapping. On site the welding joints are coated by the same materials.

Polythene

Polythene is usually applied by sintering in thickness of 2-4 mm (depending on pipe wall thickness), or sometimes by extrusion with an intermediate priming layer between metal and polythene. On site the welded joints are similarly coated or tape is wrapped around them (see butyl rubber for description).

Butyl rubber

Butyl rubber tape is applied on site to welded joints and auxiliaries. A tape of 0.4 mm thickness is wrapped around the cleaned object after a priming layer has been applied for better adhesion. this is reinforced by adding one or two layers of this PVC tape. When coating the pipes the two types of tape are wrapped around simultaneously

Asphaltic mastic

Asphaltic mastic is applied by extrusion with a priming layer between metal and coating. Thickness ranges between 10 and 20 mm. It is used particularly in water and in marshy areas, where the weight of the coating adds to the weight of the pipeline.

The densities of protective current for the various types of coating are given in below table.

coating	coating thickness	current density
asphalt bitumen	4 - 5.5 mm	1 - 100 microA/m2
polythene	2 - 4 mm	1 - 10 microA/m2
butyl rubber	(tape) 0.4 mm	50 - 100 microA/m2
asphaltic mastic	10 - 20 mm	50 microA/m2

The values given in the table are approximations and depend on factors as thickness of coating, the correct application of the coating in accordance with manufacturers instructions, installation of the pipeline, inspection and repair of damaged spots before backfill.

The required cathodic protective current will increase somewhat over the years, but not significant under normal conditions.

Monitoring the condition of buried pipelines

It is obvious that pipeline-owners need to have the best possible report on the condition of their pipelines, including coating condition and the functioning of the cathodic protection system. Coating-damages and insufficient functioning of the cathodic protection system will cause local corrosion followed by leakage. Periodic visual control on the condition of the pipeline seems to be the answer. However one must take into account that visual control will always give very local information on the condition of the pipeline which is normally only a very small part of the total pipeline routing. Such visual checks are very costly. Therefore other possibilities of obtaining information on the pipeline condition is very necessary. The existing cathodic protection system combined with specific test procedures gives such possibilities. We will discuss the existing possibilities.

Cathodic protection potential checks.

Another possibility is to measure the potentials of the pipeline under protection. To have proper protection a minimum potential of 850 mV measured against a $CuCuSO_4$ reference cell is required. Such test will be carried out once or twice a year with the test cell placed on the ground surface right above the pipeline. The voltage drop as a result of the resistance of the soil must be taken into account.

To eliminate this voltage-drop the cathodic protection power supply can be switched off during short intervals and the potential can be measured directly after switching off. Not using this so-called ON/OFF method of testing can give a to optimistic idea of the functioning of the cathodic protection system, thus concluding a proper functioning of the system which may not be the case.

Current requirement of the cathodic protection system

The current required to give proper cathodic protection for a specific project together with the potential value at the initial switching on of the cathodic protection system should be recorded and be used as a reference to values obtained during the regular inspections.
It may be possible to detract information on the coating quality from the current requirement.
The two tests described above will give the basic information on the functioning of the cathodic protection system and gives also some information on the quality of the coating.

Sometimes and for various reasons the results of these periodically test may ask for further investigation such as information on coating damages.

Pearson-tests and close potential survey

To obtain information on coating damages with above ground test Pearson-measurements and close potential tests can be carried out.

With pearson tests a continuous signal of 1000 Cy AC voltage is connected tô the pipeline and while walking over the pipeline signals can be received with detection-equipment which implicates the location coating damages. If more coating damages are found the relative value of the damage can be determined.
Also close potential survey checks can be used to find coating damages.
This method is based on the principle of changes in the potential-field around the pipeline as a result of a coating damage. By testing the potentials with short intervals over a small part of the pipeline more detailed information can be obtained on the locations where the coating is possibly damaged. Also the level of cathodic protection can be measured at the location of coating damages as well as the amount of damages.
The latter method is not very oftenly used because of its high costs due to the manpower required. However a combination between pearson tests and close potential survey tests can very well be used. First locations of coating damage are being determined with the pearson-method and at those locations the level of protection is tested using the intensive test method.

Visual control

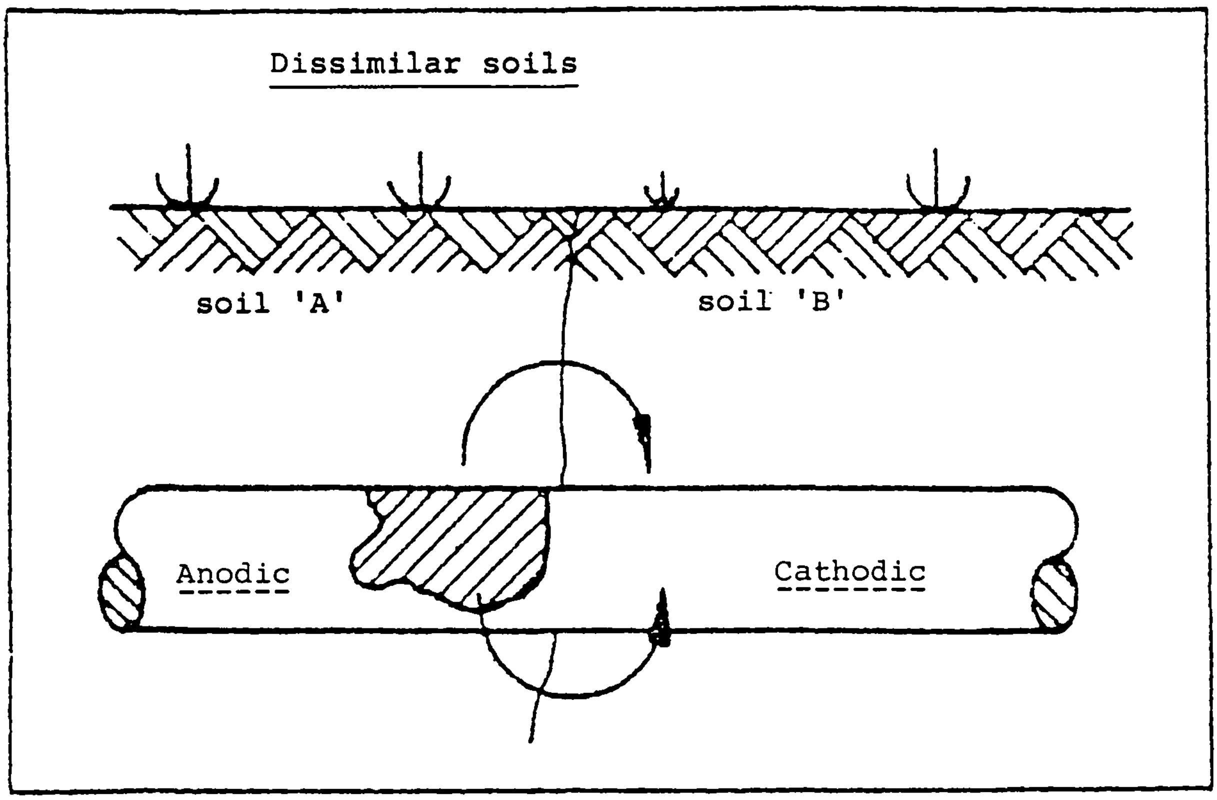
After studying the results of one or more of the afore described technics a decision can be made to carry out a visual inspection. Locally the quality of the coating as well as the presence of disbonded coating etc can be determined. Also the level of possible corrosion and/or mechanical damages can be determined. By the above mentioned technics the condition of the underground pipeline will be guarded as efficient as possible.

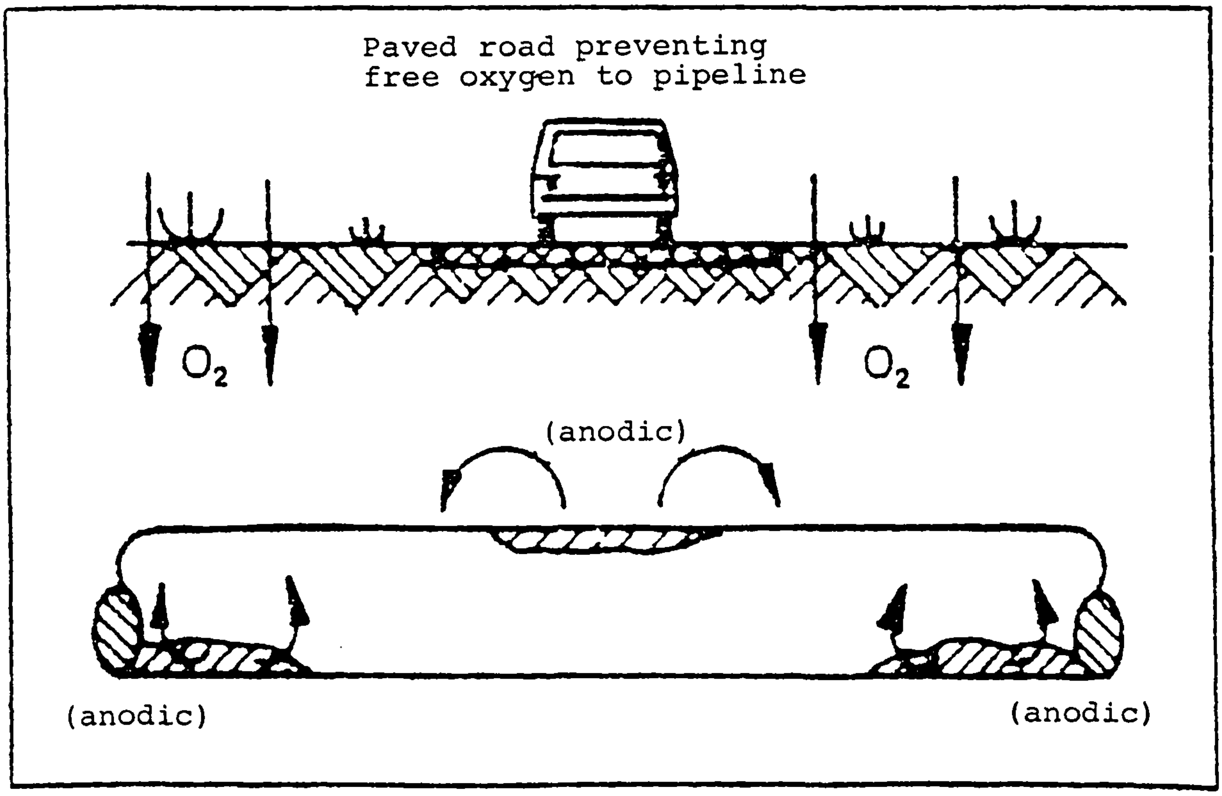
Costs and Revenues

Protection against corrosion is definitely required due to safety reasons as well as from the economical point of view. As for safety reasons protection against corrosion is even more important since leakages can occur at unpredictable times and locations.
From the economical reason it is important since corrosion is the only thread and reason for losing the entire pipeline.
Against a relatively low part of the total project costs an almost 100% protection of the pipeline system can be obtained.

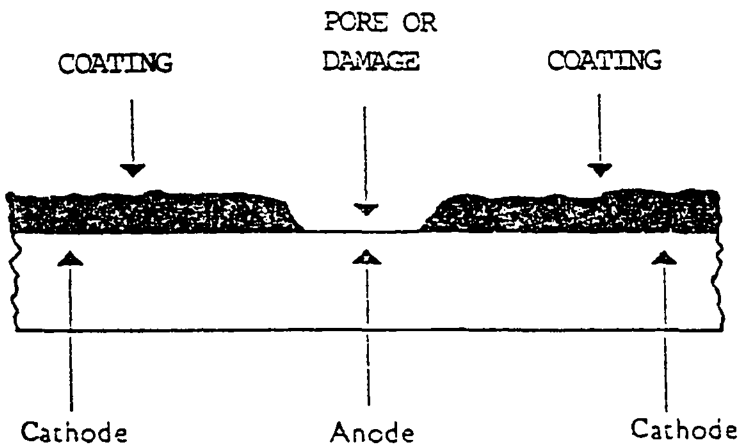
Conclusion

Against a relatively small investment external corrosion of underground pipelines can fully be controlled using technology on a high level.

