ENRIC MESSINGT

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LIST OF WORKING PAPERS

1.	SEA/EH/RSG Meet.1/4.1a	-	Hand Pump Technology for the Development of Groundwater Resources. By McJunkin, F.E. and Hofkes, E.H.A.
2.	SEA/EH/RSG Meet.1/4.1b	-	Consumer Association Testing and Research on Hand/Foot Water Pumps and Guidelines for Comparative Testing of Products. By Cuthbert, J., Kingham, J. and Sharpe, E.
3.	SEA/EH/RSG Meet.1/4.1c	-	Notes and References on Drinking Water Utilization in Rural Bangladesh and Suggestions for Research. By Skoda, J.B.
4.	SEA/EH/RSG Meet.1/4.2a	-	Community Aspects of Rural Water Supply and Sanitation Programmes at Village Level. By Hessing, E.L.P. and Kerkhoven,P.
5.	SEA/EH/RSG Meet.1/4.2b	-	Community Participation in Water Supply and Sanitation Programmes - Suggestions for Priority Research Areas and Strategies. By Stromberg, J.
6.	SEA/EH/RSG Meet.1/4.2c	-	Operations Research Applied to Appropriate Technology for Improvement of Environmental Health. By Veney, J.E.
7.	SEA/EH/RSG Meet.1/4.3a	-	Research in Rural Water Supplies and Sanitation. By McGarry, M.G.
8.	SEA/EH/RSG Meet.1/4.3b	-	Water and Wastewater Treatment and Disposal - Some Research and Development in Thailand. By Setamanit, S.
9.	SEA/EH/RSG Meet.1/4.4a	-	Environmentally Compatible Water Supply and Waste Utilization Systems for Developing Countries. By Sundaresan, B.B.
10.	SEA/EH/RSG Meet.1/4.4b	-	Integrated Approach for Water Supply and Sanitation in Rural Areas with Multiple Water Sources (Spot Tubewells and Dug Wells Fitted with Handpumps). By Subba Rao, S.
11.	SEA/EH/RSG Meet.1/4.5	-	Impact of Water Supply and Sanitation on Health (A Brief Review). By Cvjetanovic, B.
12.	SEA/RACMR 78.1/5 (Background Paper) ↑ see V.3481	-	Research in the Development of Appropriate Technology for the Improvement of Environmental Health at the Village Level. By Reyes, W.L., Unakul, S. and Acheson, M.

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PROGRAMME

Day 1 - Monday, 16 October 1978

0900	Registration		Conference Hall Lobby
	1.	Opening Session	Conference Hall
	1.1	Opening Address	Dr V.T.H. Gunaratne Regional Director
	1.2	Introduction of Participants	Mr Somnuek Unakul Regional Adviser, Environmental Health
		Group photograph	
1115-1515	Plenary		Committee Room
	2.	Mechanics of RSG work	
	2.1	Introductory Remarks (TOR)	Chairman
	2.2	Mechanics of work	Dr W.L. Reyes
	3.	Adoption of Agenda and Programme	
	4.	Review of research studies on appropriate technology in environmental health at the village level	Note: Discussion after each presentation
	4.1	Studies on hand-pumps including maintenance system and pollution aspects	Dr F.E. McJunkin Dr J. Cuthbert Dr J.B. Skoda
1530-1700	Plenary		
	4.2	Studies on operational and behavioural problems and constraints (community aspects including motivation) in the introduction of water supply and sanitation projects at the village level	Mr E.L.P. Hessing

Day 2 - Tuesday, 17 October 1978

0900-1015	Plenary		
	4.2	Studies on operational and behavioural problems and constraints (community aspects including motivation) in the introduction of water supply and sanitation projects at the village level (cont'd)	Dr J. Stromberg Dr J.E. Veney
1030-1200	Plenary		
	4.3	Studies on excreta and wastewater disposal systems including fish pond latrines	Dr M.G. McGarry Dr Surin Setamanit
1330-1515	Plenary		
	4.4	Studies on integrated water supply-excreta disposal systems	Dr B.B. Sundaresan Professor S. Subba Rao
1530-1700	Plenary		
	4.5	Studies on impact on health of water supply and excreta disposal	Dr B. Cvjetanovic

Day 3 - Wednesday, 18 October 1978

	Plenary		
0900-1015	5.	Formulation of criteria for setting research priorities	Chairman
1030-1515	Group work		
	6.1	Identification of priority research areas	Group 1, 2 and 3
1530-1700	Plenary		
	6.2	Group Reports	Group Rapporteur/ Chairman
	6.3	Finalization of priority research areas	Chairman

Day 4 - Thursday, 19 October 1978

0900-1200	Plenary		
	7.1	Introduction - Formulation of guidelines for prototype research proposal on priority areas	Chairman
	Group work		
	7.2	Formulation of guidelines for prototype research proposal on priority areas	Group 1, 2 and 3
1330-1515	Plenary		
	7.3	Group Reports on guidelines for prototype research proposal on priority areas	Group Rapporteur/ Chairman
1530-1700	Plenary		
	7.4	Finalization of guidelines for prototype research proposal on priority areas	Chairman

Day 5 - Friday, 20 October 1978

0900-1200	Plenary		
	8.	Formulation of guidelines for workplan for the development of regional research programme on appropriate technology in environmental health at the village level	Chairman
1330-1515	Plenary		
	9.	Draft report to Regional Director - Summary and Recommendations	Chairman
1530-1615	10.	Closing Session	
	10.1	Presentation of Summary and Recommendations	Chairman
	10.2	Closing Address	Regional Director

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INAUGURAL ADDRESS BY DR V.T.H. GUNARATNE, REGIONAL DIRECTOR, WORLD HEALTH ORGANIZATION, REGIONAL OFFICE FOR SOUTH-EAST ASIA, AT THE RESEARCH STUDY GROUP MEETING ON APPROPRIATE TECHNOLOGY FOR IMPROVEMENT OF ENVIRONMENTAL HEALTH AT THE VILLAGE LEVEL, SEARO 16-20 OCTOBER 1978

...

Distinguished participants to the Research Study Group Meeting on Appropriate Technology for the Improvement of Environmental. Health at the Village Level,

Ladies and Gentlemen:

First of all I would like to thank you for accepting my invitation to participate in the Research Study Group, and to welcome you to this very important meeting. I am especially glad that the Group is composed not only of experts from Member Countries of this region and from international agencies but also includes specialists from private institutions. The Group is multi-disciplinary in composition; I am, therefore, hopeful that a broad perspective of the problems referred to you will be synthesized and priority research areas realistically identified.

At the outset, I would like to draw your attention to two historic resolutions approved by the World Health Assembly last year:

- Resolution WHA 30.43 decided that the principal social targets of Member States of WHO in health should be the attainment by all the citizens of the world by the year 2000 of a level of health that will permit them to lead socially and economically productive lives.

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- Resolution WHA 30.33, endorsed the recommendations made by the United Nations Water Conference held at Mar del Plata in 1977, giving priority to the provision of safe water supply and sanitation for all by the year 1990 and designated the decade 1981-1990 as the International Drinking Water Supply and Sanitation Decade.

An important linkage between these two Health Assembly Resolutions should be recognized, namely: the primary importance of environmental health, especially safe water supply and sanitation, together with other basic health care services, in the attainment of health for all by the year 2000.

Last month, the International Conference on Primary Health Care was held at Alma-Ata, USSR. The Conference adopted what is already known as the "Declaration of Alma-Ata". The Declaration, approved unanimously by the delegates from 140 nations and numerous non-governmental organizations, calls for urgent and effective action to develop and implement primary health care throughout the world and particularly in developing countries. Article VII-3 of the Declaration states:

"Primary health care includes at least: education concerning prevailing health problems and methods of preventing and controlling them, promotion of food supplies and proper nutrition, an adequate supply of safe water and basic sanitation, maternal and child health care including family planning, immunization against the major infectious diseases, prevention and control of locally endemic diseases, appropriate treatment of common diseases and injuries and provision of essential drugs."

Thus, the provision of safe water supply and sanitation is a central activity in primary health care, which reaffirms the linkage between the two historic resolutions of the World Health Assembly.

"Safe water supply and sanitation for all by 1990"; "health for all by the year 2000". These complementary and mutually reinforcing declarations will require determined political will in each and every nation if the targets are to be realized. In addition, there is need for planning, organization, community participation, coordination, funding and international cooperation.

During recent years, the development of environmental health services in the Region has more than doubled the actual coverage of the rural population with reasonable access to safe water supply and nearly doubled the coverage with adequate excreta disposal. Some countries in the Region have already exceeded the targets of the United Nations Second Development Decade (1971-80), for water supply and excreta disposal in 1975. The Region as a whole has yet, however, to cover a substantial gap in order to meet the Development Decade targets in the rural areas as the following statistics show:

- Eight out of ten inhabitants of the rural areas in the Region did not have reasonable access to safe water supply as of the middle of the decade in 1975. In absolute numbers this proportion represents some 605 million without safe water supply.
- Nearly 95%, or some 708 million, of the rural population in the Region did not have adequate disposal of human excreta with some countries reported as having less than 2% of their total population with adequate excreta disposal.

Available information indicates that, to meet the United Nations Second Development Decade targets for rural water supply and sanitation, countries of the South-East Asia Region need to invest about 1.5 billion US dollars between 1976 and 1980, at 1975 price levels. I would point out here that this vast sum is to meet relatively modest targets: 35 per cent coverage for rural water supply and 15 per cent for rural excreta disposal.

For the developing countries, including Member countries of the South-East Asia Region of WHO, the targets of the International Drinking Water Supply and Sanitation Decade appear formidable. To meet the International Drinking Water

Supply and Sanitation Decade (1981-1990) targets, it is roughly estimated that the South-East Asia Region would need to expand its 1975 rural water supply facilities by 6 times and its 1975 excreta disposal facilities by some 20 times. These are very large expansion requirements to provide safe water supply and sanitation for all rural populations by 1990. Furthermore, the requirements of urban areas should be added, which, incidentally, are much more costly to provide than sanitary facilities for the rural areas.

With the limited resources available in developing countries, there is a need to make every input as effective as possible. This will require, in addition to the aforementioned conditions, a careful review of the technology applied in each activity to ensure that it is appropriate to the situation. This means, there is a need for water supply and sanitation technology that the villagers themselves can build, operate and maintain in working condition without much assistance from others. There is a need for technology that they can easily afford to buy if they cannot build it themselves. Technology is needed that the village families are willing to use. We need water supply and sanitation technology appropriate to the local setting. In recognition of this need, the Twenty-ninth World Health Assembly in 1976 in the Resolution WHA 29.74 specifically considered it necessary to promote research for the development of appropriate and effective methods and technologies.

The Advisory Committee on Medical Research of this Region, in its Fourth Session held in April this year, recommended that research in the development of appropriate technology for improvement of environmental health at the village level should be added as a priority area for research in the Region and that a research study group be convened. This is being realized with this meeting.

Two components of appropriate technology are beginning to be recognized. The first is appropriate technology "hardware" which refers to the products, tools or equipment, methods or processes and systems or combinations of processes and equipment; and the second is appropriate technology "software", which refers to the organizational forms, analytical and evaluation techniques, community approaches, etc. Environmental health at the village level requires both the appropriate technology "hardware" and "software". Generally, at the village level, the technology "software" which differs more from that with which we are already familiar and it requires multi-disciplinary expertise.

Most countries in the Region opted for tubewells fitted with handpumps as the first step in providing adequate supply of safe water to a significant percentage of the rural population. It is estimated that there are at present nearly 450 000 handpump tubewells with an installation cost estimated at some 80 million US dollars. The handpumps probably have an installation value of 10 million US dollars. There are feed back reports that between 20% and 70% of the handpump tubewells are not in operation at any one time due to pump breakdown. These reports indicate a need to improve the handpumps in use and/or develop appropriate operation and maintenance systems. Further, a significant percentage of the population expected to be served by the tubewells, continues to use sources of questionable quality.

Inadequate disposal of human excreta continues to be a major environmental health problem in the countries of the Region. Simple and low cost excreta disposal systems have been developed. However, rural populations continue to use the open fields and open bodies of water for excreta disposal. Some countries, notably Thailand, appear to be succeeding in this regard but most of the countries in the Region experience negligible progress, even in the presence of reportedly successful pilot projects. There is need to study this problem to develop further appropriate community approaches in order that every community, every family, every man, woman and child can participate in the global effort to have safe water supply and sanitation for all by 1990 and attain the goal of health for all by 2000.

There is no doubt that safe water supply and sanitation have a valuable contribution to make to the prevention of gastro-intestinal infections and have a positive effect on health and that investments for the improvement of water supplies and sanitation are beneficial. With the increasing use of economic justification for investment projects there is a growing need to bring up more solid evidence on the impact on health of safe water supply and sanitation. While it is true that priorities at the country level are decided on political grounds, it is recognized that evidence based on sound data concerning the impact on health of safe water supply and sanitation would facilitate decision-making on investments in this sector. There is, therefore, an increasing need to undertake studies that could provide a measure of the impact on health of safe water supply and sanitation.

In addition to safe water supply and sanitation, there are other important areas of environmental health at the village level that need to be looked into for which we are confident you will share your knowledge, experiences and insights.

The South-East Asia Region must take pioneering steps to solve the problem of providing the basic need of drinking water supply and sanitation for a billion people who inhabit this region. The task is stupendous and success will to a great extent depend on the development of a technology appropriate to the needs of our people and the socio-economic situation of the countries. I am sure your concerted effort during the coming few days, aided by your accumulated experience and wisdom, will lead to the developmen of guidelines and protocols for a series of fruitful research activities in the field of appropriate technology for environmental health. I can assure you that there will be no dearth of funds to support a well formulated research programme, particularly in this field. I am therefore eagerly waiting for your recommendations for developing a sound regional research programme on this vital subject. With this hope in mind, I sincerely wish you success in your deliberations.

Before closing, I am requesting Professor Seneviratne of Sri Lanka to serve as Chairman of the Research Study Group and Dr Surin of Thailand to be Rapporteur. I am also requesting Dr Cvjetanovic to assist the Rapporteur.

Thank you.

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WORLD HEALTH
ORGANIZATION

REGIONAL OFFICE FOR
SOUTH-EAST ASIA

Research Study Group Meeting on
Appropriate Technology for Improvement
of Environmental Health at the Village
Level, New Delhi, 16-20 October 1978

Restricted

SEA/EH/RSG Meet.1/4.1a

HAND PUMP TECHNOLOGY FOR THE DEVELOPMENT OF GROUNDWATER RESOURCES

By

F. Eugene McJunkin

and

Ebbo H.A. Hofkes

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The opinions expressed in this paper do not necessarily reflect those of the World Health Organization.

HAND PUMP TECHNOLOGY FOR THE DEVELOPMENT OF GROUNDWATER RESOURCES

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Abstract

Reviews present state of the art, including rationale for use of hand pumps, their history, types of hand pumps, operating principles, and technical analysis. Discusses problems of hand pump selection, testing, manufacture, operation and maintenance. Briefly summarizes recent developments.

BACKGROUND

A recent survey by the World Health Organization (WHO) found that over one billion people living in rural areas of developing countries lack reasonable access to safe and adequate drinking water. The importance of water supplies in transmission and control of enteric disease is well established; in the countries surveyed by WHO, waterborne diseases are generally among the three leading causes of sickness and death, particularly among children. Even the unsafe water supplies now in use frequently require many hours daily toil and travel for their collection.

To bring ready access to safe drinking water by 1990 for these rural peoples would require a capital investment of over 40 billion U.S. dollars at $US 26 per capita. Alternatively expressed, the current rate of investment would have to be multiplied fourfold and sustained through 1990. These estimates prepared by WHO, in collaboration with the World Bank, indicate that use of low cost water supply technology will be mandatory for many years to come.

Many knowledgeable observers agree with a recent analysis by the World Bank (1) that "In areas where groundwater is readily available at moderate depth, constructing a number of wells fitted with hand pumps is by far the cheapest means of providing a good water supply". Although community water systems piped under pressure to households and public standposts may be an ultimate goal, many of the unserved billion will realistically have to seek hand pumps as an interim if not an ultimate measure.

Unfortunately the record of many (probably most) hand pump programmes is not good. Serious problems exist in hand pump technology, design and selection; quality of manufacture; installation, operation, and <u>especially</u> maintenance; and organization and administration of hand pump programmes generally. The number of existing successful hand pump programmes for community water supplies is very small. The hand pump "solution" to rural water supplies is deceptively simple; it poses some major problems on a worldwide scale.

TECHNOLOGY

Hand pumps have an ancient history. Reciprooating types were known to the Romans, in widespread use in medieval Europe, and in mass production in the late 1800's. At the turn of the century there were over 3000 hand pump manufacturers in the United States alone. (Now there are fewer than a half-dozen).

<u>Reciprocating Pumps</u>

The most ubiquitous and numerous hand pump is the common reciprocating type (Fig. 1). The operating principles are outlined else-

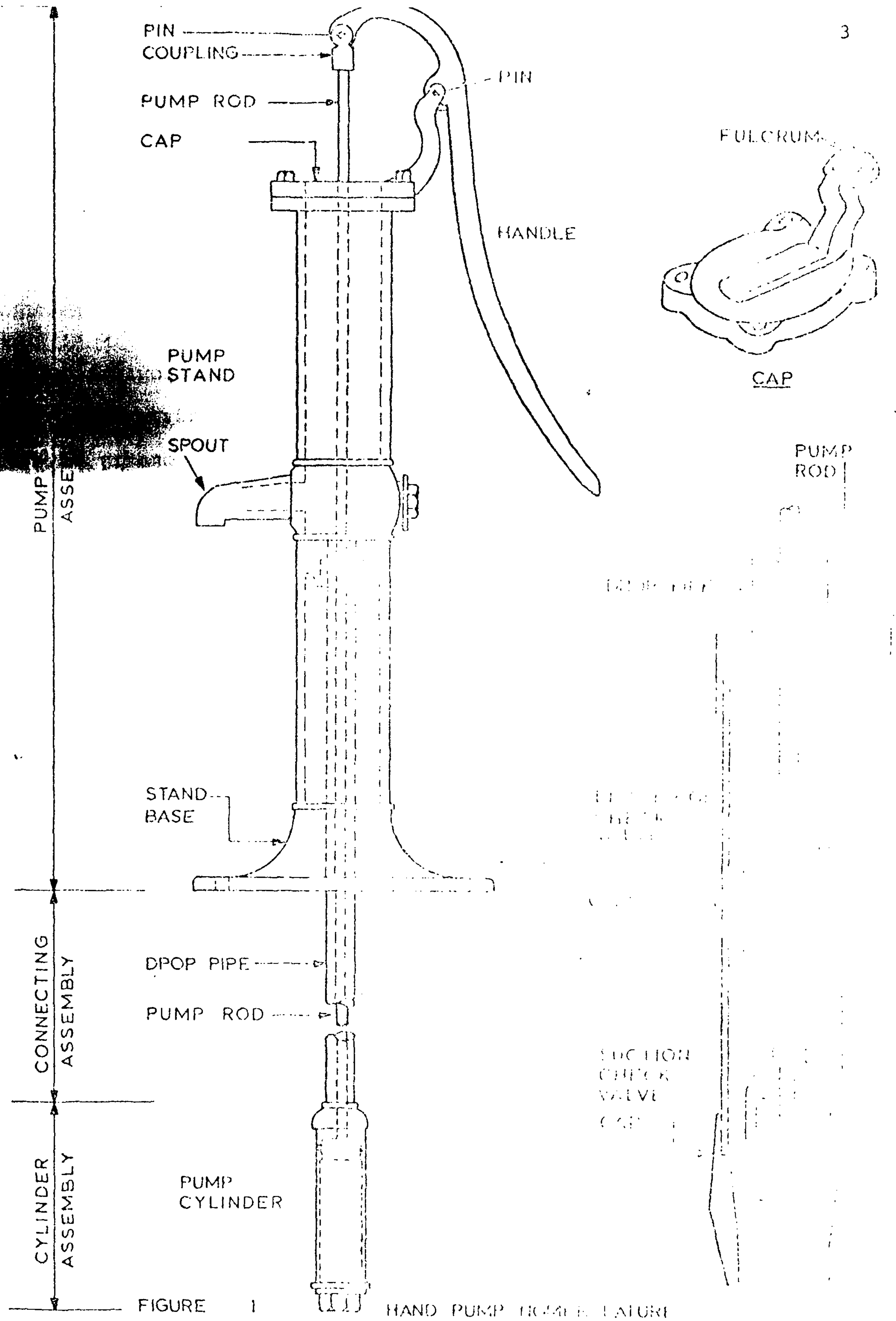

FIGURE 1 HAND PUMP NOMENCLATURE

where (2) but certain features should be noted:

(1) Transfer of the work on the handle lever to the reciprocating plunger or piston requires a fulcrum pin (pivot) and one or two other pins. These are sources of friction, and thereby wear, and require lubrication. Rotary crank and wheel operated reciprocating hand pumps have similar requirements.

(2) The hand pump handle or crank is a lever which provides mechanical advantage in raising the plunger. The mechanical advantage is restrained by the strength and the anthropomorphic geometry of the human power source - man, woman, or child.

(3) As the plunger lifts the water to the pump spout there is friction, and thereby wear, of the cups or seals between the plunger perimeter and the cylinder casing.

(4) The discharge and suction check valves open and close, and thereby wear, during each pumping cycle.

These inherent features of the reciprocating hand pump have been the focus of much research and development on hand pumps and explain many of the differences in currently manufactured hand pumps. For example:

(1) Replacement of pivots with sliding friction (journal bearings) with pivots with rolling friction (ball bearings). Also redesign of the pump handle linkage to reduce the number of pins, as in the Sholapur and Mark II hand pumps in India. Other alternatives include better quality of manufacture (closer fits and tolerances), larger pins (less unit stress), and material substitutions, e.g., wooden bearings. Less dramatic, but the quintessence of a successful programme, is the reduction of friction by proper lubrication, i.e., better maintenance.

(2) Reduction of friction between cup seals and cylinders by using smoother cylinder walls, e.g., brass rather than cast iron. Some synthetic materials show promise as a substitute for the traditional leather cup seals.

(3) Better quality valves.

The forces and wear on reciprocating hand pumps are often underestimated. The average theoretical tensile force in the pump rod of a pump with a 3-inch (75 mm) cylinder diameter and only a 50-feet (15 meters) pumping head is over 150 pounds (70 kg). Peak forces may be several times higher. To serve a population of 500 with only 10 liters per capita per day, this same pump would require over 3 million pumping cycles per year.

Diaphragm pump

Another type of positive displacement pump is the diaphragm pump. This pump also uses inlet and outlet check valves. However its "cylinder" is flexible, expanding to draw water in, contracting to force it out, much like a heartbeat. Although invented in 1730 the diaphragm pump has not been widely used for water supplies. Its merit is, vis-a-vis reciprocating pumps, that it eliminates the necessity for the moving plunger and its sliding, wearing cup seals. A recently developed diaphragm hand pump is the Swedish-made Petro Pump which uses a reciprocating lever handle to actuate the diaphragm. Another new diaphragm hand pump is the French-made Hydropompe Vergnet. This pump uses a groundlevel, pedal operated hydraulic piston to actuate the diaphragm pump immersed in the well, thereby eliminating the usual handle lever linkage. These pumps are potentially promising but more operational and cost data are needed.

Rotary pump

A rotary type pump, the helical rotary (often termed the progressive cavity pump, consists of a single thread helical rotor turning within a double thread helical stator. The meshing helical surfaces push the water up the drop pipe (riser) with a uniform movement similar to a slow moving piston in a cylinder of infinite length. This pump requires no valves, no cup seals, and - in place of the reciprocating lever linkage of the pump head - it uses a rotary crank with a right-angle gearbox to turn the rotor. Although relatively expensive, it has given good deep well service in parts of Africa and Asia where it is known as the "Mono" pump after its English manufacturer. A newly developed pump of this type, known as the "Moyno", is now available from Canada and the USA.

Appropriate technology

Appropriate technology has been defined in part (3) as technology that "is not only scientifically sound but that is acceptable to users, providers, and decision-makers alike; that it fits within local cultures, that it is capable of being adapted, further developed, and manufactured locally wherever possible at low costs; and that it is sufficiently simple in design and execution for local use". Further it "means not just a device but any association of techniques, methods, and equipment which together can contribute toward solving a .... problem".

In the context of this paper, interest in hand pumps focuses on their manufacture and, in a later section, their maintenance. In addition to production of a more appropriate hand pump tailored to local conditions, the desirability of local manufacture is based on possible opportunities for:

(1) lower capital costs of production.

(2) transportation savings.

(3) reduction in foreign exchange requirements.

(4) stimulation of local initiative, industry and labor.

(5) better availability and access to repair and replacement parts.

There are two types of local manufacture. The first is mass production in foundries, machine shops, and factories of cast iron or steel pumps similar to those in the international export market. Such manufacturing is practical and practiced in many developing countries, notably India. The appropriateness of a particular technology will vary widely. For example foundries are widespread in Southeast Asia. They are rare in West Africa.

Local manufacture does not guarantee "appropriateness". Many LDC-manufactured hand pumps are not indigenous but are poor quality imitations of imported pumps. Further, lack of competition or competition solely on the basis of price are institutional shortcomings detrimental to evolution of appropriate technology. Viable technical specifications are needed. Unfortunately there are as yet no international hand pump specifications or testing procedures for guidance.