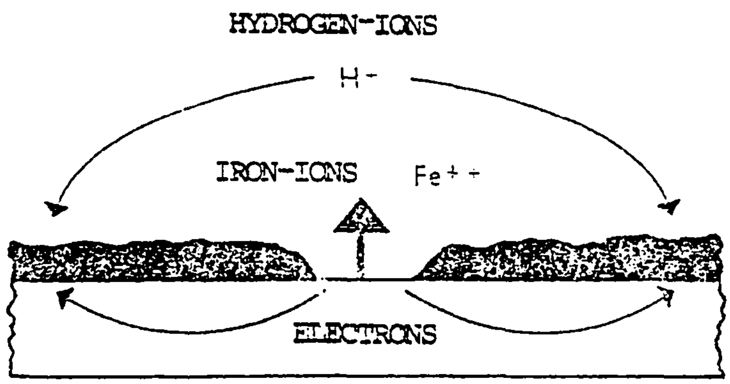

Dissimilar soils
soil 'A'
soil 'B'
Anodic
Cathodic


Paved road preventing
free oxygen to pipeline
O_2
O_2
(anodic)
(anodic)
(anodic)

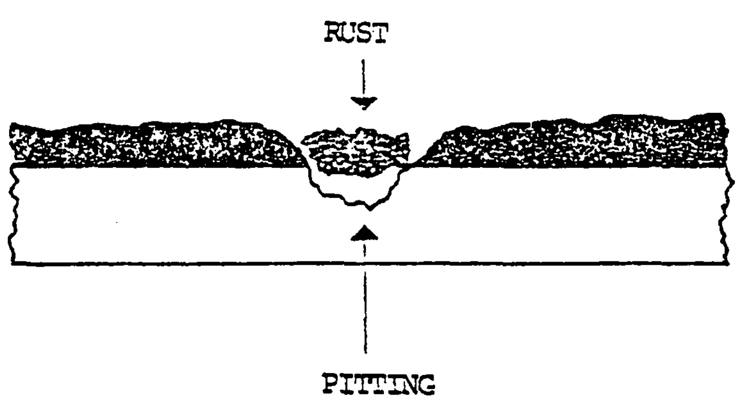
C O R R O S I O N



PORE OR DAMAGE
COATING
COATING
Cathode
Anode
Cathode

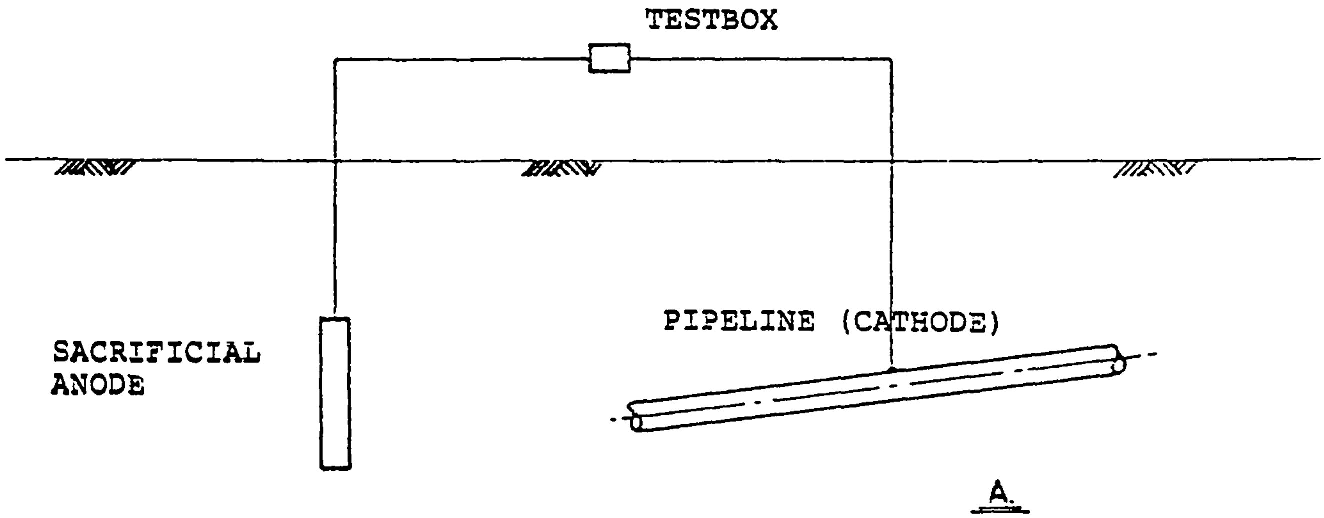


HYDROGEN-IONS
H+
IRON-IONS
Fe++
ELECTRONS

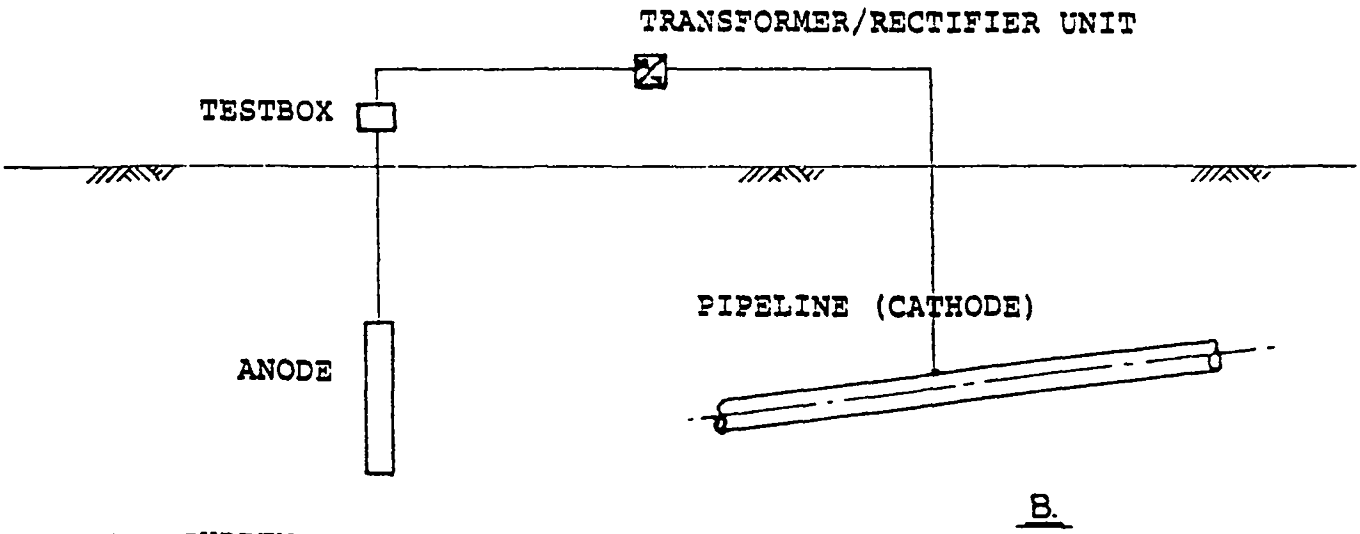


RUST
PITTING

Principle of cathodic protection

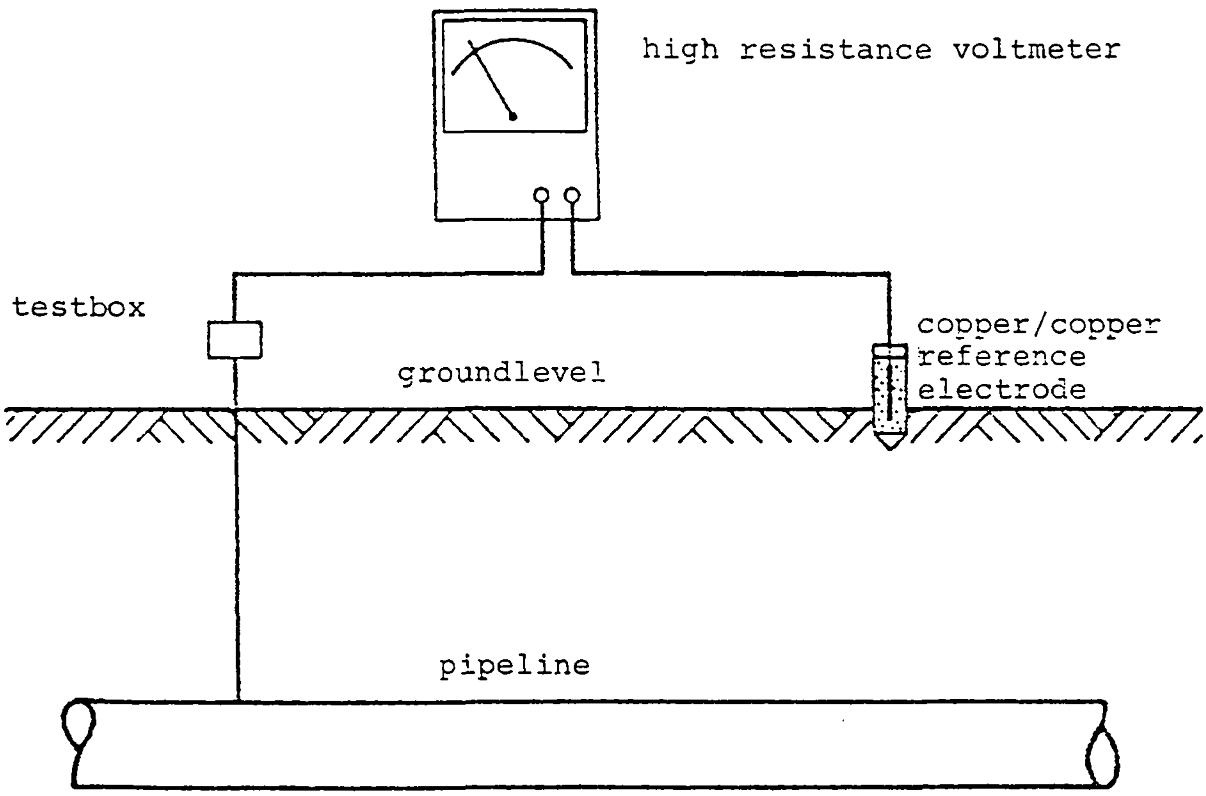


SACRIFICIAL ANODE SYSTEM



IMPRESSED CURRENT SYSTEM

Principle potential measurement



OPTIMISING OPERATIONAL CONTROL AND MANAGEMENT UTILISING INFORMATION FROM AN ADVANCED MULTI-FUNCTIONAL SCADA SYSTEM

by :

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ABSTRACT

This Paper will briefly describe the re-configuration of, plus latest additions to an established SCADA system supervising both water supply and sewage functions. The improvements to system include:-

a. Replacement of the original master station computers by powerful modern mini-computers.

b. The addition of an off-line modelling computer linked to the main telemetry machines.

c. The addition of new, low cost, intelligent Remote Transmission Units (R.T.U's.) communicating with the control centre via the public telephone network on a daily basis.

Significant advances in both on-line control and operational management are being made using information from the enhanced system, especially in the following areas:-

a. The implementation of substantial research work into the scheduling of pumps to minimise pumping costs.

b. The installation of bulk flowmeters to split distribution zones into smaller districts for continuous waste monitoring.

c. The widespread application of pressure control utilising the intelligent R.T.U's for leakage control.

d. The integration of various data systems using a single operational database to enable the assessment of overall running costs to be made 'on-line'.