Some large hand pump programmes have established their own hand pump factories to manufacture pumps and parts of their own design. The Shinyanga Project in Tanzania is an example. The Shinyanga pump is assembled for the most part from standard galvanized iron and polyvinyl chloride pipe fittings, machine parts, drilled and chamfered standard lumber, and a welded steel base plate. Thus far it works well in its milieu.

A second type of local manufacture requires a lower level of technology and lends itself to production in small quantities by village artisans. These are sometimes termed "off the shelf" assemblies. Many examples of these types of hand pumps are available through private voluntary organizations such as the Intermediate Technology Development Group (U.K.), Volunteers for International Technical Assistance (US), et al.

MAINTENANCE

Background

Hand pump technology and maintenance cannot be evaluated independently. Indeed one of the important issues in hand pump technology is the degree to which the pump should be maintenance free. The arguments for labor-intensive technology for developing countries imply use of hand pump technology with a high labor component, i.e., with high maintenance costs, relative to initial capital investment. A direct correlation between pump prices and pump reliability may be theoretically valid but is difficult to establish in reality.

On the other hand the institutional difficulties and frequent inadequacies of maintenance programmes (thirty to eighty percent of hand pumps out of operation at one time is a not uncommon experience) have stimulated the search for maintenance free pumps, even if they cost more.

Many authorities contend that maintenance is the critical element of hand pump programmes. The possible causes of poor maintenance may provide some insight into improvement of maintenance.

(1) Poor quality of hand pump design and manufacture. To a considerable extent this condition is also the result of many years of trimming weight, bearing sizes, etc. in seeking low bids (tenders)

in the absence of definitive specifications. Much hand pump procurement has an inherent bias towards low initial capital cost and ignores life cycle costs.

(2) The technology in use makes frequent lubrication mandatory. Iron and steel journals and bearings, poor fits and large clearances, lack of lubricant reservoirs, exposure to weather, etc.

(3) Underestimates or lack of appreciation of the structural and bearing loadings in deep well pumps.

(4) Large variety of hand pumps in use with accompanying need for many different spares. Little parts interchangeability, sometimes even between the same models of the same manufacturer. Even for fasteners, e.g., bolts and nuts.

(5) Lack of feedback from maintenance to engineering and procurement personnel. Little analysis, for example, of the most common failures. Inadequate record keeping.

(6) Poor maintenance skills, lack of training, inadequate tools, (for example, few village maintenance men have a clevis for pulling up pump rod, drop pipe, and cylinder), lack of transport, and lack of supervision are characteristic of many programs.

(7) Invisibility of maintenance and lack of urgency. Users return to their pre-hand pump source. Maintenance supervisors are far removed from scene or need.

(8) Lack of glamor or peer status. "Deferred maintenance" is often first action in a budget crisis. Maintenance rarely the path to promotion or financial reward.

(9) Lack of appreciation of preventive maintenance. Maintenance too often seen as repair function.

Maintenance systems

Most hand pump maintenance programmes can be characterized as a one level or a two level system. The one level system is one where all maintenance is the responsibility of the central organization. In the two level organization, maintenance is shared with local villages or communities.

The central organization in both systems usually installs the pump. The well may be its task or that of another central agency. For dug wells the village may provide labor under central agency supervision. The central agency usually handles major repairs or replacement of the pump in both systems. It maintains stores of parts and lubricants and provides transport, warehousing, and training. When the central agency provides routine maintenance, it often uses a roving maintenance man or team who may or may not have a vehicle and who services from 20 to 200 pumps (the numbers varying with circumstances) on a repetitive basis.

In joint central and local systems the local community (or a resident employed by the central agency) assumes responsibility for all lubrication and minor repairs, for example, replacement of shallow well cup seals ("leathers"). Where villagers deal only with the basic maintenance tasks requiring frequent attention, then the back-up service may visit the pump at regular intervals for a thorough servicing.

In some programmes certain villagers may be given a thorough training in pump maintenance and virtually all responsibility left in their hands. These approaches are being tried in Kenya and in Tanzania. Each village is required to nominate a person before the well is sunk who will go to the district office for two weeks to learn about shallow well construction and maintenance, particularly of the pump. He will then be responsible for the well once it is sunk, and will carry a small stock of spare parts in his house. If a major breakdown occurs he will go back to the district water office and either get the parts needed to do the repairs himself, or else get the district water engineer's fitters to do the job. (4).

Some people have argued that if a pump could be designed capable of being made by a village craftsman using simple tools and off-the-shelf local materials, then the maker of the pump would always be on hand to repair it when necessary and the village would be entirely self-sufficient in its pump requirements. This argument is supported by the observation that many low-lift, animal-powered irrigation pumps of "traditional" design are built and maintained by village craftsmen. These pumps are not much used for community water supplies even in their own milieu. Other designs, more suitable to drinking water supplies, have been proposed, built, and used, but not widely. They have been apparently functionally or structurally inadequate for intensive, deep well use, lacked durability, been too expensive, or been unacceptable to local users or markets.

When hand pumps are installed subject to unusually strenuous and isolated conditions, and their failure is of vital impact to their users, very expensive, nearly maintenance-free hand pumps may be used. These use fly wheels, crank shafts with antifriction bearings, pressure lubrication, etc., and have been successfully used for long periods with only annual maintenance. Their expense however limits their use severely.

New Construction and Maintenance

The relationship between new well construction and hand pump maintenance frequently receives insufficient attention at the time when new projects are planned. A hand pump well construction project requires a long-term commitment to maintaining hand pumps and providing spare parts. Whether the financing for new construction comes from internal or external sources, the relationship between construction and maintenance exists and should be considered from the start if the investment is not to be wasted.

There are many reasons for overlooking the relationship between construction and maintenance costs. Sometimes the organization responsible for well construction is different from the organization responsible for hand pump installation which is again different from the organization responsible for hand pump maintenance. Sometimes without any real justification it is hoped that the local community will somehow maintain the well. International donor agencies frequently have funds available for new construction but are not prepared to finance hand pump maintenance, considering this to be a responsibility of the recipient country. For their part, the countries receiving assistance have a legitimate need for additional wells, but also find it difficult to make adequate provision for the maintenance of existing hand pumps. It happens therefore, that new construction is sometimes used to replace existing wells and hand pumps which could have been repaired at much less cost.

This bias towards new construction at a high cost instead of hand pump maintenance at a lower cost is clearly unsatisfactory and as a result there is an increasing trend by donor agencies to link new construction with adequate provisions for hand pump maintenance. The objective of these provisions being to avoid the inadvertent generation of maintenance expenditures which cannot be raised within the country assisted. Recent assistance projects by UNICEF, India (Tamil Nadu) and Bangladesh are examples of this trend. (5).

SELECTION OF HAND PUMPS

Costs

Only the larger hand pump programmes can afford to design and develop new hand pumps. Other programmes must necessarily select from hand pumps already on the market; for larger orders some design modifications of current pumps may be possible. In either event hand pumps are compared and selected on the basis of relative total cost, capital costs of purchase and installation plus costs of operation and maintenance.

Inasmuch as all pumps do not have the same service life expectancy, capital costs must be placed on a common basis - usually discounted to equivalent uniform annual cost; making possible the addition of annual operation and maintenance (O & M) costs to obtain comparative total costs on an annual basis.

The following much simplified two pump example is illustrative and could be extended to a larger number of pump alternatives. A discount rate of 10 percent is assumed.

Given: Two pumps, A and B, which meet the necessary requirements for discharge, head, power, handle force, user acceptability, sanitation, etc.

	Pump A	Pump B
Capital Cost, P	\$300	\$600
Service Life, n	5 years	10 years
Operation and Maintenance Cost Per Year, M	\$120	\$100

Find: Which is the "cheaper" pump?

Solution: Annual capital cost R of a present single payment of P dollars over n years at compound annual interest i:

$$R = P \times \text{Capital Recovery Factor} = P \times \frac{i(1+i)^n}{(1+i)^n - 1}$$

For Pump A

$P_a = \$300$, $i = 0.10$, and $n = 5$

and $R_a = \$300 \times CRF = \$300 \times 0.26380$

$R_a = \$79$

For Pump B $P_b = \$600$, $i = 0.10$, and $n = 10$

and $R_b = \$600 \times CRF = \$600 \times 0.16275$

$R_b = \$98$

Total Annual Costs C = Annual Capital Cost R + Annual O & M Cost M

For Pump A $C_a = R_a + M_a$

$C_a = \$79 + \$120 = \$199$, say

$C_a = \$200$

For Pump B $C_b = R_b + M_b$

$C_b = \$98 + \$100 = \$198$, say

$C_b = \$200$

Answer: On an annual basis, the pumps are equal in cost.

Suppose a Pump C was available at a purchase and installation cost of $600 but with a service life of 15 years. Discounted at 10 percent, its annual cost would be about $79, the same as the annual cost for Pump A - even though its initial capital cost was $600/$300 or twice that of Pump A. The useful life expectancy of various hand pump models is difficult to predict with much accuracy and varies with the conditions of service and with levels of maintenance. Nevertheless, as the example shows, catalog unit price or even bid or tendered unit price should not be the sole criterion in comparing hand pumps. Also price and cost are not necessarily identical.

Data on hand pump maintenance costs are sparse. These costs are difficult to predict *a priori* and depend primarily on local circumstances. They are invariably underestimated; estimates based on historical data sometimes fail to recognize that these data often represent costs of *inadequate* maintenance programmes. Any programme with estimated annual maintenance costs less than $50 per hand pump is suspect. Some deep well programs may require $150 or more per pump.

Other cost considerations include:

(1) Cost of well development: the cost of the hand pump should be related to the cost, yield, and reliability of the well.

(2) Conditions of service: stress and wear on a hand pump is directly proportional to the number of people it serves and to the depth from which the water must be raised. Many people and deep water tables mean greater stresses and justify greater costs per hand pump; for example brass rather than cast iron cylinders.

(3) Reliability: where the population is solely dependent on hand pumps for water, additional investment in hand pumps is merited, either per each or in duplicate installations (e.g., two or more hand pumps per well). A cheap pump is no bargain when it is not working.

(4) Local versus imported hand pumps: hard currency costs may require weighting in comparing costs.

(5) Distribution of payments: social objectives may weight selection toward high maintenance/low capital cost hand pumps in order to distribute income within the area served rather than transfer payments to the capital or abroad.

Specifications

The specifications should be oriented towards a limited number of hand pump models based on pre-qualification, preferably through field testing or proven experience under local conditions, supplemented by component by component review of the design. Proliferation of hand pump models in a single program can lead to difficult maintenance problems - inventories, spares, purchasing, lubricants, training, et al.

Use of a single hand pump model would be the ultimate in standardization but should be avoided inasmuch as few pumps are fully suited to all installations and dependence on a single supplier is hazardous to price competition and to factory service.

The performance requirements of hand pumps within the programme should be identified, tabulated, and categorized.

With the needed inventory established, the ergonomic (strength, power, etc.) and anthropometric (height, reach, etc.) requirements can be matched with the appropriate ranges of cylinder diameters, mechanical advantage, handle dimensions, stroke lengths, and pumping speed as described earlier in Hand Pumps (2). This information should then be summarized and specified for each pump as an allowable range of discharge (Q) for a stated pumping head (H), pumping speed (N), and stroke length (S). Maximum slip and minimum mechanical efficiency can be specified *if* a means of verification is available.

The dimensions and threading of pump rods, drop pipes, cylinders and cylinder caps should all be standardized and interchangeable even between pump models. (They can also be bid separately from the top of the well pump stand assembly). These dimensions must be compatible with the wells to be used.

The minimum bearing sizes can be calculated for each pump. The number of different pin sizes should be limited and a unified threading system used. A standard cotter pin should be adopted. For small orders the manufacturer's standard bearings and pins may have to be accepted.

Fits, tolerances, and allowances should be established. Guidance is available from standard sources (2 *et al*.); however local manufacture may require interim compromise.

The construction material for each component should be specified. Allowable alternate materials if any should be specified. Any special treatment such as hardening or galvanizing should be described. These should be cross referenced to widely accepted commercial standards and practices.

Other requirements to be specified include:

(1) Type of cylinder - open or closed, liners or inserts.

(2) Types of valves.

(3) Spout requirements for thread and valve, if any.

(4) Stuffing box requirements.

(5) Spares required.

(6) Lubricants required.

No international standard hand pump specification is extant. No widely accepted standard or "protocol" for evaluation or comparison of hand pumps presently (1978) exists. Such a protocol is now under development.