A. THE OPERATIONAL SCADA SYSTEM

This section of the paper describes briefly the development of a control system for water supply operations since 1974. The extension of control from a single function activity (Water Supply) to a multifunctional role incorporating Water Distribution, Sewage Disposal Works and Sewerage Systems.

The supervisory control scheme may be regarded as being brought into operation in four phases (1974, 1977, 1983 and 1987) with planned expansion throughout all phases.

Thus the Phase I telemetry installation was based on a central processor unit, with presentation of data by a 'four-colour' V.D.U. complemented by a relatively simple mimic diagram. System data recording was covered primarily by two electric printers.

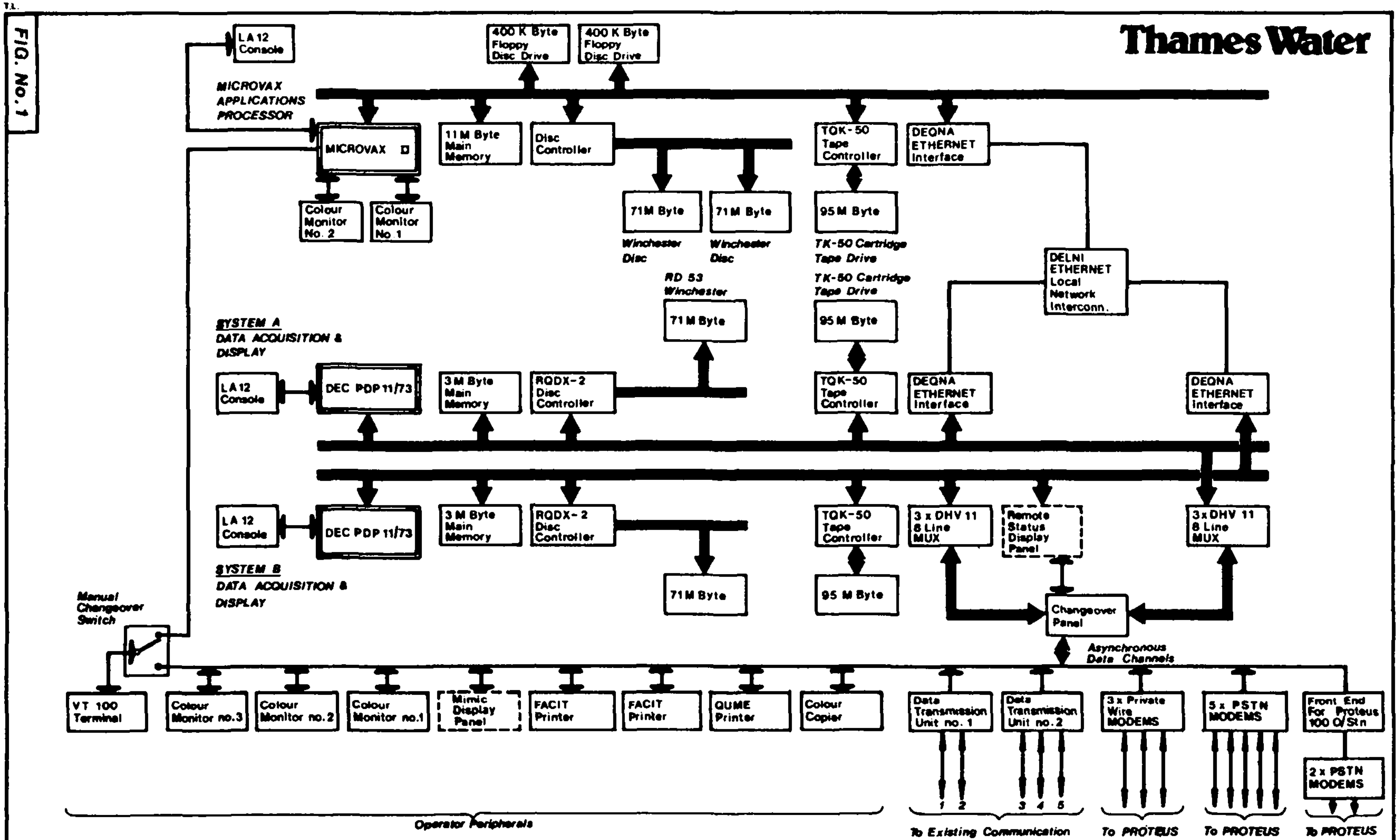
The prime function of Phase I was the operation of a water supply/distribution network covering some 17 installations. Communication links between master station and R.T.U's were established over a mixed cable network of 15% rented telephone circuits and 85% private lines.

This basic system was retained in Phase II, the most significant feature of which was the employment of V.H.F. radio to bring in alarm information from 72 remote sewage works and sewerage pumping stations within the Authority's divisional area. This second phase was achived in early 1977 making the system multifunctional. Software improvements at this time enabled a significant advancement to full "conversational" mode considerably improving its data handling capabilities together with the flexibility to "re-compile" the system without calling the manufacturer's programmers.

Further re-organisation (1977) added a significant additional adjoining area for the operation of the water supply/distribution function. The phase III extensions to the system were then planned, implemented and were commissioned by early 1983.

Although all the R.T.U. equipment in the first two phases was retained, the control centre building, master station computers and peripherals were all replaced with a modern, purpose built building and new 'state of the art' hardware. A substantial number of new R.T.U's were installed at the additional sites to be monitored. The network at this stage had a total of 65 R.T.U's on the main Time Division Multiplexing (T.D.M.) system with additional 72 V.H.F. radio alarm R.T.U's added with the Phase II modifications. The network is described in depth in an I.W.S.A. Paper (Parker & Pond, 1983).

Yet further re-organisation (1984) within the Authority placed a requirement on the control cente for coverage of a much larger geographic area. This fact, together with the proven track record of the existing SCADA system, provided us with an ideal platform to carry out a programme of research and development. Three of the most significant areas of research were described in an I.A.W.P.R.C. Paper (Parker, 1985) and covered topics dealing with a new approach to zone pressure control, remote supervision and monitoring of a medium size sewage treatment works using computer emulation techniques, and automatic water quality monitoring in the distribution network.



Bourne End Control System

PHASE IV IMPROVEMENTS

mainstream computer system schematic

In 1985 Thames Water Authority placed a major research contract with Tynemarch Systems Engineering Ltd., a Company formed by staff at Imperial College London, for an investigation into the implementation of optimum on-line control of pumping plant for a complex water supply network. The Chilterns area system was chosen for the feasibility study for the following reasons:-

a. The Chilterns' network was already served by the Phase III extensive SCADA system covering all water supply installations.

b. All pumping station flows, inter-zone flows and reservoir storage levels were monitored remotely at the control centre.

c. Hardware at the control centre could be easily upgraded to incorporate an on-line data archive plus the addition of an off-line modelling computer upon which the optimising software could be developed.

d. Detailed extended period simulation models of the hydraulic performance of the distribution system had already been developed on mainframe computers and hence could be used to test the network behaviour.

The control centre computers were replaced in Autumn 1987 (see Fig. 1) by powerful modern DEC PDP 11/73 mini-computers with extensive disc drive capacities for on-line data archiving, plus a new link to an off-line DEC MICROVAX II modelling computer which can process selected information from the control system database. Radical changes to the telemetry network were introduced at the same time; the most significant of which was the replacement of the Phase II V.H.F. radio R.T.U's with low cost units which communicate via the public switched telephone network (P.S.T.N.). The system capabilities now allow for the expansion of the network to a total of 75 hard wired (T.D.M.) R.T.U's and 560 (P.S.T.N.) R.T.U's of varying capacity and intelligence.

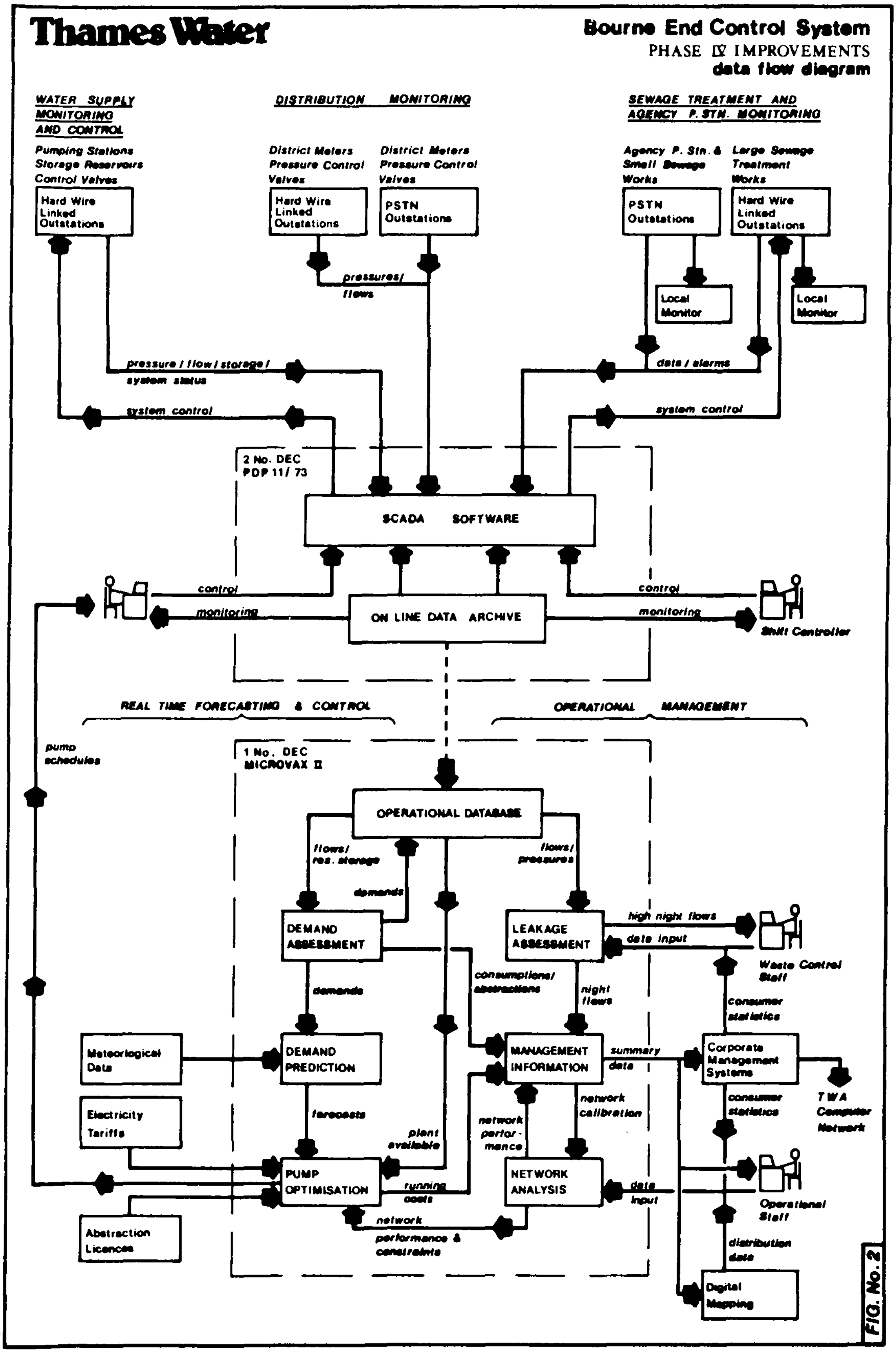
With the continuing pressure placed upon management to operate all the Authority's installations at optimum efficiency, the introduction of a the off-line modelling computer in the control centre has enabled us to develop significant systems which are described in depth in the remainder of this Paper.