CURRENT RESEARCH AND DEVELOPMENT

Historical and recent (through 1976) hand pump research and development were reviewed in the handbook, Hand Pumps, by McJunkin (2). The hand pumps and studies reviewed therein included the AID/Battelle pump; the All India Institute of Hygiene and Public Health studies of five Indian hand pumps; the WHO/UNICEF/India deep well pump then known as the Bangalore pump; the UNICEF/Bangladesh "New No. 6" shallow well pump; the Hydro-Pompe Vergnet earlier described; the Sholapur or Jalna-type pumps from India; the U.S.T. or Kumasi pump from Ghana; the Swedish Petro pump earlier described; the Shinyanga pump earlier mentioned; the Dutch Kangaroo pump; et al. These are not repeated here. Several developments since 1976 merit attention however.

Field testing of the AID/Battelle hand pump is proceeding in Costa Rica and Nicaraugua under an agreement involving the governments of those countries, the U.S. Agency for International Development (AID), the Central American Research Institute for Industry (ICAITI), and the Georgia Institute of Technology (U.S.). The AID/Battelle pumps under test were manufactured in Costa Rica and Nicaraugua.

Thirty AID/Battelle deep well and shallow well hand pumps are being evaluated in the field. For comparative purposes, four other, imported pumps are also being tested, including the Dempster (U.S.), Kawamoto Daiichi "Lucky" (Japan), Marumby (Brazil), and an experimental pump developed by the International Development Research Centre (Canada). (Also see Moyno below).

A comparative testing programme for hand pumps has recently been initiated by the Harpenden Rise Laboratory (U.K.) with support from the Overseas Development Ministry (U.K.). Some 12 different pump models are under test in the laboratory at Harpenden Rise under a scientific protocol, perhaps the most complete yet implemented. The pumps under test include most of the "best sellers" in the international export market, several with wheel-type handles, a helical rotary type, the DPHE/UNICEF "New No. 6", developed in Bengladesh, the AID/Battelle, and four of the most novel newcomers to the market.

The extensive comparative field tests of hand pumps undertaken in northern Ghana by the Ghana Water and Sewer Corporation, assisted by the Canadian International Development Agency and Wardrop Associates, Consulting Engineers, described in Hand Pumps, have been completed. Unfortunately this report is not publicly available.

Development of the "Bangalore" pump described in Hand Pumps has proceeded and field tests are imminent. The latest model has been renamed the "India-Mark II".

Development of new, novel pumps by manufacturers has greatly accelerated. In addition to the Vergnet, Petro, and Kangaroo models described in Hand Pumps, a new helical-rotary type, the Moyno, has been developed by Robbins and Myers, Inc. (U.S. and Canada) and cable-driven cylinder and two-cylinder models by Briau (France).

Prototypes of the Moyno are under test in Nicaraugua, Ghana, and Indonesia.

The International Development Research Centre (Canada) has several projects underway which concentrate on use of different materials, particularly plastics; improvement of valves and seals, and wooden bearings. The World Bank is also sponsoring studies on wooden bearings.

McJunkin's general observations in <u>Hand Pumps</u> (2), based on an extensive review of hand pump research and development through 1976, are reproduced below (updating in brackets):

(1) Pump improvements that seem obvious in the office or laboratory often do not work in the field. A corollary is that successful performance in the laboratory does not guarantee success in the field.

(2) Many investigators seem unaware of the work of others on hand pumps. Literature reviews are virtually non-existent and communication between investigators is poor. Communication media are inadequate. ((Publication of Hand Pumps has improved this)).

(3) Cost data are generally insufficient for operational decisions. Life cycle costs arennever analyzed. ((Exception in Ghana, 1978)).

(4) Comparison and evaluation of hand pumps on an international basis will require common definitions, criteria, and methodologies which are presently unavailable, even as a checklist. Some investigators have even failed to measure the pumping head, others to count the cycles in their tests. ((Under development by IRC)).

(5) Experimental methodology is rarely stated, often even the hypothesis is only implicitly stated. Scientific objectivity leaves much to be desired. Conclusions are awesomely extrapolated from limited, short-term testing of single, handmade prototypes.

(6) Many basic assumptions are untested. For example, no thorough, fully conclusive, definitive study of wear and abrasion of PVC pipe for use as pump cylinders has yet (1976) been published. ((Some work underway, 1978)).

(7) Cross-disciplinary studies have been rare. With a few notable exceptions, modern findings from such subjects as ergonomics, anthropometrics, metallurgy, lubrication, friction, materials science, <u>et al</u>., have been ignored.

(8) Many investigators have grossly underestimated bearing wear and loading common to deep well hand pumps for community use. Many hand pump handles (and other working parts) receive over 5 million strokes per year. The average pump rod tension for a 3-inch (approx. 75 mm) cylinder under a head of 100 ft. (30 m) is over 300 lbs. (140 kg); instantaneous loading may be much more.

(9) For all but the largest, most research and development programmes should start small with improvements to existing models, locally available; and concentrate on improved maintenance, larger bearings, better cup seals, and smoother cylinders.

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Research Study Group Meeting on
Appropriate Technology for Improvement
of Environmental Health at the Village
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TESTING AND RESEARCH ON HAND/FOOT WATER PUMPS

AND

GUIDELINES FOR COMPARATIVE TESTING OF PRODUCTS

By

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The opinions expressed in this paper do not necessarily reflect those of the World Health Organization.

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CA
TESTING
AND
RESEARCH

PROJECT NO. Z.9977

TESTING AND RESEARCH ON HAND/FOOT WATER PUMPS

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GUIDELINES FOR COMPARATIVE TESTING OF PRODUCTS

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Copies of these Papers are filed with the authors in HRL Archives and with the Head of Research. We propose also to send copies to the UK Ministry of Overseas Development (which is funding our present hand pumps laboratory testing project No.Z.9923), to WHO-International Reference Centre in The Hague, Netherlands for its forthcoming conference, to other interested international agencies, such as the World Bank, UNICEF PAHO USAID CIDA IDRC and to Associated researchers such as Environmental Services Corp., (USA), Georgia Institute of Technology (USA), International Rural Water Resources Laboratory (University of Maryland, USA), S.B.Kirk and Associates (UK).

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C O N T E N T S

I - TESTING & RESEARCH ON HAND/FOOT WATER PUMPS

1. RURAL WATER SUPPLIES : PROBLEMS AND APPROPRIATE TECHNOLOGY

1.1 Introduction

1.1.1 The supply of water in less developed countries, particularly in rural areas, has long been a serious problem. A supply of clean, potable water is the largest single contributory factor to the reduction of the high mortality rate encountered in such countries; nevertheless it was estimated that in the S.E. Asia region in 1975, eight out of ten people did not have reasonable access to a safe water supply.

1.1.2 In many countries much effort has been expended in attempts to alleviate the problem. The use of handpumps in either dug or tube wells provides perhaps the cheapest and most widely used form of water supply. Even so, the problems have not diminished, but are perhaps even accentuated. This is evidenced by the high percentage (sometimes > 50%) of pumps in some areas (India has been particularly cited), which lie broken or fail to function properly. On the other hand there are pumps in other parts of the world which have given reliable service for decades. Further, hand pumps have been available for at least 200 years, and the technology is very well established. Why then do such problems persist one might ask?

The visible causes of these problems arise from several sources -

a. A pump used for a rural water supply may be used by as many as 1000 people. Many of these pumps were designed for use on farms in rural areas of industrial countries and simply cannot tolerate the intensive use required.

b. The manufacturing quality, particularly of cast iron pumps made in developing countries, is often poor.

c. The capital available for purchase of pumps is frequently severely limited. As a result, cheap pumps, which may be less reliable, are likely to be purchased.

d. There is often very little or no maintenance carried out on the pumps, resources to carry it out being severely limited. This is perhaps the major problem since others would be relatively less important if maintenance were carried out.

The reasons for improper maintenance vary considerably but are usually due to one or more of the following -

a. Poor availability of imported spares, and lack of skills to make spares locally.

b. Lack of local technological knowledge sufficient to provide adequate maintenance, often combined with remoteness of the pump from any servicing centre.

c. Difficulty of organising maintenance services.

d. Lack of awareness among villagers of the importance of clean water and the consequent vandalizing or neglect of pump installations.

e. Lack of clearly agreed and accepted responsibility for the pump.

1.1.3 The problems are thus well known and yet, despite much discussion, expense and new pump design they remain rife. One common answer is that the technology involved in the manufacture and maintenance of the pumps is not suited to the pump users. An <u>appropriate technology</u> must be used.

1.1.4 Before discussing what is meant by an appropriate technology it will be useful to consider the differences between the environments in which hand pumps were used in the nineteenth century in Western countries and those prevailing in many developing countries today.

When the Industrial Revolution swept through most countries in the western world in the 18th and 19th centuries, it had one characteristic trait: progress was achieved by the invention of new technologies. For example, a steam engine could not be built until its principles of operation were fully understood, and the necessary materials developed. An electric motor could not be made before the interactions between magnetic field had been determined experimentally. In brief, the uses of a new technology, and people educated to use it, were both known and available <u>before</u> the technology was applied. Thus, when a new machine was introduced, there were people who appreciated its value and could also maintain it. No machine can be utterly reliable and, however good and sophisticated the technology, some maintenance is always necessary.

This situation is as true for pumps as for any other technological product. Hence, even in the 19th century, pumps could be made using the then comparatively new technologies of machining, casting and forming metals, particularly wrought and cast iron. These pumps were frequently very reliable in the situations where they were used and many pump designs have changed little since then.

1.1.5 The situation in less developed countries today is very different; in particular, the level of technological expertise is generally much lower. The introduction of pumps made in the industrialized world to such countries immediately gives rise to a problematical situation. Firstly, and most importantly, the technology is not understood and thus it may not be possible to provide effective maintenance. Secondly, the need for a pump (as opposed to e.g. a dirty water hole or a stream), may not be understood; this, in turn, will lead to neglect of a pump if other water sources are available, particularly if the attitude of the villagers is very conservative.

There seem to be two answers to these problems. The first is to educate the people to understand the basic principles of the need for clean water, to appreciate the benefits of a pump and to ensure that at least some of the users understand its operation and can maintain it.

The second solution which is often proposed is that mentioned previously i.e. the use of a <u>technology appropriate</u> to the pump users. As this is perhaps the solution most commonly suggested we will consider this for the moment.

1.2 Appropriate Technology

1.2.1 Appropriate technology can be described generally thus (cf WHO Document No.ATH/77.3).

"The word technology means not just a device, but any association of techniques, methods and equipment which together contribute towards solving a problem. 'Appropriate' means that the technology is not only scientifically sound but acceptable to users, providers and decision makers alike; that it fits within local cultures and that it is capable of being adapted, further developed, and manufactured locally wherever possible at low cost".

1.2.2 In this context, therefore, the hypothesis is that a pump should be made locally, of locally available materials, and of such a design that it is culturally, aesthetically and socially acceptable. It should also be cheap. This hypothesis however involves three (hidden) assumptions.

a. That appropriate technology is that which solves the problem of providing safe water supplies in the communities under consideration.

b. That the community appreciates the need for safe water sufficiently to provide the motivation, and hence the necessary community structure and organisation, to deal with the problems. This may mean arranging manufacture of a locally made pump, or simply ensuring that maintenance can be done and is done (not necessarily by someone in the village).

c. Perhaps the most important assumption is that there is already in existence an appropriate technology which can solve the problems within the community that will use the pump (or that, at least, such an "appropriate technological" solution can be found).

1.2.3 In many places in the world these three assumptions are undoubtedly true, and there have been several examples of locally made pumps proving successful. In considerable areas (serving hundreds of millions of people) however one or more of these assumptions is probably not true. For example a rural agrarian community may be able to make basic farming implements from local materials (such as wood and rope) and may have an extensive knowledge of the flora and fauna of its region. The manufacture of a wooden boat would perhaps present no problem, but nowhere could the technology be found to manufacture a hygienic and efficient water pump. Moreover, if there are abundant rivers and streams, the need for a water pump would never make sense to it despite experience of ill-health (caused by polluted water) because it probably would not appreciate the connection. (The London Broad Street pump case is not much more than a century old).

1.2.4 Local manufacture of pumps or the designing of a pump to fit existing local skills may be unnecessary. There is no reason why a pump bought from abroad cannot be used with success in a less developed country, providing the conditions laid down in the 1.2.2.b are satisfiedl.

In a sense the technology can be appropriate even when there are no facilities to manufacture the pump in the country concerned. The words "appropriate technology" very often seem to be misused in referring only to technologies which are currently available in the local community.

1.3 The Water Supply Problem - Conclusions and Recommendations

1.3.1 In the final analysis therefore, there may be no answer to the problem as it stands, i.e. there is no 'appropriate' technology.

Every area of the world has its own peculiar cultural and sociological patterns and there cannot be a single, simple, all-embracing, definitive answer to the water supply problems. Some schemes have been reasonably successful and others have been almost complete failures. Indeed a prime reason for this paper and the numerous seminars and discussions around the world is that, despite many studies, trials, surveys, experiments and new pump designs, there is still no clear, common statement of direction. The reason perhaps is that studies have concentrated on only a part of the total situation and have failed to place the questions being asked and their answers in an agreed multidisciplinary framework (cf Mcjunkin, WHO IRC Technical Paper No.10, 1977; "Cross disciplinary studies have been rare. With a few notable exceptions, modern findings from such subjects as ergonomics, anthropometrics, metallurgy, lubrication, friction, materials science etc., have been ignored").