B. ADVANCES IN ON-LINE CONTROL & OPERATIONAL MANAGEMENT

1. Optimisation of Pumping

A major part of Thames Water Authority's water supply operating costs is electricity charges for pumping. Chilterns area alone currently spends around £1.3 million per annum on electricity for water supply pumping. Preliminary investigations suggested that there was considerable scope for reducing these costs by the introduction of optimum pump schedules, that would take maximum advantage of the U.K. electricity tariff structure and preferential use of the most efficient pump sets.

In the U.K. electricity supply boards offer a choice of charging structure to their industrial consumers. Some of these encourage the off-peak use of electricity by presenting financial incentives to the consumer to reduce peak loads, which leads to a more uniform pattern of power consumption, thus reducing generating costs and total required generating capacity. Basically these incentives are both diurnal, in


Thames Water
Bourne End Control System
PHASE IV IMPROVEMENTS
data flow diagram
WATER SUPPLY MONITORING AND CONTROL
DISTRIBUTION MONITORING
SEWAGE TREATMENT AND AGENCY P. STN. MONITORING
Pumping Stations
Storage Reservoirs
Control Valves
Hard Wire Linked Outstations
District Meters
Pressure Control Valves
Hard Wire Linked Outstations
District Meters
Pressure Control Valves
PSTN Outstations
Agency P. Stn. & Small Sewage Works
PSTN Outstations
Large Sewage Treatment Works
Hard Wire Linked Outstations
pressures/ flows
Local Monitor
Local Monitor
pressure / flow / storage / system status
system control
data / alarms
system control
2 No. DEC PDP 11/ 73
SCADA SOFTWARE
control
monitoring
ON LINE DATA ARCHIVE
control
monitoring
Shift Controller
REAL TIME FORECASTING & CONTROL
OPERATIONAL MANAGEMENT
pump schedules
1 No. DEC MICROVAX II
OPERATIONAL DATABASE
flows/ res. storage
flows/ pressures
demands
DEMAND ASSESSMENT
LEAKAGE ASSESSMENT
high night flows
data input
Waste Control Staff
consumptions/ abstractions
demands
night flows
consumer statistics
Meteorological Data
DEMAND PREDICTION
MANAGEMENT INFORMATION
summary data
Corporate Management Systems
TWA Computer Network
Electricity Tariffs
forecasts
plant available
network performance
network calibration
consumer statistics
PUMP OPTIMISATION
running costs
NETWORK ANALYSIS
data input
Operational Staff
Abstraction Licences
network performance & constraints
distribution data
Digital Mapping
FIG. No.2

the form of reduced charges for total energy consumed at night, and seasonal, in the form of charging for maximum power consumption during winter daytime periods.

The formulation of a pumping schedule to achieve minimum electricity charges is not, however, necessarily comparable to one that achieves minimum overall operating cost for a water supply undertaking. As the diurnal pattern of domestic electricity and water use are generally similar in nature, to take advantage of off-peak electricity rates consequently involves a policy of increased nightime pumping. This can lead to higher night pressures in some distribution systems resulting in an overall decrease in pumping efficiency together with an increase in leakage and frequency of bursts within the distribution network. Thus to obtain a real minimum operating cost in many complex water supply systems the optimal pump schedule should contain an assessment of these increased costs against the expected savings in electricity charges.

Also, an increased off-peak pumping programme will necessitate a greater diurnal variation in service reservoir storage and hence a reduced margin of safety against problems such as bursts or pumping station failures. In cases where the amount of off-peak pumping is limited by the storage in the reservoir it is important to formulate a method of adjusting the pump schedule according to demand to ensure minimum reservoir storage levels are not exceeded whilst off-peak pumping is maximised. In addition to this, the pump schedules must also be adaptable to current pump availabilities, and various operational constraints.

In simple, isolated distribution systems usually containing a single sourceworks and reservoir, it may often be possible to build considerable flexibility into a manually prepared optimum schedule. In these cases very little extra savings are gained by the preparation of on-line pumping schedules.

However, as the supply networks become more complex and inter-related, so the options increase rapidly and it becomes far more difficult to apply a simple, manually derived schedule. Usually, maximum savings can only be achieved with an on-line computerised system. Obviously the difference between a manual and computer based solution in cost terms will vary depending on the actual network chosen.

Full details of the optimisation software developed under the research contract can be examined in a paper entitled 'Optimisation and Operational Control of Water Supply Networks' by G. Germonopoulos, R. Garrett, P. Jowitt and S. Cook and presented at the International Conference Computer Applications for Water Supply and Distribution, 1987, Leicester Polytechnic, U.K., 8th-10th September 1987.

Basically, the optimiser software consists of a suite of programs which are normally executed sequentially and automatically every day. The first program establishes communications between the PDP 11/73 telemetry computers and the Microvax II modelling machine. It sends a list of raw data files which are requested from the on-line data archive within the PDP 11/73 and transferred to the operational database of the Microvax II (see Fig. 2). Demands are then calculated from zonal flows plus reservoir storage values and a processed file containing daily demand data appended accordingly.
The second program forecasts the next day's demand and the demand profile on a zone by zone basis using historic information from the

daily demand file plus any relevant meteorological data required. The program will normally proceed automatically but manual intervention is possible to modify or replace the forecast in special circumstances.

The third program consists of the optimiser itself. Firstly, information on the current state of the network is transferred to the Microvax from the PDP machine to initialise the optimisation. The pump scheduling is formulated as a linear program to minimise unit electricity costs but with an iterative procedure to account for maximum demand electricity charges (KVA). Typically, this results in 10 runs of the linear program resulting in a total run time of around 10 minutes.

The forth program is an implementer routine which translates the optimal schedule produced by the linear program into pump switch timings. The program also retrieves demand forecast data, network configuration data , plant availability and constraint data from the database to produce demand forecast tables and graphs, reservoir profile tables and graphs, and pump priority tables which are available both on-screen and as print-outs. The optimiser software also contains a network simulation program which can be used to determine network operating costs as well as heads and flows. This simulator has an explicit leakage function and accommodates pressure dependent demands.

The full optimisation routine is currently being evaluated for cost effectiveness on-line but initial results suggest savings of between 8% in summer periods to 15% during winter months will be achieved.

2. Improvements in Leakage Control

Continuous Waste Monitoring

Traditionally, most active waste detection programmes in the U.K. were based on waste metering. This method involved dividing the distribution system into small areas at night, each being isolated by closing certain valves and then fed via a waste water meter, either temporarily or permanently installed, to measure the minimum night flow.

The routine reading of these meters was then used to give an indication of those areas where serious new leakage had arisen so that these leaks could then be located.

In the Chilterns supply area of Thames Water there are 160 waste districts covering a population of 270,000 and thus, the routine reading of these is quite labour intensive and costly because many districts can only be valved in during the night hours. The relative rise in the cost of manpower in the last two decades coupled with a dwindling labour force placed an enormous strain on the ability to maintain an effective waste metering programme.

The introduction of Phase III of the SCADA system at Bourne End as outlined in Section A enabled the input and outputs to all distribution zones (i.e. booster pump flows, control valve flows) and reservoir storage levels, to be recorded hourly at the master station. This information could be used to monitor the overall nightflow levels for each distribution zone, thus indicating those areas to which leak detection activities could be most profitably directed. This system of 'zonal' metering worked well for small zones but the occurance of new leaks went undetected in the larger zones because of their size, thus the system of routine waste water meter reading was still required to determine high leakage areas.

However, recent improvements in the range and reliability of flow meters has made it possible to consider installing bulk meters for waste evaluation purposes. Large distribution zones can be divided up into smaller, permanently metered districts covering 4 or 5 waste water areas and, with similar rapid advances in micro-electronics, it is now economic to monitor these meters continuously, using telemetry to relay both pressure and flow data back to a central control centre. The nightflow informaton from these 'district meters' thus enables the worst waste meter areas to be quickly identified.

Approximately 50-60 new bulk flow meters are currently being installed within the Chilterns area distribution network and will enable the larger distribution zones to be split into a total of 30-35 districts of between 2-4,000 properties each. The flow into each district will be continuously monitored by new low cost intelligent R.T.U's and the information sent back to Bourne End control centre by either P.S.T.N. or T.W.A's own private land lines. Because a district meter must be able to cope with peak flows as well as measure low flows accurately, the selection, sizing and siting of the meter is of paramount importance. A detailed computer model of the hydraulics of the distribution network was used to determine meter positions and size. For flow measurement, meters of the electro-magnetic type have been selected for the following reasons:-

a. Their extreme accuracy over a wide range of flows.

b. Their reliability and minimal maintenance requirements (no mechanical moving parts).

c. They present no obstruction to the flow and thus cause virtually no additional head loss within the distribution network even at peak flows.

The decision to incur a higher initial capital cost on meters and on remote monitoring as opposed to manual reading was based on the need for a robust, long term future policy on leakage control. With this approach the additional capital cost is significantly smaller than the overall revenue cost of a continued manpower requirement to maintain a less technological solution.

The advantage of a district meter system is that once districts have been isolated and boundary valves proved, nightflows can be monitored at any time without recourse to further valving and expensive nightwork. So, in the Chilterns area, a move to bulk metering is also taking place at waste meter, as well as district meter level to reduce nightwork as much as possible, but yet increase the ease and frequency of nightflow monitoring. Gradually, waste meter zones which could only be run at night are being re-established, wherever possible, into zones that can run constantly, or at least be valved off during the daytime and old, chart based meters replaced by new helix type meters for which data logging or remote reading facilities are available.

Pressure Control Utilising Low Cost Intelligent R.T.U's

The principle of using pressure reducing valves (PRV) to reduce excess mains pressure and hence leakage is well establised in the Chilterns area. Until recently those in use were all of the conventional hydraulic, or weighted fixed outlet head type. These devices were of varying age and the reliability of many had become questionable. The upgrading of the master system hardware and installation of new low cost R.T.U's for district metering provided the opportunity of using the R.T.U's for the widespread application of pressure reduction using a microprocessor based pressure control valve.

The position of a valve situated at the R.T.U. site is controlled by software in the R.T.U. which receives signals, via a British Telecom wire, from a remote pressure sensor recording the mains pressure at the point of minimum pressure within the pressure controlled area. The position of the valve is adjusted such as to keep the pressure at the remote sensor point constant irrespective of demand. Full details of control procedure are described in an I.A.W.P.R.C. Paper (Parker, 1985).

Installation of the microprocessor based valve has several significant advantages over controlled fixed outlet or flow compensating PRV's:-

a. The valve is controlled directly by the pressure at the most sensitive point in the system, whereas both flow compensating and fixed outlet PRV's are set up based on an estimate of the remote pressure at peak flow. Hence a tight control on pressure under both normal and extraordinary flow conditions is 'guaranteed' using a pressure based control system.

b. The system's main mechanical component is a simple actuated valve. Thus the reliability has been much better than many of our conventional hydraulic PRV's with their complex control pipework.

c. When combined with district metering, and so using the same R.T.U's, the additional cost of pressure control is simply the actuated valve plus the remote sensor. Hence used in this context, the installation of the system is very cost competitive with hydraulically based PRV's. The software that controls the valve is programmed into the R.T.U. as a standard facility.

d. Because the unit is linked via telemetry to the central control centre, its performance can be evaluated on line at any time and new parameters downline loaded to the R.T.U. if necessary to improve its performance. The unit can also be 'alarmed' so that any problem can be acted upon immediately. With hydraulic P.R.V's however, even with regular servicing and inspections, it may be some time before a malfunction is detected.

Where the siting of the pressure control device cannot be combined with the district meter R.T.U. then hydraulically controlled PRV's, of the resilient sleeve type, are being used.

The widespread application of pressure control also has an important 'spin off' to the pump scheduling exercise, in that much of the distribution system can be protected from the higher night pressures generated by increased off peak pumping. The cost effectiveness of the savings in electricity charges are therefore enhanced.

Thames Water

Bourne End Control System
PHASE IV IMPROVEMENTS
expenditure profiles for leakage policy options

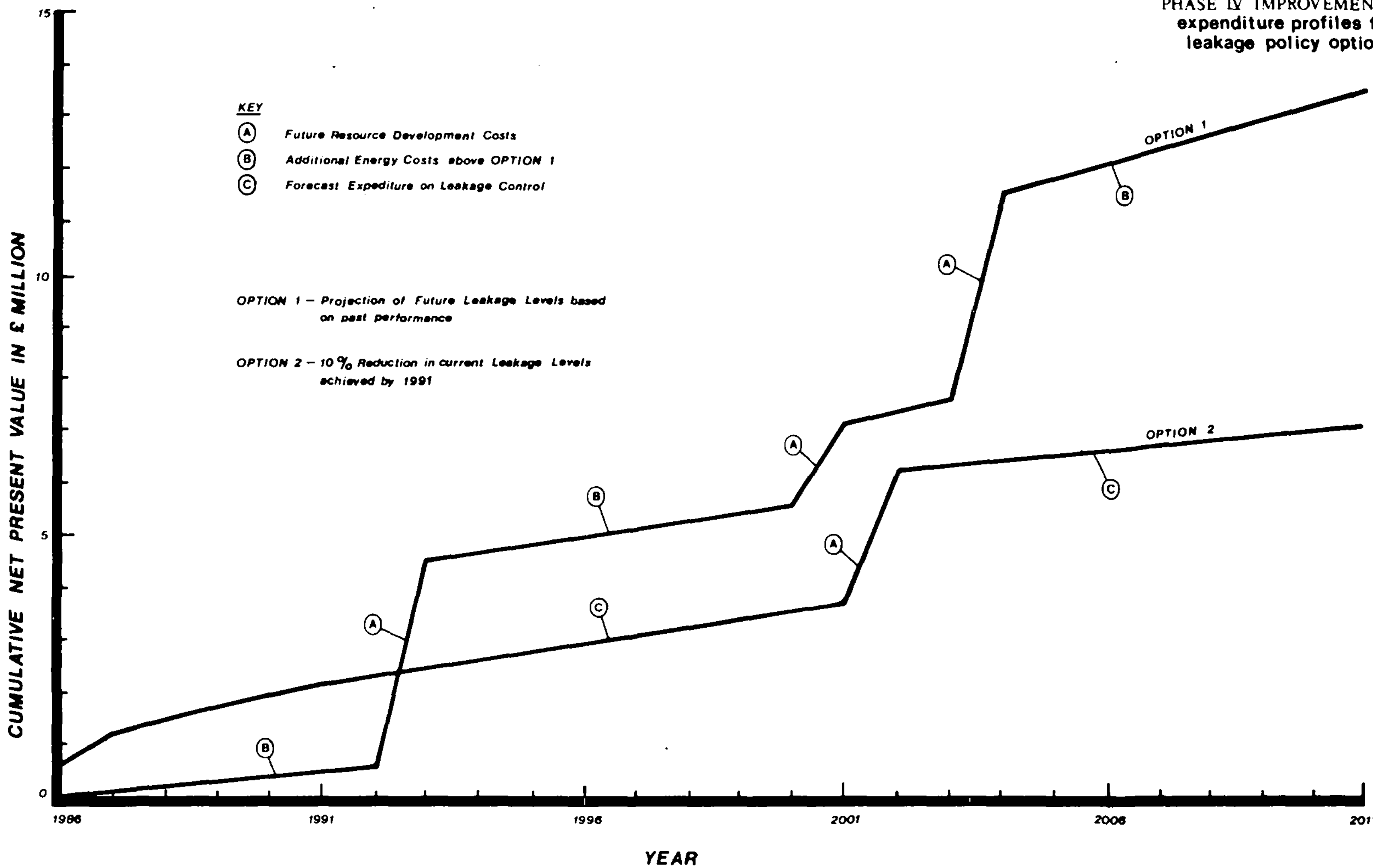


FIG. No.3

Figure 3 illustrates the projected savings of the entire leakage control programme, including district metering and pressure control, in Net Present Value terms. Option 1 is based on a continuation of past performance on leakage control and includes future resource development costs plus additional pumping costs above Option 2. Option 2 includes for all forecast expenditure on leakage control including district metering, waste metering, pressure control and repair of leaks, plus the revised expenditure of resource development to meet the reduced rate of growth. Option 2 assumes that a 10% reduction in current leakage levels is achieved by 1991. Results from zonal metering, current pressure control schemes and district meters commissioned so far, indicate that this target will be achieved and probably exceeded.

Figure 3 demonstrates there are no quick savings to be made from leakage control and thus investments should be aimed at achieving returns in the longer term. Hence our decision to purchase district metering equipment of the latest technology with minimum maintenance and manpower requirements should realise greater savings.

3. Integrated Data Management

Figure 2 illustrates the main uses of information collected by the enhanced SCADA system and the means by which it is processed. Basically, raw data collected by the master station is labelled and stored on the disc drives of the two telemetry computers. Up to seven days of information can be stored in this manner before it is overwritten. In this form the data can be easily accessed by the SCADA software for on-line calculations or for graphical presentation to provide 'up to the minute' monitoring of the system.

The Microvax II modelling computer may request a selection of this data to be transferred at any time. It is then processed and utilised by the main software packages contained within this machine and also stored in the operational database.

The decision to incorporate the additional hardware outlined in Section A into the existing SCADA system with a single operational database has many advantages. For example, the effect of optimum pump schedules on leakage levels can be readily assessed, and this information incorporated into the scheduling program. Similarly, information on demands calculated from nightflow levels from the district meters can be compared directly with pump flows and changes in storage on a 'zonal' basis.

Thus the integration of the various data systems enables a much better assessment of overall running costs to be made 'on-line'. Also the production of management statistics and the interaction with other Thames Water information systems is greatly simplified and made more cost effective. Information such as consumer statistics and industrial consumption can be obtained from financial systems and stored within the operational database for use by all the software packages.

Finally, the establishment of a single multi-functional control centre with links to smaller SCADA systems removes the need for on site computer backup or supervisory shift working for these systems, yet enables specialist software for process optimisation to be developed and utilised locally.

ACKNOWLEDGEMENTS

The Authors wish to express their thanks to Serck Controls of Coventry, U.K., Tynemarch Systems Engineering of London, U.K. and Thames Water Authority, all of whom have contributed greatly towards the success of the Project.

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POTABLE WATER PLUMBING STANDARD UNDER THE SAFETY USAGE PLAN IN TAIPEL

by :

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ABSTRACT

There are six chapters of preface, designs, materials,works, tests and conclusions will be discussed simply in here to show how to help plumbers designing and constructing a sound potable water plumbing system in a building in accordance with Taipei Potable Water Plumbing Standard.

I PREFACE

Far away times, It was not difficult to take water from rivers and wells as drinking water after being boiled by residents of Taipei. The first water works was build in year 1903. Nowaday, there are more than 6 water works of Taipei Water Department (TWD) produce and supply about 1.75 millions cubic meters of water, qualities match the qualities of potable water, to nearly 3.5 millions people living in city and surburbs per day. Most of people keep the habit of drinking water after water being boiled, because they don't think the potable water from plumbing system is safe enough to drink directly. There are some water contaminated events occured because potable water plumbing systems in the building was not designed well or hadn't good management after the system intalled. Hence, Safety Usage Plan,has been carried out by TWD since 1983 and consists of reservoirs building, water works enlargement, public mains renewal and potable water plumbing system improvement, makes the potable water to be sufficient and keeps the qualities of water to be homogeneous from water works to faucets there occupants can use it safely.

In the side of fixtures. There is only a public faucet for houses or a building of some families, then one tap to one family for counting easily. Nowaday, bathrooms with bath, water closet, washbasin, shower, etc. are very common in families. Fixtures are fixed in the building as convenient as possible. Taipei Potable Water Plumbing Standard (TPWPS) with 39 articles ,established in 1973 and revised in 1985 by Taipei City Government, is a plumbing code abided by plumbers for design and construction a good plumbing system. It is also a bridge of management among TWD, plumbers and occupants.

The paper shows how TWD makes an effort to carry out TPWPS to help plumbers and occupants to make a sound potable water plumbing system to union the other parts of Safety Usage Plan.

II DESIGNS

All building must be provided with potable water in quantites adequate to occupants' need. Plumbing fixtures, devices and appurtenances should be supplied with water in sufficient volume and at pressure adequate to enable them to function properly.

For each fixture in a building a maximum requirement for water flow, l/min, can be anticipated. Table 1 indicates the minimum flow rate and pressure that plumbing code require must be provided.

Branch pipes to fixtures should be sized to provide the miximum flow and minimum pressure the fixture must be required Table 1 also indicates the size of branch pipe to each fixture.

Mains, serving these branches, are sized for the maximum water demand that all the fixtures would be operating at the same time. Table 2 shows the percentage of simultaneous operation of all the fixtures. Sizes of mains can be calculated with two methods as follows.

1. Diagram Method
   Diameters of mains in a building may be calculated with equivalent pipes table (Table 3) and simultaneous operating percentage table (Table 2). Instance as diameters of pipes of toilet room (Fig. 1) can be calculated by a calculated diagram (Fig. 2). It is easy to calculate a small plumbing system by diagram mathod. It is better to calculate it directly on the drawing of larger plumbing system with Table 2 and Table 3.

2. Fixture Unit method
   A fixture-Unit is defined 28.4 l/min, fixture Units of fixtures are shown as Table 4.
   Total fixture-unit value of fixtures served by a pipe should be calculated at first. And in accordance with estimating curve shown as Fig.3 and Fig.4 where flow rate may be found from the figure. Then the diameters of pipes may be calculated by the formula as follows.

$$D = 20\sqrt{\frac{Q}{6\pi V}}$$

Q: Water demend 1 /min

D: Diameter of pipes (m/m)

V: Water velocity m/sec

Water velocity depends on the size of pipe shown in Table 5 being suggested by TWD.

If the pressure of public water mains is large enough to raise water upward and still retain desired pressure at plumbing fixtures, potable water can be distributed by upfeed water-distribution system (Fig 5). In Taipei only first floor and one story building are allowed to be served by the upfeed method, because the lowest pressure of public water mains is about from 0.3 kg/cm^2 to 0.7 kg/cm^2 when the maximum water demand is served. Otherwise the downfeed water-distribution system (Fig 6) should be done.

It is conventional to pump water to one or more elevated storage tanks, from which pipes convey the water downward to plumbing fixtures. It is forbidden that pump is operated from a public mains directly to prevent drawing so much water that the pressure in the mains would be considerally reduced. So a suction tank at the bottom of the building should be installed for pumps. The tank is refilled automatically from the public mains. The size of service pipe of a building is bigger than 50 m/m in diameter, a receiving tank should be installed on the ground when the suction tank under the ground level to avoid having influence on the pressure of public mains.

The pressure at which water is delivered to fixtures must lie within acceptable limits, Otherwise, low pressure may have to be increased by pumps, and high pressures decreased with pressure reducing valves.

Tall building may be divided into zones, each of which is served by a separated downfeed water-distribution system, Each zone has its own storage tank that was supplied with water by its own set of pumps from suction tank in the basement.

All water-supply and distribution piping must be well designed so that there is no possibility of backflow at any time. The minimum required air gap shown on Fig. 7 should be maintained at all times.

The tank is bigger than 5 M^3 , can be partitional to provide independent, side-by-side chambers, each with identical piping and controls. During hours of low demand, a chamber can be emptied, cleaned and repaired, while the other chambers supply water as needed.

A guide to installation of user's reservoir and tank those describe about material, volume, structure, installed place, cleaning are regulated by TWD.

The total water demand of building may be calculated by following formula

1. For domestic building

$$Qd = N \times F \times q$$

Qd: Water demand per day (1/day)

N : persons per family
Generally 5 persons per normal family and 2 persons per small family of one room with a bathroom.