1.3.2 We stress the need for a common way of evaluating the problems of pumps-in-use-in-environment-in-community in order to point the way successful practical solutions. The main points may be summarized thus:

a. There must be the motivation amongst the pump users, both to use the pump and see that it remains usable. A good reliable pump which is relatively maintenance-free may give good service for a time even where this motivation is lacking, but it can never be completely satisfactory. If there is no motivation no technology, 'appropriate' or otherwise, can compensate for the education necessary to instil it in the users.

b. The pumps to be used in any water supply scheme must be carefully chosen to be compatible with the cultural and social habits of the users. They should be reliable, reasonably easy to maintain and perform acceptably. Manufacture within the developing country should be encouraged wherever possible as it contributes to the independence, self-sufficiency and educational level of the country concerned; it will also reduce the likelihood of poor availability of spare parts and prove cheaper, provided quality can be maintained.

c. The organisational infra-structure for installing and maintaining the pumps must be well defined and appreciated and made to work by those who are responsible for it.

At present however there seems to be a dearth of comparative information on the brands of pump available and we feel such comparative tests are very important.

2. THE PHILOSOPHY OF PUMP EVALUATION

2.1 Approach to Pump Evaluation

2.1.1 The basic need is for a common statement of the way to evaluate pumps in the context of their environment and the community which uses them. This must include developments in the pumps themselves, and the relationship between the pumps and the sociological, economic, cultural, anthropometric and geological parameters which influence their use. Any such statement must be wide enough to include all known influential parameters and yet not so definitive that it can only be applied in a few areas of the world. The real situation is extremely complex, and moreover is disturbed by observation. The best approach to the problem should include three studies viz. comparative testing of pumps available under the controlled environments available in a laboratory, field trials, and surveys. These three are inter-linked and should be organised in such a way that the results are comparable across the boundaries of each study.

2.1.2 Comparative tests on as many brands of pump as possible are important for several reasons.

a. These tests show up differences between various pump designs and hence conclusions can be drawn as to which type of pump might be most suitable in any given geological setting.

b. The pumps' ergonomic aspects can be evaluated and hence judgements made as to which might be easy to use.

c. Tests can highlight design features which are both sound engineering and have been proved in tests, and hence may be recommended for incorporation in existing pumps.

d. Pump characteristics which would cause problems under certain operating conditions, or could clash with cultural traditions or habits, can be enumerated.

e. An idea of the likely reliability of a pump can be obtained. The main advantage of such laboratory tests is that those factors which are random and varying in practice, such as climate and hydrology, can be closely controlled; i.e. results are truly comparative.

2.1.3 Field trials are difficult because they disturb the situation they are trying to test. They are necessary to test the conclusions reached by laboratory tests and to discover how theory corresponds to practice when the actual usage - environments are more complex than can be simulated in a laboratory. By their very nature the results obtained are only completely true when applied to the area(s) in which trials were conducted.

2.1.4 Surveys in the region where pumps are to be installed are essential to enable meaningful conclusions to be drawn from comparative tests.

They are of three types -

a. Geological surveys to determine particularly (from the point of view of the pumps) the acidity of the water, the type of impurities present and the characteristics of the aquifer throughout the year.

b. Surveys to determine the cultural - sociological habits of the users so that -

(i) The most efficient maintenance procedures can be formulated.

(ii) Due consideration can be taken of any socio-cultural habits which could affect pump performance. e.g. patterns of water usage, of water collection, other uses of the pump or its emplacement.

Many of these individual users and user group variables can only studied in similar neighbouring communities which have pumps installed.

c. Surveys to determine the socio-technical situation so that the production engineering, production management, quality assurance possibilities for local manufacture of pumps, pump parts, or spares, can be evaluated.

In less developed areas, the answers may be that little manufacturin capability exists but, in more industrially developed areas, such surveys could point the way towards gearing available firms, resources and skills to the successful manufacture of pumps. (For an expanded view of the concept presented here we refer readers to the work of Miller and Rice in Ahmedabad in the 1950's-1960's; "The Enterprise and its Environment".)

2.2 Comparative Testing and the Implications for Water Pumps

2.2.1 In any comparative brand test careful design of the test procedure is essential to make the results as reliable as possible. It is not intended here to go into a detailed discussion of comparative testing philosophy as this is the subject of a separate paper; in addition several booklets have been written on the subject (ISO Guide 12, IOCU Guide to Comparative Testing).

The more important principles are summarized below -

a. Testing must be independent of manufacturers, politics and any other external influence which could affect either the results or the conclusions drawn. This may be particularly difficult when the work relates to products for LDC use which are likely to be purchased in very large numbers by a few governmental and international agencies.

b. Testing must be objective as far as possible and unbiased i.e. independent of either the person carrying out the tests, or any previous test results.

c. Results of tests on any range of products must be comparable and be derived from realistic tests such that they can be used to draw useful conclusions.

d. Testing must be designed with the requirements of the product and its market in mind, and such that the significance and usefulness of the test results can be understood by the users. For example, a complex array of technical tests is of little use to a non-technically educated user unless their effect is shown by simple practical tests to back them up.

2.2.2 Designing a suitable test programme for hand-and-foot operated water pumps for use in developing countries presents some problems e.g.

a. The pumps vary widely in design so that comparison in some cases is difficult e.g. in comparing the comfort in use of a hand-operated and a foot-operated pump.

b. The physical, sociological and cultural environments in which the pumps are installed vary so that it is difficult to envisage and foresee every kind of problem which could occur and hence to test for it.

c. The interchangeability of components on some pumps makes it difficult to decide which combination to test. For example many pumps are supplied with several sizes and types of cylinder, and pumping depths quoted by manufacturers vary considerably even for one cylinder size on equivalent pumps. Ideally when testing a series of pumps, they should all be designed for a similar depth. In the authors' experience this has proved impossible and allowance has had to be made for this when testing. In our own tests we limited ourselves to deep well pumps to avoid comparison difficulties and because of funding limitations.

2.2.3 The next section explains the philosophical approach to the testing of pumps and section 4 how the tests have been carried out in practice. Some of the tests may require modification in the light of further knowledge, but most of them have been fully substantiated.

It is felt that the following are requirements if the pumps are to be tested successfully.

a. A wide knowledge of prevailing customs and cultural and sociological backgrounds in developing countries.

b. Experience of comparative testing and tried and proved methodologies for obtaining valid conclusions based on various usage/environment profiles.

c. The ability to call on a wide range of scientific and technical skills in the practical testing of the pumps.

The pumps can then be ranked according to their total scores. In practice it will probably be found desirable to examine also the ranking orders obtained by concentrating on the particular attributes specified by the "branches". In this case the score is the sum of (rating x weighting) for one "branch" only.

In general, conclusions can be drawn from the analysis described above, and although it is here applied to the comparative laboratory tests, the principles can be applied much more widely. In particular the analysis can only be as good as the weightings supplied, and to do this the results of surveys are necessary; those of field trials are a great help.

Having therefore shown briefly the main requirements of a pump, the next step is to consider in more detail the actual tests recommended. The next two sections deal with the details of our comparative laboratory tests and proposed field trials.

2.3 Requirements for Laboratory Testing of Pumps

In testing the pumps themselves, there are three particular areas for examination.

2.3.1 A thorough expert examination of the pump design, with confirmatory tests to establish -

a. Manufacturing quality and suitability of materials selected.

b. Adequacy of design to withstand the intensive use often encountered in LDC's.

c. Suitability of design for manufacture in LDC's; an assessment of the skills, facilities and materials required.

d. Likelihood of any corrosion or degradation due to the environment.

e. Foreseeable problems associated with the peculiarities of the mechanical design.

f. Feasible ways in which the product could be improved and/or made simpler and cheaper to manufacture and maintain.

g. The skills, facilities, tools and materials necessary for preventative maintenance and/or repair of probable breakdown or wear.

2.3.2 Testing by a variety of users in practical situations simulating normal use to establish the convenience and ease of use, and how these vary with the user's height, sex, age, fitness etc..

2.3.3 Thorough endurance testing in simulated environment and varying water qualities to reveal any areas likely to cause poor reliability.

Once the tests have been done, it is necessary to use the results to predict the likely cost effective performance of a pump in any given situation. In the final analysis it can only be done by the organisation buying the pumps, as such factors as price, spares availability, likely ease of maintenance etc., must be taken into account and these will vary both from country to country and also within various regions. The testing organisation, therefore, should report its results in such a way as to make this analysis as simple as possible for each water programme installation agency. Thus, though all results should be presented clearly and concisely, preferably in tabular or graphical form as appropriate, a further stage is desirable. The authors propose that at present the most suitable method is SMART (Simple multi-attribute ranking technique) a system where different weightings are given to a list of attributes combined with scores for each pump in the tests to given an overall score. The weightings can be supplied by the pump user purchasing agency to evaluate the most suitable pump for the situation where it is to be installed. The testing organisation should present typical weighting "trees", describing the kind of conditions in which they apply and give guidance to enable readers to select the weightings which apply in their own case.

2.4 Analysis of Results

The first stage in any multi-attribute utility analysis is to devise a weighting "tree", which effectively shows the features and test results to be considered when evaluating the pumps. The major areas of importance are decided first, which in this case are : design, ergonomics and user tests, performance, durability and safety; these are the "branches" which are subdivided into "twigs", and can then be further subdivided into "twiglets". The authors' suggested weighting tree for Harpenden Rise Laboratory's present tests is given in Fig. 1-3. This is a design mainly for deep well pumps, but would require only slight modification for suction pumps. For each individual item on the tree which is not further subdivided, a rating must be assigned for each pump. Normally this is on a 1-10 scale, 1 being poor and 10 very good. This rating is fixed and is dependent only on the test results or subjective assessments of experts based on corroborated data. In certain circumstances where one pump is exceptionally good or bad, it is permissible to give a larger positive or negative rating so as to bias the whole evaluation of that pump. For example, the efficiency of a pump would normally be rated on a 1-10 scale. If, however, it was found that one pump could only operate efficiently at a very fast speed, indeed at such a speed as would enable only the strongest men to use it, and that it was inefficient at the lower speeds at which it would normally be used, a large negative rating, say - 100, would be awarded and this would completely eliminate the pump from further consideration in the overall assessment, even though the pump itself performed well in other tests.

Weightings must then be attributed to each item on the "tree" which effectively indicate its importance. The total sum of all the weightings for each "branch" is normalised to 100. Similarly the sum of the weightings for the twigs on one branch must equal the branch weighting. The same is also true for twigs and twiglets.

The actual weightings will depend on the country and area in which the pump is installed, and can best be supplied by those with experience of the various factors which contribute to the success or failure of a water supply project in the area concerned. As an example consider a pump which is to be made in a less developed country, with no foundry facilities, and installed in a district where the culture, training and experience of the users is such as to make maintenance by a villager almost impossible. In such a situation high weightings would need to be given to simplicity in the manufacturing equipment necessary to make the pump, the ease of maintenance and the pump reliability.

If, on the other hand a pump is to be installed in an area where literacy and engineering skills and experience are high and, moreover, the pump is to be bought in from abroad, neither of the first two factors will be important, provided the reliability of the pump is acceptable. These factors can thus be given low weightings.

To show how this principle works, three specimen weighting "trees" are attached, together with a description of the kind of conditions in which they might apply. (Fig.1-3).

When all the ratings and weightings have been finalised, for each pump the sum of the products (weighting x rating) is found. Note that this product may be either (twiglet weighting x twiglet rating) or (twig weighting x twig rating) if there are no twiglets on any particular twig. Similarly for branches where there are no twigs. The resulting sum should give an overall rating out of a nominal maximum of 1000 (maximum rating of 10 x total weighting of 100). The overall ratings for the pumps are placed in descending order; the pump with the highest rating being considered the most suitable.

3. TEST PROPOSALS

3.1 Buying and Initial Inspection

All pumps should be bought, anonymously wherever possible, through the normal source of supply, ensuring that, in any case, the supplier does not know that these particular samples are intended for tests.

In the case of water pumps the normal purchasing channels would be a government department, International agency, or some other powerful public body, who would order large numbers of pumps from any one supplier, for a specific and defined rural water supply programme. In such a situation the purchasing power and leverage of the buying organisation, and the specificity of the conditions of end-use, coupled with the size of the order, can easily lead to particular modifications being requested, or particular features being incorporated into the pump design by the manufacturers. This, of course, would pose some problems in comparative testing of pumps. On the one hand, if poor results are obtained from two samples of a pump bought anonymously, the manufacturer may claim that special attention and special quality control applied to a large "governmental" order would remove the problems. Reasonable doubt however should remain about his organisational ability to fulfil such a claim. On the other hand there is a temptation to buy samples for testing openly through government/international agencies and to request such special features as would be appropriate. The difficulty then is that one will be testing specially prepared prototypes which might be expected to be very good indeed, but doubt remains about the manufacturer's ability to maintain such quality in pumps manufactured in routine production with less skilled labour. In the case of our present project it was decided to test only standard models of pump, remaining doubtful of the manufacturer's abilities to maintain any higher quality in special designs ordered in large numbers.