F : number of family

q : Water demand per person per day
250 1/day/person is suggested by TWD

2. For public building

A. $$Qd = \sum_{N=0}^{x} Nx \; qx$$

N: Fixture value

X: Type of fixture

q: Water demend per day per fixture (1/day).
It is always given in the local building plumbing code.

B. $$Qd = K \cdot Ao \cdot n \cdot q$$

K: Effective area percentage

Ao: Total area of building

n: persons per M^2

q: water demand per person per day in the building

K. Ao. n. q. are also given in the local building plumbing code.

Water demand always multiply to a peak factor as a design water demand. Peak factors are suggested by TWD as follows:

if $Qu < 0.28\ \ell/sec$ $P = 1.5$, $Qu = 0.28 \sim 0.56\ \ell/sec$ $P = 1.4$
$Qu > 0.56\ \ell/sec$ $P = 1.3$ (Table 8)

Size of service pipe of downfeed water-distribution may be calculated as following formula is defined by TWD.

$$Di = 29.85 \sqrt{Qd / V}$$

Qd: Design water demand (l/day)

V: velocity within pipe (m/sec)

In downfeed water-distribution system the volume of storing in the tank should be more than forty percent of designing water demand per day in order to prevent accident of public mains. Ordinary there is about 30 percent of storing water in the suction tank and 10 percent is in the elevated tank. Elevated tank should not be bigger than suction tank.

The volume of storing tank should not be bigger than the volume of 48 hours design water demand for keeping valuable residual chlorine.

Diameters of main pipes and service pipes (shown on Table 6) are simplified by TWD to help plumbers designing a plumbing system easily.

Sizes of upfeed risers to elevated tank may be calculated with the formula

$$Dr = 146 \sqrt{\frac{Vt}{30V}}$$

Dr : Diameters of upfeed risers(m/m)

Vt : Volume of elevated tank (M^3)

V : velocity within riser. 1.6-2.0 m/sec is suggested generally.

Usually, a main meter is set on service pipe and separated meters are set on main pipe for measuring amount of water which is conveyed to a building or to each family on separated floor. Records of main meter must be as same as total records of separated meters in a building. If no, there must be problems happened, such as pipe leakage, tank gaping, meter damage or incorrect record. These problems have to be examined, checked, and repaired by occupants being helped by TWD.

The meter should match the pipe and be installed by TWD in suitable place. Where is easily accessible to meter readers. A meter place code was established in year 1981.

Valves, especially check valve and gate valve, should be installed in a suitable place to stop water flow within the pipe or to prevent contamination from possible polutants.

III MATERIALS

When choosing materials for potable water piping, care should be taken to see there is no possibility of chemical action, or any other action that might cause a toxic condition. The PH value of potable water is about 6.8 in Taipei. It is a corrosive water may be cause some chemical reaction with materials. Chemicals shown in Table 7 are allowed to come out from the material of piping within its permitted quantities.

$$O_2 + 2Fe + 2H^+ \rightarrow 2Fe^{++} + 2OH^-$$

$$4Fe + SO_4^= + 10H^+ \rightarrow H_2S + 4H_2O + 4Fe^{++}$$

$$Zn(OH)_2 + 2H^+ \rightarrow Zn^{++} + 2H_2O$$

$$Pb(OH)_2 + 2H^+ \rightarrow Pb^{++} + 2H_2O$$

$CaCO_3 + H^+ \rightarrow Ca^{++} + HCO_3$

Only stainless steel pipe, copper or brass pipe, ductile iron pipe, cast iron pipe with cement coating, PVC. pipe and PB pipe, can be used in potable water plumbing system are regulated by TWD.

Lead is a toxic chemical, copper or brass piping is expensive and not common in Taiwan, steel pipe and white iron pipe (Znic-plated iron pipe) is corroded easily in the water of P H≈6.8. Hence, PVC. or PB. pipings and tubings used for cold water plumbingsystem and stainless steel pipings and tubings used for hot water plumbing system are suggested by TWD.

The second hand pipings or tubings are definitely not allowed to reuse on potable water plumbing system. Fixtures and its appurtenances should be in accordance with national standard plumbing code, are also regulated in TPWPS.

IV WORKS

The quality of water must be maintained while the water is being conveyed within the building to the point of use. Hence, the potable water distribution system must completely be sealed to prevent from contamination. No cross connections may be made between this system and any portion of the waste-water removed system.

The water-distribution system should be so laid out that, at each plumbing fixture requiring both hot and cold water, the pressure at the outlets for both supplies should be nearly equal. Pipe sizes and types should be selected to balance loss of pressure head due to friction in the hot and cold water pipes, despite differences in pipe lengths and sudden large demands for water from either supply.

The structural safety of a building should not be damaged in any way by the result of installation, alteration, renovation, or replacement of plumbing system or any of its parts.

A specific pipe hole for piping shoud be installed in a building of six stories or more stories shown in TPWPS, but it is better that a lower building to have it also. Pipes should be installed and supported to prevent stresses and strains that would cause damage to the system. It is sufficient to support vertical pipes at their base in every floor. Maximum support spacing for horizontal pipes depends on pipe diameter and material . Each support should be designed and installed to carry its share of the total weight of the pipe. Supports should permit movement of the pipe caused by thermal dimensional change or difference in settlement of building. The material of supports should be strong enough to prevent from corrossion.

Underground pipes should be placed deep enough so that not be damaged by heavy traffic. In Taipei, the depth of pipes as below should be abided by plumbers.

1. Not less than 50 cm under the walk
2. Not less than 70 cm under the road which its width is less than 6 meters.
3. Not less than 120 cm under road which its width is more than 6 meters.
4. Not less than 120 cm as the diameter of pipes is larger than 75 mm.

Pipes, subjected to external corrosion, should be protected with coating, wrapping or other means that can prevent from corrosion. Pipes should not be installed connecting with the other pipes that is not used on potable water plumbing system, or else contamination could be occurred.

Dissimilar metals should not be connected together, because corrosion will happen.

Receiving tank and suction tank should be installed independantly and keep at least 45 cm away from structual body of building for preventing from contanination and being managed easily. It is shown in Fig 8.

V TESTS

Drawing of potable water plumbing systerm, planned out by artists or plumbers, should be examined and approved by TWD before the system being installed. A examining table shown on Table 8 is established to help examiner to check and approve drawings that plumbers can follow and build the potable water plumbing system. Pipes joints, and connections in the plumbing system should be made to discover leaks or defects in the system.

Hence, Pressure test should be done for examining the plumbing system. After a plumbing systerm has been completely installed, it have to sustain the pressure of 10 kg/cm^2 for 30 minutes. There are no leaks or defects to be discovered, otherwise, plumbing system should be checked carefully and refixed, then pressure test should be made again until standing the test.

In Taipei the works of pressure test and examination of potable water plumbing system are executed by Taipei Examination and Test Center, which is under the supervision of TWD., of plumbing company union. A test table shown on table 9 for helping the works of test and examination.

VI CONCLUSIONS

To build a sound potable water plumbing system for occupants in a building is the duty of artists and plumbers.

To manage and use the potable water plumbing system carefally is the duty of occupants of the building. To carry out Taipei Potable water plumbing standard and control Potable water plumbing systems to coincide with standard is the durty of TWD. Combining TWD, Plumbers and Occupants in a group makes an efforts to maintain the quality of the potable water while the water is being conveyed within the building to the point of use, then the goal of the safety usage Plan being carried out by TWD will have been attained.

Here some suggestions are presented:

1. Potable water plumbing system should be operated correctly and examined constantly.

2. Materials of piping and tubing should be chosen in accordance with the quality of potable water, and should be examined by National Standard Bureau constantly. The results of material examination should be considered to a facter of material chossing.

3. Plumbers and persons who does the work of potable water plumbing system should be under good training and get the permittion from local government before they pratise as a plumber.

4. Potable water plumbing system should be examined and tested accurately

after being installed, should be disinfected before being operated for preventing from contamination.

5. Advertisements,how to use potable water plumbing system in safe conditions and how to save potable water that is valuable and finite resources, should often be shown by water works or local government.

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Table 1 The minimum flow rate and pressure of different fixtures.

Fixture	Flow rate *		Required Pressure**	Size of branch pipe ***
	1/Time	1/min	Kg/cm^2	mm (Diameter)
Basin Fancet of bathroom	10	8-15	0.3	10
Ordinary basin fancet	3	5-10	0.3	10
Bathtub fancet	125	25-60	0.3	13
Shower	24-48	8-14	0.3	13
Ball cock for closet	10	6-12	0.3	10
Flush valve for closet	15	80-120	1.0	25
Flush valve for urinal	5	20-30	1.0	13
Drinking fountain		5-10	0.3	10

* Article 4 of TPWPS
** Article 16 of TPWPS
*** Article 11 of TPWPS

Table 3. Equivalent Pipes Table

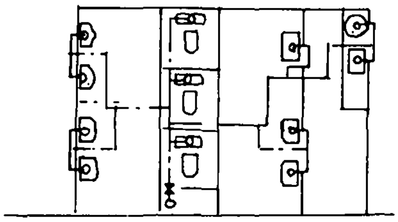
Dia.	5	8	10	13	20	25	30	40	50	63	75	90	100
6	1												
8	2.1	1											
10	4.5	2.1	1										
13	8.2	3.8	1.8	1									
20	16	7.7	3.6	2	1								
25	30	14	6.6	3.7	1.8	1							
30	60	28	13	7.2	3.6	2	1						
40	88	41	19	11	5.3	2.9	1.5	1					
50	164	77	36	20	10	5.5	2.8	1.9	1				
63	255	120	56	31	15.5	8.5	4.3	2.9	1.6	1			
75	439	206	97	54	27	15	7	5	2.7	1.7	1		
90	632	297	139	78	38	21	11	7.2	3.9	2.5	1.4	1	
100	867	470	191	107	53	29	15	9.9	5.3	3.4	2	1.4	1

Table 2 : Percentages of simultaneous operation of the fixtures

Fixtures value	Flush valve of W. C.	Other fixtrues
1	100	100
2	50	100
3	50	80
4	50	75
5	45	70
8	40	65
10	35	53
12	30	48
16	27	45
24	23	42
32	19	40
40	17	39
50	15	38
70	12	35
100	10	33

Table 4 Fixture units per Fixture

Fixture type	Fixture-unit value		Fixture Type	Fixture-unit value	
	Domestic	Public		Domestic	Public
Flush value for closet	6	10	Bath	2	4
Ball cock for Closet	3	5	shower	2	4
Flush value for urinal	2	5	kitchen sink	2	5
Basin	1	2	Laundry tray	3	4



1. Urinal
2. Wash basin
3. Water closet
4. Wash basin
5. Flushing sink
6. Kitchen sink
7. heater

Fig. 1: fixtures of toilet room

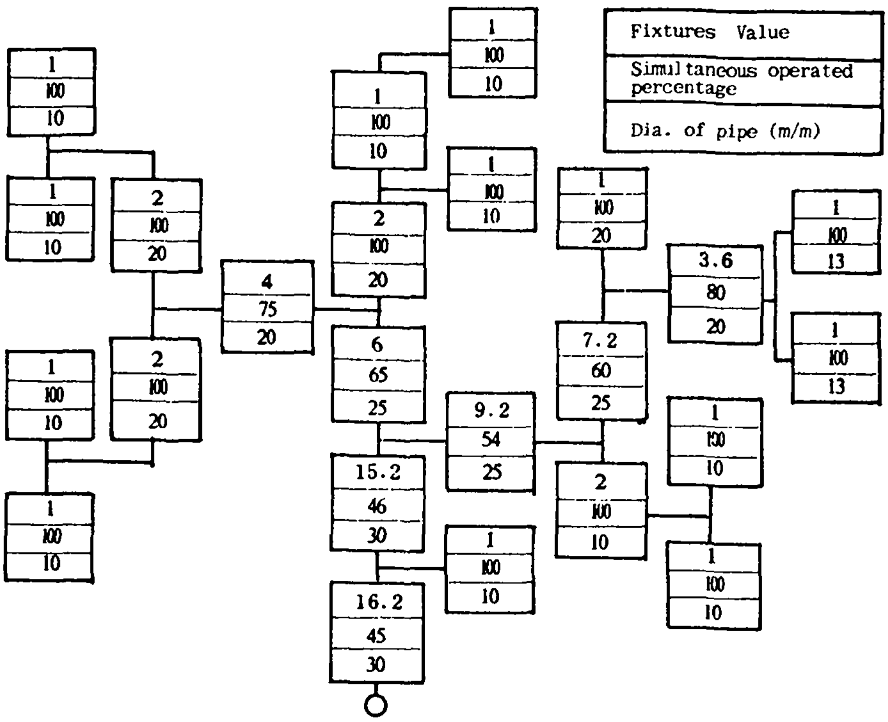


Fig. 2 : A calculated box diagram

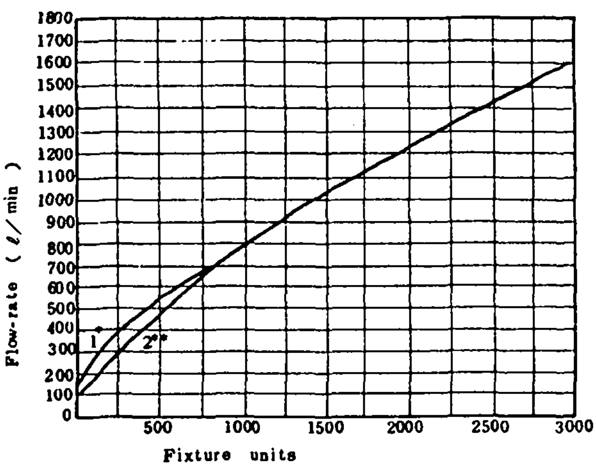


Fig. 3 Estimate curve for water demand load

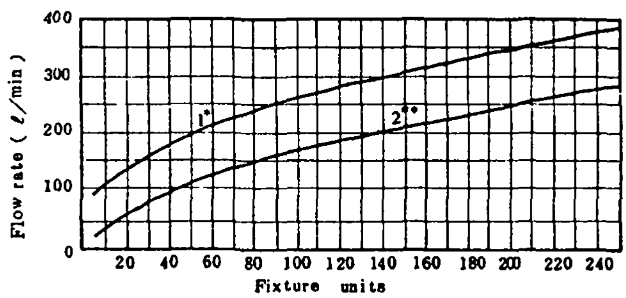


Fig. 4 Enlargement of low-demand portion of Fig. 3

* : Flush valve fixtures are with other fixtures in a system

** : Ordinary fixtures are without flush vlave fixture in a system

Table 5: Designing velocities within pipes

Diameter of pipe	Water velocity
m m	m / sec
13	0.6
20 - 25	0.7
40 - 50	0.8
more than 75	1.0

Table 6 Diameters of ma.n pipes and sevice pipes

Fixture value	Dia. of main pipe	Family value *	Dia. of service pipe **
2 - 5	20 m/m	under 5 families	20 m/m
6 - 9	25 m/m	6 - 14	25 m/m
10 - 17	40 m/m	15 - 36	40 m/m

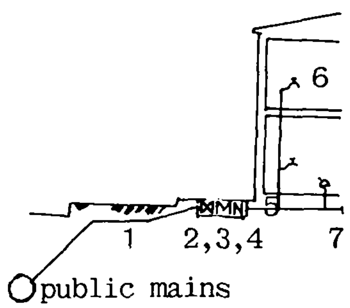
* Ordingary a family has one or two bathrooms.

** It is only indicated in downfeed distribution plumbing system.

Calculation of diameters of service pipes of upfeed distribution plumbing system are as same as main pipes of downfeed distribution plumbing system.

Table 7 Maximum quantities of chemicals permitted in potable water

Materials	mg / 1	Possible source
Lead	0.1	PVC pipe, Lead pipe and its appurtenants
Iron	0.3	Steel pipe, wrought iron pipe, cost iron pipe and its appurtenants
Copper	1.0	Copper, brass pipe and its appurtenants
Zinc	5.0	Zinc-plated steel pipe.



1. service pipe
2. gate valve
3. meter
4. check valve
5. main pipe
6. fixture
7. branch pipe

Fig. 5 : Upfeed water-distribution system

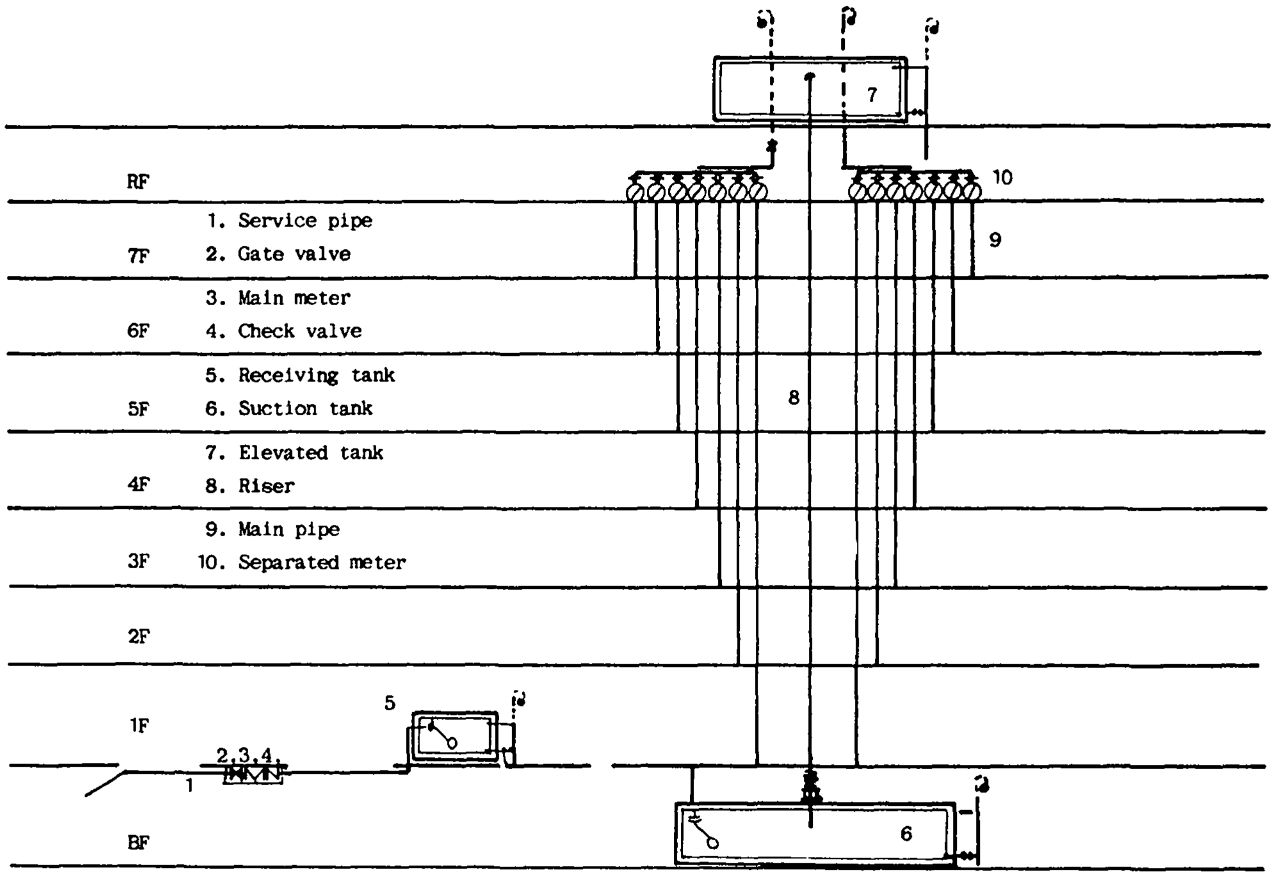
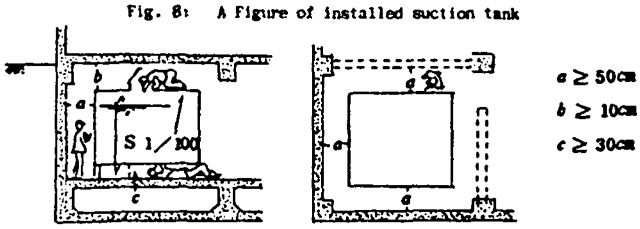


Fig. 6: Downfeed water-distribution sytem

Fig. 8: A Figure of installed suction tank



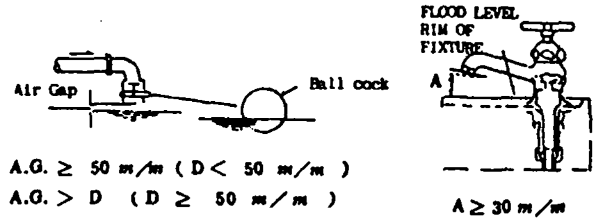


Fig. 7 Minimum air gaps

Table 8 : Examining table of plumbing drawing

NO. Date:

1. Diameter of Service Pipe of Downfeed Distribution Plumbing System

(1) Water Demand (Qu)

a. For Domestic Building

$$Qu_1 = (\qquad) \text{ cap.} \times 250\ \ell/c/d \times \frac{1}{10\ hr/d} \times \frac{1}{3600\ sec/hr}$$
$$= (\qquad)\ \ell/sec$$

b. For not Domestic Building

(l/day)

Building \ Fixture		W. C.	Urinal	Water Basin of Toilet	Wash Basin of Bathroom	Kitchen Sink	Flushing Sink	Bath		Σ q
Official Building	Demand	900	400	240	960	1200	510	760		
	No.									
	Total									
	Demand									
	No.									
	Total									

$$Qu_2 = \Sigma q \times \frac{1}{10\ hr/d} \times \frac{1}{3600\ sec/hr} = (\qquad)\ \ell/sec$$

$$Qu = Qu_1 + Qu_2$$

(2) Design Water Demand (Qd)

$$Qd = Qu \times P = (\qquad)\ \ell/sec \times (\qquad) = (\qquad)\ \ell/sec$$

(if $Qu < 0.28\ \ell/sec$ $P = 1.5$, $Qu = 0.28 \sim 0.56\ \ell/sec$ $P = 1.4$)
$Qu > 0.56\ \ell/sec$ $P = 1.3$

(3) Diamater of Service Pipe (Di)

$$Di = 29.85\sqrt{Qd/V} = (\qquad)\ mm$$

(if $Di < 40\ mm$ $V = 0.7\ m/sec$, $Di = 40 \sim 50\ mm$ $V = 0.8\ m/sec$)
$Di > 75mm$ $V = 1.0\ m/sec$

2. Volume of Suction Tank (V_G) and Elevated Tank (V_T)

(一) $V_G = Qd \times 30\% = Qd \times 10.8 = (\qquad)\ M^3$

(二) $V_T = Qd \times 10\% = Qd \times 3.6 = (\qquad)\ M^3$

3. Diameter of Riser

$$D_P = 21\sqrt{V_T} = (\qquad)\ mm$$

NO.