On receipt all brands should be inspected for any differences between samples of the same brand, for any similarities between different brands which would indicate a similar component source, and for any defects, damage and wrong or missing components. In general two samples of each pump will be sufficient for laboratory tests.

Where pumps have various cylinder sizes and types the choice will have to be made of the components to be tested. In our tests we selected a cylinder diameter of 57-64 mm, where this was appropriate, or otherwise a pumping element which could be used at a depth of 20-40 metres. It was felt that a larger cylinder of around 75 mm diameter would not provide so severe a test. The use of a narrower cylinder might introduce turbulence problems which are not typical of the larger cylinders.

3.1 (contd)

When removing the pumps from their packaging, an assessment of the suitability of the latter should be made, and the security of the pumps in it, and the protection which it affords, commented upon. The following information should then be listed.

(a) Brand

(b) Model

(c) Manufacturer/supplier and address

(d) Cylinder diameter (nominal), if appropriate

(e) Drop pipe and pump rod sizes, (where applicable)

(f) The range of well depths recommended by the manufacturer

(g) The type of pump

(i) deep well lift, reciprocating

(ii) shallow well suction, reciprocating

(iii) rotary type e.g. Mono

(iv) flexible membrane (diaphragm) type

If necessary, other types e.g. semi-rotary may need to be included

3.2 Construction

The purpose of this section is to describe the construction of the pump in such a way that the final user of the test report can understand fully the method of operation of each pump, and have sufficient information to organise suitable transport, equipment and labour for installation or repair.

Schematic drawings should be provided which show -

(a) The method of operation of the pump stand drive mechanism

(b) The type of pump rod, with couplings (where appropriate) to the pump head and plunger

(c) The types of cylinder and valve together with ancilla y components such as suction pipes and strainers

Drawings should be labelled to show all relevant dimensions, and the materials of all important components should be specified.

The procedure necessary to remove the pump from the well should be described and the operations involved in replacing all valves, seals and cylinders. If the method of repair of any other component is not obvious e.g. the handle, this should also be explained. Information should also be provided about the tools required, sizes and types of any fastenings and details of the spare parts and materials commonly needed (.e.g gaskets, leathers).

Photographs should be taken to show the pump stand and all important components, as well as any other unusual or interesting features discovered during the tests.

Finally, the following information should be tabulated -

(i) The weights of the pump stand and cylinder

(ii) The weights per metre of any pump rod and rising main

(iii) Measurements of the surface roughness of the internal bore of the pumping cylinder (where this.is applicable). The lay direction of any surface marks should also be stated and any other factors, which could affect the cylinder or seal wear, should be commented on e.g. non-circularity of cylinder and variations of this along the cylinder length.

3.3 Design

Because pumps are bought in large quantities and design modifications can be made, at least gradually over a number of years, it is important that any design assessment be constructive as well as critical.

An assessment of the design of the pump probably requires the greatest consideration of any part of a test programme, because it inevitably depends on the skill, knowledge and experience of the assessor. It should be carried out by at least two people who have a wide experience of engineering design, corrosion and ergonomics and who have the necessary knowledge of the sociological, economic and cultural backgrounds prevailing in different developing countries. Separate expert judgements by consultants may be essential in some cases, and tests may need to be conducted to verify both the tentative conclusions and those which are likely to have the most significant effects. It is impossible to indicate everything which should be assessed, but in general the following points should be taken into account -

a. The possibility of incorrect tolerances or clearances causing poor performance and whether these arise from a manufacturing defect or an inherent design fault. Particular areas to watch include seals, valves and bearings.

b. Whether any components are designed in such a way as would make it difficult to maintain a consistently high quality during manufacture.

c. Whether there are any parts of the pump which have a fundamental design fault which would result in either highly localized stresses leading to premature failure or rapid wear of a moving component.

d. How easily the pumps could be made in developing countries. That is: do any of the components require manufacturing processes of a high technology content which might not be available in developing countries? The types of manufacturing process, the materials and skills required should be considered.

e. The proper selection of materials. This may be important from an engineering point of view e.g. strength and impact resistance, and also from the point of view of corrosion and tribology. Particular attention should be given to bimetallic corrosion couples.

f. Whether the design makes repair and maintenance as simple as possible.

g. The adequacy of provisions to exclude foreign matter and surface water from contaminating the well.

h. The possibility of simple modifications to the pump which would enable it to be made more cheaply or would give a better performance without increasing the cost.

i. The resistance of the design to abuse which might be reasonably forseeable e.g. impact side loads on the handle, pilferage and removal of fastenings, and impact of the handle against any stops.

3.4 Ergonomics

A pump should be designed so that, within the limitations of its method of operation, it is as easy and comfortable to use as possible. In most cases in less developed countries, water is pumped into free standing receptacles positioned under the spout. Thus the spout height should be such that all likely containers can be positioned under it, and yet not so high that excessive splashing is likely to occur. Similarly the water flow pattern should be non-turbulent and suitable for filling narrow necked containers as well as wider ones.

The handle should be comfortable to hold and easy to operate by as many different types of people as possible. The handle should be of such a height that excessive stooping or reaching by the operator is avoided. Foot-operated pumps should always be provided with a suitable handle which the operator can use to keep his balance whilst pumping. Consideration must be given to ease of operation by children, handicapped people, the elderly, and pregnant women.

As individual pumps vary so much it is difficult to quote individual parameters which should be measured. The following however should be given where applicable -

(i) The maximum and minimum height of the handle above the ground

(ii) The mechanical advantage of the handle operation

(iii) The angular movement of the handle when operating a full stroke

(iv) The exit pattern of the water. Included in this description should be the spout height, the angle to the vertical at which the water emerges, the distance from the pump at which water hits the ground, the turbulence of the emerging water and the minimum diameter horizontal hole into which all the water can be directed assuming a constant pumping speed.

3.5 Installation of Pumps for Performance Tests

3.5.1 When testing pumps in the laboratory two requirements are found during installation which are not demanded in normal usage. Firstly the accessibility of all parts of the pump during the test without first dismantling the entire assembly. This is particularly relevant to the pumping cylinder where leakage rates, for example, must be measured with the pump intact. Secondly, the ability to alter the pumping head easily and over a wide range, e.g. 7-50 metres for a deep-well pump.

3.5.2 At the Harpenden Rise Laboratory, these problems were solved by building a tower on the side of the main building about 7 metres high with a hut 2.5 m x 4.3 m x 2 m high erected on the top of it. Six pumps were installed in the hut with the drop pipes inside the tower. The pumping elements were immersed in a large tank of water and all water raised by the pumps was returned to the tank via a recirculatory system. To keep the water levelin the tank constant, a weir was fitted across the centre of the tank with the water flowing over the weir being pumped back into the main portion of the tank. There is also a facility for testing the pumping elements of two extra pumps without pump stand and handle assemblies.

To enable the effective pumping head to be varied, a specially designed head simulation valve was built and incorporated into the drop-pipe of each pump. By adjusting this valve the effective head could be varied from 7 to 60 metres without causing flow restrictions.

Into the bottom of the drop-pipe of each pump a 'T' piece with a valve was fitted. This served two purposes. Firstly a pressure gauge could be fitted to check the pumping pressure and the operation of the head simulation valves. Secondly the drop-pipe could be preesurized with compressed air to measure the leakage rates from the cylinders under different pressure heads.

As pumps vary considerably it would be tedious to describe exactly the details of installation for each pump. Figure 4 shows the set-up for a typical pump. Photographs of the head simulation valve are also attached (Figs. 13 and 14).

In order to analyse the forces involved during the pumping operation various parts of the pumps were fitted with strain-gauges, each pump individually as dictated by its construction. A typical reciprocating lift/force pump, for example, was strain-gauged, firstly on the handle to show the force being applied by the operator, secondly at the top of the pump rod where there is the maximum tension, and thirdly at the bottom of the pump rod to show the actual force applied to the plunger. At the bottom of the rod, a specially designed sealed proving ring type load-cell was used, as the whole system is immersed in water. The output from the gauges was taken out through a highly flexible flat ribbon cable via a water tight seal in the wall of the drop-pipe. Figures 5 to 12 show drawings and photographs of typical strain-gauged assemblies used in the tests. A displacement transducer was also fitted to indicate the relative movement of the pump.

3.5.3 Once installation of all the pumps is complete the pumps should be run -in for a short time by hand, and their operation checked. In particular the operation of all valves and seals should be verified, ensuring that there is no excessive friction or leakage.

At this point, while the pumps are still unworn and in good condition it is best to perform the user tests (section 3.8).

3.6 Performance Tests

Performance tests should now be carried out. Some or all of these tests may also need to be repeated at different stages during the endurance testing of the pumps in order to monitor the wear.

a. Leakage tests

The rate of water leakage through the pumping element in a reverse direction to normal flow should be measured. The relationship between leakage rate and pressure head should be shown. A convenient way of performing this test is to seal the water outlet and pressure the drop-pipe with compressed air.

b. Volume flow test

The amount of water pumped at varying stroke rates and using the full stroke length should be measured. The test should be repeated for various pressure heads; these will depend on the pumps being tested. For the deep well pumps tested at Harpenden Rise Laboratory (HRL) heads of 7 m, 25 m and 45 m were used.

c. Measurements

Measurements should be carried out on any part of a pump which is likely to show deterioration during endurance tests. Typical measurements might be the cylinder bore (diameter, eccentricity, cylindricity), seal dimensions, and the play in any bearings or pivots.

d. Operational characteristics

These are measured using the strain-gauges attached to the various pump components. In the tests done at Harpenden Rise Laboratory, the outputs from the strain gauge bridges were connected to a strain gauge amplifier. The gauged components were then calibrated and the gain of each strain gauge amplifier adjusted so that all outputs were matched. These were then fed into a high speed data logger which recorded the outputs digitally on cassette tape. The output from each transducer was sampled every 40 milliseconds. The data was then analysed by computer and graphs showing the forces in various parts of the pump against time and displacement were plotted directly by the computer.

A complete set o data should be recorded for each pump at fast and slow stroke rates (.e.g 20, 40 and 60/min) and for the various pumping heads which are relevant to the type of pump being tested. The authors used heads of 7, 25 and 45 m. A continuous data record for about 10 strokes was found to be sufficient. Further, the actual volume of water collected per stroke should be measured for each test condition.

3.6 (contd)

From the results the following should be given for each test condition :

(i) Graphs showing the variation of force with time and displacement for all the strain gauged components.

(ii) Actual work done (from integrated force-displacement graphs) by the pump operator and on the pumping element.

(iii) The efficiency of the pumping element and the pump as a whole.

For very high speed recording of the strain gauge outputs a storage oscilloscope may be necessary, but this is far less flexible than a data logger.

3.7 Endurance Testing

Endurance tests should be conducted using a pumping head suitable to each pump. Published data varies considerably and choice of the actual pumping head is probably best judged as a compromise taking into account -

a. the manufacturer's quoted pumping head(s)

b. the mechanical advantage of the handle

c. the cylinder diameter

d. the stroke length

e. the volume flow tests

The endurance rig to drive each pump should be made to reproduce as far as possible any side loads or twisting forces which could occur on the pump handle in normal use. A programmed variable stroke length should also be used where this is what would occur in practice. The speed can be varied but for our tests we used a fixed speed of 40 strokes/revs per minute.

At Harpenden the pumps are being tested for 4000 hours with a minimum break of 1 hour each day, in four stages of 1000 hours each.

1) For the first 1000 hours (running time), clean hard water is being used.

2) Acidified soft water is being used for the next 1000 hours. The pH should be checked frequently (every 2 days) and, if this increases significantly above 4.5, dilute hydrochloric acid should be added to bring the pH to the correct level.

3) For the third period of 1000 hours, soft water mixed with a very fine clay is being used. We used a natural grade of Keiselguhr as being a type of fairly consistent quality.

4) For the last 1000 hours small amounts of fine sand should be added to the water.

Any deterioration, breakage or wear should be examined when it becomes noticeable. Any repairs undertaken should be recorded. To monitor the wear it may be necessary at various stages in the endurance test programme to repeat some or all of the performance tests. At the end of the endurance all pumps should be dismantled and thoroughly examined and the effects of the test commented on.

3.8 User Tests

One intractable problem of user tests is the wide variety in the nationalities of people who use the pumps, as well as their different ages. When any test is conducted in one country, the most meaningful results are obtained by using people who live in that country. Trying to obtain users from different developing countries of the World would prove very expensive and, in the authors' view, of no significant extra benefit.