Table 9 : Test Table

DATE:

Applicant		Telephone	
Location of Building			
Materials	Piping and Trbing Be with ㊣ Mark		☐ PVC ☐ PB ☐ Stainless steel ☐ Brass or Cooper ☐ Others
Piping System and Pump System	1. Fixtures Location		☐ Yes ☐ No
	2. Diameters of pipes		☐ Yes ☐ No
	3. Location, Structure of Tanks is lagel		☐ Yes ☐ No
	4. Volume of Suction Tank		____M × ____M × ____M
	Volume of Elevated Tank		____M × ____M × ____M
	5. Receiving Tank		☐ Yes ☐ No
Meters	1. Location of Main Meter		☐ Yes ☐ No
	2. Check Valve		☐ Yes ☐ No
	3. Location of Separated Meter		☐ Yes ☐ No
	4. Order of Separated Meter		☐ Yes ☐ No
	5. Distance for Meter		☐ Yes ☐ No
Pressure Test	10 Kg/cm2 30 minutes		☐ Yes ☐ No
Results			
Examiners			

PLAN FOR AND RESULT OF REHABILITATION OF DISTRIBUTION MAINS

by :

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1. INTRODUCTION

1.1 Water Supply

Construction of our modern facilities for waterworks was started in 1910 and the first modern waterworks were put into service in 1914, with a supply of 50,000 m^3/day. More than 72 years have passed, and the water demand has increased in keeping with the development of Nagoya City, the expansion of the city area, the increase in population and the city's economic development.

Up to the present time, eight expansion projects have been completed, and our waterworks have a total capacity of 1,424,000 m^3/day at present. The district supplied includes the whole of Nagoya City and a part of the municipalities on the circumference, covering a total area of about 351 km^2. The population served at the end of 1985 numbered about 2.2 million, and the ratio of diffusion was 99.6%.

Our water supply source is surface water from the Kiso River. The raw water is taken in at Inuyama in Inuyama City and Asahi in Bisai City. Our waterworks have three purification plants, one in Kasugai, one in Nabeya-Ueno and one in Oharu. Their capacities are 590,000, 290,000 and 544,000 m^3/day respectively.

1.2 Distribution Systems

Purified water is distributed to customers directly or via twelve pumping station from the three purification plants. The district supplied is divided into seventeen distribution blocks in accordance with the ground level, the scale of the pumping station and the characteristics of the present pipe networks.

Each pumping station has an automatic control system, whose controls are concentrated at the Higashiyama Control Center.

The length of distributing pipes was about 7,690 km in Fiscal Year 1985. The breakdown of pipe size was as follows:

Trunk lines	(ranging in size from 450 mm. - 1,500 mm.) :	370 km.
Distribution mains	(ranging in size from 75 mm. - 400 mm.) :	4,410 km.
Small size distribution mains (ranging in size from 25 mm. - 40 mm.) :		2,910 km.

Of the trunk mains, about 86% are of ductile cast-iron, about 13% are of cast-iron and the remainder are of steel. Of the distribution mains, about 64% are of ductile cast-iron, about 31% are of cast-iron and the remainder are mostly asbestos-cement and some steel. About 93% of the small size distribution mains are of vinyl chloride, the remainder are polyethylene and lead pipes.

On the other hand, in Nagoya City, water is connected to customers' homes by distribution pipes of less than 400 mm. The number of homes serviced was about 560,000 in Fiscal Year 1985.

2. REHABILITATION PROGRAM OF DISTRIBUTION MAINS

2.1 Background of the program

Our pipe networks have been gradually increasing along with the development of Nagoya City since they were put into service.

The pipeline length was 289 km. in Fiscal Year 1914, but it has grown by 27 times to its present size. Especially, in the 1960's, water demand increased remarkably, and the water supply works were expanded to reinforce the facilities in the whole area supplied, thereby forming the basis of the present system.

Distribution mains account for 60% of the assets of the Bureau. They are the most important parts that connect the purification plants, pumping stations and customers' homes.

However, since the pipes are located underground, they are subject to damage by heavy traffic, corrosion by the soil, differential settlement, electrolytic corrosion and road works. As they grow older, they become weaker.

As a result, troubles with the pipes themselves occur such as cracks, breakages, corrosion, looseness of joints and so on. This leads to the discoloration of the water and bad water-flow that originate from the corrosion of pipe walls.

Occurrences of troubles and accidents caused by old pipes in the period before the 1970's were infrequent, so they were improved one by one along with the measures taken to respond to increased demand. However, these incidences increased in the 1970's and the numerous complaints from citizens made it necessary to create specific projects to improve the situation.

On the other hand, the ratio of effectiveness had been at a 70% level in the 1960's. This was low compared to other big cities in Japan. In those days, the Ministry of Health and Welfare of Japan aimed to present guide-lines for a water effectiveness ratio at 90% or more in the form of the water leak prevention measures. Therefore, it was also necessary to improve the worn out pipes from the point of view of the improvement of effectiveness ratio.

In addition to all of this, there are a lot of earthquakes in Japan. Taking precautions against earthquakes is encouraged to minimize damages. This tendency has grown, and importance has been attached to the reinforcing of the pipelines since they are damaged easily.

In response to the situation, we decided to carry out pipeline rehabilitation programs starting in Fiscal Year 1975.

2.2 The rehabilitation program

When the rehabilitation program was planned, the object was to improve the unlined cast-iron pipes in the pipe wall, asbestos-cement pipes and a part of the small-sized distribution mains. The length of the pipes was about 3,700 km. of the total 6,300 km. at the end of 1974.

We collected data on certain pipes, such as burst pipes, leaky pipes, pipes causing bad water-flow and discoloration of water, pipes that followed the same route as other planned road works and noted the bad situations for laying pipes in the ground. After examining the results of the investigation, we decided to improve the pipes one by one in order of priority.

As for pipeline rehabilitation planning, we decided to improve 3,140 km. by the 3rd phase, taking the finances into consideration. The rest will continue to be improved, as funds allow.

Following are the outlines of the pipeline rehabilitation program:

(Unit: km.)

	1st phase 1975∿1980	2nd phase 1981∿1984	3rd phase 1985∿1988	Total
Replacement	910	650	650	2,210
Lining	350	330	250	930
Total	1,260	980	900	3,140

2.3 The improvement program for service connections

In order to reinforce water-leak countermeasures, we decided to improve service connections hand in hand with the rehabilitation program for distribution pipes.

This program includes the replacement of lead pipes with polyethylene pipes, because the leakage of water due to the lead pipes that our waterworks was using for service connections had been increasing. We installed polyethylene pipes as a test in 1972. They have brought excellent results for leakage prevention. Therefore, we decided to use polyethylene pipes for real projects.

Connections by lead pipes amounted to 360,000 by the end of 1974. They were to be replaced by polyethylene pipes by 1985 in this program.

3. EXECUTION OF PROGRAMS

3.1 Method of pipe rehabilitation

(1) Replacement

In Nagoya City, the fundamental method of pipe rehabilitation is replacement by ductile cast-iron pipes. This method will be the best for effective prevention against bursts, water leaks, discolored water, bad water-flow and for simplicity of joint work and maintenance. But we sometimes run into a difficult case where can't replace pipes by excavation because of the underground conditions and the road's environment. Many cases of these situations are given to the distribution mains in the town area. In these cases, the "Pipe in Pipe Method" that inserts ductile cast-iron pipes or steel pipes into existing ones, is sometimes used.

As for the prevention measures against earthquake disasters, our waterworks have been making designs to strengthen the pipes in the area which is most likely to be affected by an earthquake and to make the main pipes outside of the weak zone earthquake-proof. And we have been replacing the old pipes with earthquake-proof distribution pipes in those places.

(2) Pipelining

In case of trouble such as discolored water and bad water-flow, the "Epoxy Resin Lining Method" is mostly used to renovate pipes that are judged durable and are too new to replace. The "Hose Lining Method" and the "Cement-Mortar Lining Method" are sometimes used to renovate pipes that don't have service connections.

3.2 Results of improvements

The rehabilitation program of distribution pipes has been carried out steadily. We have improved about 2,686 km. from Fiscal Year 1975 to Fiscal Year 1985. It is about 85% of the programed 3,140 km..

The items for improvement are as follows:

(Unit: km.)

Method	Pipe length
Replacement	1,850
Pipe in Pipe	2
Epoxy Resin Lining	827
Hose Lining	4
Cement-Mortar Lining	3
Total	2,686

In the replacement, the earthquake-proof distribution pipes amount to 115 km..

Meanwhile, the improvement program of service connections has also been carried out. We had replaced 320,000 connections with polyethylene pipes by Fiscal Year 1985, about 90% of the original program. As for the approximate 40,000 connections of the rest, they belong to the simultaneous installment for the improvement of distribution and will not be installed individually. Therefore, we intend to replace them continuously.

4. EFFECTS OF IMPROVEMENT

Two programs have brought several excellent results for our waterworks management. The effects are as follows:

1) The complaints from citizens over bad water-flow have decreased, although there were many in the 1970's.

2) The complaints from citizens over discolored water have decreased by 200∿300 cases per year now, although there were 2,000∿3,000 cases per year in the 1970's, and the degree of water discoloration has fallen gradually.

3) The number of burst repairs has decreased as follows:

Fiscal Year	Iron Pipes	Asbestos-Pipes	Total
1975	239	132	371
1980	189	64	253
1985	103	31	134

4) The number of road-leak repairs has decreased as follows:

Fiscal Year	Distribution Pipes		Valves, Hydrants, Air valves	Service Connections	Total
	More than 75 mm.	Less than 40 mm.			
1975	542	6,454	1,203	29,590	37,789
1980	400	2,197	887	13,519	17,003
1985	298	1,305	660	9,617	11,880

5) Ratio of effectiveness and Ratio of accounted-for quantity have increased steadily.

Fiscal Year	Effectiveness ratio (%)	Accounted ratio (%)
1975	78.1	75.2
1980	84.5	77.8
1985	87.5	81.6

The up-width of accounted ratio ranks second among six cities with populations over one million for the period from 1975 to 1985.

5. IDEAS ON PIPELINE REHABILITATION PLANNING

The pipeline rehabilitation program that our waterworks has executed so far has mainly placed emphasis on the prevention of bursts and water leakage and on decreasing complaints from citizens over bad water-flow and discolored water. In the rehabilitation program, we have been improving high priority pipes first, as problems arise.

Also distribution mains and small size distribution mains that can be easily replaced have mainly been improved. These pipeline rehabilitation works have been bringing great effects, but it will be necessary to plan more efficient programs for pipeline rehabilitation from now on.

In this age of high rate diffusion, waterworks have become increasingly important facilities in maintaining the quality of life of citizens and the function of cities. Keeping the function of "Lifeline" for the base of living has become an increasingly important problem.

In such a situation, pipeline rehabilitation is done not simply to improve the old pipes but also to consolidate the distribution systems synthetically and intentionally, in accordance with future plans concerning distributive areas and pipe networks.

It is also necessary to form pipe networks that are able to control water distribution effectively even under emergency conditions such as earthquakes or water shortages by, for example, the consolidation of connection pipes for backup between each distributive area, the block formation of pipe networks and the consolidation of based networks between each other block. These measures are more important for improving the efficiency and the reinforcement of distribution systems.

Furthermore, for pipeline rehabilitation planning, it is necessary to collect accurate information on pipelines and pipeline rehabilitation. It is also necessary to record the informations, arrange it and make out a pipeline rehabilitation manual. We are investigating how to execute these measures now.

6. CONCLUSION

Pipeline rehabilitation is an unavoidable eternal theme in continuous waterworks management. The necessary investment in works is not always related directly to increased profit. But, in the long run, it allows effective future maintenance of waterworks management and social profit. Therefore, it will be necessary to evaluate the effectiveness of pipeline rehabilitation according to long range plans.

Distribution systems differ according to the topography, scale and historical development of the cities they serve. Therefore, I think that the guide-lines and plans for pipeline rehabilitation should be devised according to the actual conditions of water supply management of the cities involved.

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THE 6TH ASIA PACIFIC REGIONAL WATER SUPPLY CONFERENCE AND EXHIBITION

DECEMBER 12-16, 1987
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