We suggest, therefore that user tests should always be conducted using people living in a country where the anthropometric data are well known and that only obvious extrapolations of data to other peoples should be made.

Our user tests involved sixty people in ten groups of six each, chosen as follows -

Group	Designation				
1	Women :	Height (m)	1.695	-	1.90
2	Women :	Height (m)	1.615	-	1.695
3	Women :	Height (m)	1.45	-	1.615
4	Men :	Height (m)	1.79	-	2.00
5	Men :	Height (m)	1.68	-	1.79
6	Men :	Height (m)	1.55	-	1.68
7	Children: Male:	Height (m)	1.50	-	1.65
8	Children: Male:	Height (m)	1.35	-	1.50
9	Children: Female:	Height (m)	1.50	-	1.65
10	Children: Female:	Height (m)	1.30	-	1.50

All children were aged 11-13 years.

The users were allowed to try out the pumps briefly before the test so that they could determine for themselves the most suitable method of operation.

They were then asked to use each pump to fill a bucket up to a mark on its inside which indicated a volume of 10 litres. A questionnaire, a copy of which is given here, was then filled in.

During the pumping, the user test supervisor recorded the number of strokes used and the time taken to fill the bucket to the required level. The purpose of this was twofold. Firstly, so that from a comparison of the volume pumped with the number of strokes, a judgement of a typical stroke length could be made and how it varied between types of user. Secondly, so that an estimate could be made of the typical stroke rate at which any pump might normally be used.

The results were statistically analysed using a specially devised system based on a two way analysis of variance so that differences between users and pumps could be found both in each individual group and between groups generally.

WATER PUMPS

(Instructions to Users)

Thank you for coming to help with our test. We are asking you to try out 6 pumps for us following the order as given on the top right hand side of your questionnaires. We want you to use the pump until you are familiar with it, then, when you think you have discovered the best method for pumping, please fill up the bucket to the marked level. Do not start filling the bucket until the Laboratory Supervisor tells you to do so, as we want to record the time taken and how many strokes it takes to fill the bucket. This is a test of the pump, not you, so please don't feel you are trying to break any records!

When you have finished pumping please fill in the questionnaire and give it to the supervisor before going on to the next pump.

To fill in the questionnaire, ring the number applicable. If you make a mistake, cross it out and ring the right one.

(e.g.) Not at all easy Very easy

1 (2) 3 (4) 5

Please explain your ratings in the comments column, and comment as necessary.

JUNE 1978

WATER PUMPS

USER QUESTIONNAIRE

Date ....

User's Name Mr/Mrs/Miss ....

User's Height ....

User's Age (if under 21) ....

User No ....

Pump Code ....

	QUESTIONS & INSTRUCTIONS	RATINGS	COMMENTS
Q1	How suitable was the handle height for you?	Much too high ... Much too low 1 2 3 4 5	
Q2	How comfortable was the handle to hold in use?	Not at all comfortable ... Very comfortable 1 2 3 4 5	
Q3	How much effort was required to work the pump?	A lot of effort ... Very little effort 1 2 3 4 5	
Q4	Overall, how easy was the water pump to operate? (Please explain rating in the comments column)	Not at all easy ... Very easy 1 2 3 4 5	

4. FIELD TRIALS

4.1 Introduction

Given that the aim of testing is to find out how pumps will behave in real use and how they will withstand real environmental conditions, field trials have an important place in the work which intermediate between controlled environment laboratory tests and the final use.

Field trials have the advantages over laboratory tests that they take place in environments and with users which are nearer to the eventual populations. Field trials have the disadvantages that the installation situations and environments are much less controlled and well-characterized than in laboratory tests and that the users and usage are completely uncontrolled. Attempting to overcome these difficulties is time consuming and costly.

4.2 Experimental Design

The purpose of field trials is to test the samples - pumps in this case - on criteria relating to the use they will have and the way they will be treated in real life. These criteria may have to do with environmental factors and/or human factors that cannot readily be reproduced in a laboratory or otherwise simulated.

By definition therefore, the conditions under which the samples are tested in field trials will be uncontrolled. The problem is to distinguish, in the results of the tests, differences between the samples which are inherent and those which have arisen due to the environment in which the tests were performed. If results are affected differentially by the test conditions, and these effects cannot be measured and accounted for, it will be impossible to predict how the samples will perform in different environments in the future, and if this is the case the test results will be useless.

So, the essence of good field trials is to organise them as a series of experiments designed specifically so that results due to the samples themselves, and results due to the (variable) conditions under which the tests are being held, can be distinguished. The rules for organising such a series of experiments come under the science of experimental design.

The principles of experimental design lay down that for each sample and each set of test conditions, either a test is performed or its results can be predicted, for every possible combination. (For example, if there are 25 brands and 4 sets of conditions, 25 x 4 = 100 separate tests are held, or at least enough to be able to predict what would happen in all 100 possible combinations).

The first stage therefore of any field trials on pumps would be to determine (empirically) how many different sets of test conditions would adequately cover all likely environments where pumps would be expected to operate.

Given the engineering problems of physically installing pumps and then replacing them with alternative samples, it would seem easier if possible to identify several separate locations which present the same set of test conditions. This, if it could be done, would enable the necessary number of combinations to be tested.

4.3 Carrying out the trials

4.3.1 In a field test of pumps, some of the main difficulties are connected with the essential fact that pumps are intended to be used by rural communities. Even taking 300 people per pump as a guide to pump density there will be few opportunities to vary the type of people using any one brand of pump (as would be normal in a laboratory user test). Furthermore, if a substantial number of brands is to be examined, the field trial may have to cover quite a large geographical area (which could lead to difficulties in inspection, non-comparable volume usage of the samples etc).

Several samples of each brand ought to be tested to increase the significance of the results by statistically removing the variables between different villages, (the objective being to evaluate pumps, not villages).

Installation is important and should be carefully controlled by the comparative testing organisation (CTO): there is little point in comparing some pumps which are installed in a hygienic, well-engineered, structurally sound way with others which are little more than "lash-ups". Obviously details of the installation should be appropriate to each brand, and any manufacturer's instructions should be considered but, at the same time, the installation methods must not be inappropriate to the region(s) in which the field testing is being done (presumably the same as, or related to, the region in which the eventual pump installation programme will be carried out).

4.3.2 Similarly, with regard to manufacturer's instructions for use and maintenance. Such instructions as are likely, in a normal rural water resources/pump installation programme, to be given to users/villages should be given: the CTO must avoid the situation where, because this is a test, exceptional care is lavished on users and/or pumps. One suggestion, however, is that the groups/villages available should be divided into two similar sections. Sufficient duplicate samples of each brand of pump should then be made available, so that it is possible to supply half the user group with the amount of instructions and maintenance help normally associated with a pump installation scheme in that area, while giving the other half more detailed instruction and help. In this way it should be possible to prove to what extent this is a limiting factor in the success of pump schemes, as has been sometimes suggested.

4.3.3 The CTO should not itself carry out skilled maintenance or repair over and above that which would be usual in the region, unless to investigate the value of such help, and evaluate it against the total costs. Attempts to use skilled engineers who may be available, because a comparative test is being done in the field, would invalidate the results of the test for use in choosing pumps for installation in the field without skilled engineering assistance for maintenance.

4.3.4 Measurements of pump performance (e.g. volume delivered per stroke, length of stroke, force needed on handle/pedal, wear in bearings, leakage, wear in piston seals etc.), observations of performance, wear, physical condition, etc., should be made at regular intervals by (itinerant) skilled engineers (or the like) : for example, such a person could travel regularly around a route taking in all the pumps. There are difficulties about the comparability of usage of different pumps, so that, ideally, a volumetric meter should be attached to each : this could lead to problems when reading it (if it is a submerged meter) or vandalism/accidental damage (if it is easily accessible).

The engineer(s) probably should not attempt any observations of convenience/ease of use/user satisfaction (they are likely to encounter problems of the Hawthorne effect and other socio-cultural difficulties). They might attempt some discreet, unannounced, observation of intensity of usage (how many people per half hour, approximate quantity of water drawn, proportion of men/women/children, approximate size of users).

Since tests are comparative, certified instruments should be used in making any measurements. All observations, signed and dated, can be made on pre-written proforma, and all relevant detail must be recorded at the same time. All comments should be substantiated e.g. "pump not working", "light usage","two children needed to move the handle", are comments which are vague and useless by themselves.

4.3.5 The socio-cultural observations may be best made by people who are already in the villages concerned, rather than by highly educated, skilled, technologists (even of the same nationality). There is unlikely to be any point in trying to use detailed questionnaires with technical questions, but the observations are probably best made by someone who can deal with a relatively disciplined, orderly discussion, of the user groups' experience of the pumps intelligibly to "outside" pump programme managers/aid agencies/ pump designers etc.. This is an important cross-cultural/translation role and we consider that people such as the Peace Corps.,/WHO/UNICEF etc., workers who have been in the area for some time for reasons unassociated with pumps might be able to help.

4.3.6 Tests could also be carried out on different in-village maintenance systems e.g. appointing one man to carry out regular maintenance for a fee, for payment by users to have pump on his land etc.. However, it would be important not to confound the results of these tests (in the statistical sense) with comparative testing of pumps.

4.3.7 It is probably desirable to try to get information on simple, fairly cheap ways in which pumps could be improved to deal with some of their disadvantages (e.g. changing materials, enlarging bearing sizes etc.).

4.3.8 The analysis of the (copious) results and the evaluation of the pumps comparatively (e.g. by SMART or some other objective method) must be considered before the tests start. The appraisal of results of any experiment is inseparable from the design of the experiment itself (and often appraisal and usefulness is implied or entailed by the nature of the experiment); this is most particularly true for a field test in the conditions envisaged (which will be almost entirely limited to free-form usage).

4.4 Bias

Bias due to self-selection of the responding sample of users is most likely in field trials, or surveys of field operation, of water pumps in LDC's. Firstly there is likely to be a biased response to the test/survey administrators; since they may be either foreigners or substantially better educated and wealthier-and probably from an urbanised area - the village population may well select the most articulate, intelligent, and prestigious of its members to respond to questions or to operate the pump while observations are being made. Attempts to defeat such self-selection by arbitrarily plucking forward a reticent bystander are more or less doomed to failure, since the "bias" exists in the shared attitudes and feeling of the whole village group towards the survey-administrated field trial observer group; (e.g. C.Bion "Experiences in Groups" etc.).

In all user tests and surveys, (and, again, particularly in field observations or field trials carried out in communities which are not thoroughly used to the paraphernalia of surveys, experiments, and a surfeit of "mass media" communications) there is also a strong possibility of the Hawthorne effect (or "circus" effect). This arises when the mere fact of being observed/ being asked questions leads to a change in the behaviour/conscious thought of the subject. In user tests or observations of field trials, for example, the users may simply tend to "act out" an enhanced, dramatised version of previously sub-conscious attitudes to the product being tested. Being in in a user test, being observed as a user, may arouse in the user conscious thought about his/her treatment of the product. This could lead, either to careful usage and observance of instructions/"proper" modes of use (which might give better performance and longer product life") or to "harder" and more punishing treatment of the product. Either way, effects on the product could be appreciably different from those in the "unobserved" situation, and the users' attitudes to the product are likely to be altered, so that answers to user test or field trial questionnaires may be biased. The Hawthorne effect may be minimised when there is minimum "distance" between the users and the organisers on any of the usual socio-economic dimensions, and when the users genuinely understand and believe that their personal (or group) performance is not being evaluated and they have nothing to gain or lose from the results, whatever they may be. It is clear that, in the case of field trials of water pumps in LDC's, these conditions are difficult to satisfy, but it is essential that the experimental design and the arrangements for making the necessary observations should take into consideration, and deal with the difficulties outlined in this section.

5. FUTURE RESEARCH NEEDS

At present there seem to be quite a number of needs for further research work of widely varying complexities.

An attempt is made here simply to list some of the needs, as we see them.

5.1 Pumps which are Already Widely Available

5.1.1 Controlled and complete laboratory tests are needed to characterise more completely the advantages and disadvantages of the pumps. Their weak spots should be identified and the extent and importance of the weakness disclosed. This work should be done in conjunction with results from field trials.

Laboratory tests should cover as much as possible of the parameters which are important in, and would be observed in, the field. Although they can never equal results of good field trials, laboratory tests must include careful, comparative evaluations and tests of ergonomic/anthropometric factors, and the effects of environmental conditions.

Our own work is limited firstly to deep well pumps and secondly to only twelve of these: there are many more pumps which merit similar research, including shallow well types - with the pumping element above ground and generally giving a much greater volume-per-stroke than the deep-well versions Extending this work is mainly a question of finance.

5.1.2 Field trials and/or surveys of existing installations are needed to describe fully the performance and failures of these pumps in the field. Again their weak-spots should be identified and local reparative or preventive maintenance activities should be fully described. It is essential that field trials be designed carefully, including treatment of geological, social conditions, installation structures and maintenance/repair methods as parameters in the research, the effects of which should be measured in a clear and separable manner.

It is also highly desirable that the methods used in field trials and surveys of existing pump installations should be co-ordinated between countries and regions, in this way results could be "pooled" thereby giving the opportunity to treat them as one large experiment and providing valuable information about the effects of geographical, sociological, infra-structure-dependent variables. This co-ordination and co-operative use of common methodology is not easy; some of the detailed techniques which might be needed include the use of common pro-forma observation records, and free exchange of original data rather than of conclusions alone.

It is desirable that field trials and surveys should be designed to give as much information as possible about all attributes of pumps so that laboratory results and field test results can be compared as directly as possible. Of course there are parameters which are more easily measured in laboratory conditions than in the field (detailed chemical analysis and hardness measurements of materials are obviously two) but every effort should be made to obtain at least some measures of these parameters (a quick on-the-spot approximate analysis of metals can be done with a "pocket" instrument; substantial water analysis can be done with small portable battery-powered instruments, and hardness can be measured relatively simply - the limitations of measurements and observations which are made in the field (e.g in accuracy and precision) should always be stated of course).

If resources permit field trials preceded by laboratory tests on the same samples would be desirable, although - apart from proving the methodology of accelerated durability testing - there would be no need to carry out durability trials in the laboratory if the field trial design is adequate and the sample numbers sufficient.

5.1.3 Design improvements : wherever possible, if an existing established pump design can be improved by relatively minor design changes or additions these should be considered. Examples might be changes in diameter of pin bearings, changes in bolt size or in methods of fixing, changing the material of a handle (e.g. from cast iron to wood, anchored by metal), changes in piston washer material). Changes should only be considered where data obtained in well constituted tests clearly indicate a specific weakness. Changes should not be taken as far as redesigning castings or changing materials for major parts of pumps.
All such changes would require careful and repeated checking to ensure that they actually produce the improvements required. For example, changes to the diameter of pins for bearings in order to improve the load carrying ability of the bearings and increase life in the field should be monitored by measuring stress and wear under laboratory tests, by accelerated durability testing in the laboratory and by field trials - in all cases several samples of the original design and several of the new design would need testing together to ensure that the comparisons are correctly monitored. Care must also be taken in the testing of new designs or prototypes, by skilled staff in small teams; such pumps may not be representative of volume production by batch processing (or mass production) techniques.

5.2 Pumps which are New

5.2.1 Laboratory testing should be done (as 5.1.1) with the addition of possibly more effort to evaluate materials and design.
These pumps should be tested against more established designs. Care note should be made of instances where efforts to simplify certain aspects of traditional pump design have entailed making other parts more complex; even if the simplifications are successful the complexities entrained with them in the innovative design may lead to the whole system being no better, or even worse, than the original.
An example might be the replacement of an expensive machined metal pump cylinder by plastic pipe, which might entail the use of expensive ABS pipe, and complex plastic machining of piston parts and cylinder valves. Generally speaking, assessment of the cost/benefit balance of innovatory designs can only be made after thorough testing and investigation of the pump as a whole, and probably specific subassemblies of it.

5.2.2 Field trials of new pumps should also be carried out with such an experimental design that the benefits of the innovations will be seen in relation to existing designs. Again care must be taken that the (relatively few) samples required for field trial experiments are not specially prepared prototypes unrepresentative of the quality which will be produced when large numbers are made. (The retrospective fitting of modifications to new designs in the field is an expensive, difficult and - to the users - demoralising procedure, which should be obviated by all possible means.

5.3 Usage Situations - Non-technical Factors

All testing (laboratory or field) of all pumps must pay particular attention to the usage-situation. That is to say, the sociological, geological, environmental, cultural and economic bounds of the regions for which pumps are being tested must be a priority consideration. If the region concerned is too large it will be necessary for the researchers to specify over what ranges of usage conditions a particular pump, or design, or sub-unit would be expected to function well. Since these considerations seem generally not to have been central in many extant research studies, it is the more important now to ensure that they are included in all present or future studies.

5.4 Appropriate Technology and its Social/Regional Setting

5.4.1 Since the durability, maintenance and local manufacture of water pumps are key considerations in successful pump programmes, and since these are all heavily influenced by sociological and cultural factors, particular research into these influences would seem to be indicated. It is all too easy to do technological research, the reporting of which contains plenty of statements which explain the paramount importance of social factors while actually largely ignoring them. Indeed it is all too difficult to deal with such factors.

5.4.2 Both maintenance of pumps and their manufacture entail a degree of technological understanding and a socio-technical "infrastructure" or organisation. Indeed, it might be the case that if pump programmes around the world were analysed, those found to be the most successful in dealing with manufacture/maintenance problems would be found in communities with the highest technical understanding, generally. On the other hand this correlation might as much be connected with economic factors or with ease of communication between the local region and the originators of pumps - who have generally been the capital-intensive-sophisticated-technology regions.

5.4.3 Good installation and maintenance of pumps, let alone local manufacture, require social organisation, administration, management, infrastructure, a system - or whatever one likes to call it. There seems to be a need for research into what social organisation or system can produce the best results.

It must be particular to the region concerned, there may be a need not so much for experimental research into what will work, as for actual direct development in situ of social organisations which do work. The only suggestion we have here is that perhaps it may be desirable to view the whole pump programme, and parts of it (e.g. manufacture, spares production, maintenance, a village, groups of wells/communities etc) as "socio-technical open systems" ("Systems of Organisation") - E.J. Miller and A.K.Rice Tavistock 1967, "Task and Organisation" - E.J.Miller, Wiley 1976), and to apply the methods, both of analysis and implementation, to the setting up of maintenance systems, malfunction warning systems, and where appropriate, manufacture.

5.5 Co-ordination

Whatever else may be needed, co-ordination of efforts is a "must". Design, technical testing, field trials, surveys, analysis and implementatio of maintenance and manufacture probably amount to too large a package for any/most countries/agencies to cover completely. Much work has been done, and much is being done.

All too often co-ordination between different research programmes seems to be difficult. Co-ordination is necessary, so that commonality of aims, methods, and reporting may facilitate the transfer of conclusions from one programme to another, across the world.

In the context of co-ordination, it is quite important for the results and thinking of one conference to be available to others, and we end here in sincere hope that there will be full communication between the WHO/SEARO meeting in New Delhi (October 1978), the World Bank's meeting in London (December 1978) and the WHO/IRC meeting in England (March/April 1979), although the precise aims of each meeting are somewhat different.

FIGURE 1

WEIGHTING TREE

DESIGN OF ABOVE GROUND COMPONENTS 27	Manufacturing Equipment	0	Foundry	0
			Machining	0
			Cutting, drilling, welding	0
			Presswork	0
			Sheet metalwork	0
			Protective coatings	0
			Mouldings (Polymeric)	0
			Woodworking	0
			Fitting skills	0
	Adequacy of Design	0	Tolerances	0
			Clearances	0
			Dimensions	0
			Manufacturing requirements	0
	Design Complexity	0	---	0
	Materials Selection	4	Engineering	2
			Corrosion	2
	Simplicity of Repair	4	Hand/foot pedal	1·5
			Bearings	1·5
			Other components	1
	Sanitary Considerations	3	Spout design	0·5
			Resistance to contamination	2·5
	Robustness	8	General	3
			Resistance to impact loads	5
			Resistance to pilferage	0
	Maintenance	8	Extent of maintenance	6
			Ease of maintenance	2
DESIGN OF BELOW GROUND COMPONENTS 23	Manufacturing Equipment	0	Foundry	0
			Machining	0
			Cutting, drilling, welding	0
			Presswork	0
			Sheet metalwork	0
			Protective coatings	0
			Mouldings (Polymeric)	0
			Woodworking	0
			Fitting skills	0
	Adequacy of Design	0	Tolerances	0
			Clearances	0
			Dimensions	0
			Manufacturing requirements	0
	Design Complexity	0	---	
	Materials Selection	4	Engineering	2
			Corrosion	2
	Simplicity of Repair	4	Valves	1·5
			Seals	1·5
			Pumping element	1

FIGURE 1 (Cont'd)

WEIGHTING TREE

DESIGN OF BELOW GROUND COMPONENTS (cont)	Ease of Installation 7	General	4
		Likelihood of damage	3
	Maintenance 8	Extent of maintenance	6
		Ease of maintenance	2
ERGONOMICS AND USER TESTS 12	Spout Design (Ergonomic) 2	Height	0.8
		Exit water pattern	0.6
		Water turbulence	0.6
	Handle Height Suitability 4	Men (tall)	0.5
		Men (short)	0.5
		Women (tall)	1
		Women (short)	1
		Boys	0.5
		Girls	0.5
	Handle Comfort (Overall) 1	---	
	Ease of Operating Pump (20 m) 5	Men (tall)	0.5
		Men (short)	0.5
		Women (tall)	1.5
		Women (short)	1.5
		Boys	0.5
		Girls	0.5
PERFORMANCE 8	Leakage Rate When New 4	High head	4
		Low head	0
	Efficiency 4	High head	3
		Medium head	0
		Low head	0
		Stroke speed variation	1
ENDURANCE 25	Corrosion (Pumping Element) 2	Hard water	0
		Soft water	2
	Corrosion (Rising Main) 2	Hard water	0
		Soft water	2
	Corrosion (Pump Stand) 2	Hard water	0
		Soft water	2
	Mechanical faults (Pumping Element) 5	Clean water	5
		Sandy/silty water	0
	Mechanical Faults (Rising Main) 3	Clean water	3
		Sandy/silty water	0
	Mechanical Faults (Pump Stand) 5	Clean water	5
		Sandy/silty water	0
	Wear (Pumping Element) 3	Clean water	3
		Sandy/silty water	0
	Wear (Pump Stand) 3	----	
SAFETY 5		----	

FIGURE 2

WEIGHTING TREE

DESIGN OF ABOVE GROUND COMPONENTS	32	Manufacturing Equipment	10	Foundry	3
				Machining	1·5
				Cutting, drilling, welding	0
				Presswork	1·5
				Sheet metalwork	0
				Protective coatings	1
				Mouldings (Polymeric)	1
				Woodworking	0
				Fitting skills	2
		Adequacy of Design	5	Tolerances	1
				Clearances	1
				Dimensions	1
				Manufacturing requirements	2
		Design Complexity	2	---	
		Materials Selection	3	Engineering	1·5
				Corrosion	1·5
		Simplicity of Repair	3	Hand/foot pedal	1
				Bearings	1
				Other components	1
		Sanitary Considerations	2	Spout design	0·5
				Resistance to contamination	1·5
		Robustness	5	General	0·5
				Resistance to impact loads	1·5
				Resistance to pilferage	3
		Maintenance	2	Extent of maintenance	1
				Ease of maintenance	1
DESIGN OF BELOW GROUND COMPONENTS	30	Manufacturing Equipment	10	Foundry	3
				Machining	1·5
				Cutting, drilling, welding	0
				Presswork	1·5
				Sheet metalwork	0
				Protective coatings	1
				Mouldings (Polymeric)	1
				Woodworking	0
				Fitting skills	2
		Adequacy of Design	5	Tolerances	1
				Clearances	1
				Dimensions	1
				Manufacturing requirements	2
		Design Complexity	3	---	
		Materials Selection	3	Engineering	1·5
				Corrosion	1·5
		Simplicity of Repair	3	Valves	1
				Seals	1·5
				Pumping element	0·5

FIGURE 2 (Cont'd)

WEIGHTING TREE

DESIGN OF BELOW GROUND COMPONENTS (cont)	Ease of Installation 3	General	1·5
		Likelihood of damage	1·5
	Maintenance 3	Extent of maintenance	1·5
		Ease of maintenance	1·5
ERGONOMICS AND USER TESTS 12	Spout Design (Ergonomic) 2	Height	0·8
		Exit water pattern	0·6
		Water turbulence	0·6
	Handle Height Suitability 4	Men (tall)	0·5
		Men (short)	0·5
		Women (tall)	1
		Women (short)	1
		Boys	0·5
		Girls	0·5
	Handle Comfort (Overall) 1	---	
	Ease of Operating Pump (20 m) 5	Men (tall)	0·5
		Men (short)	0·5
		Women (tall)	1·5
		Women (short)	1·5
		Boys	0·5
		Girls	0·5
PERFORMANCE 8	Leakage Rate When New 4	High head	0
		Low head	4
	Efficiency 4	High head	0
		Medium head	0
		Low head	3
		Stroke speed variation	1
ENDURANCE 15	Corrosion (Pumping Element) 1·5	Hard water	1·5
		Soft water	0
	Corrosion (Rising Main) 1·5	Hard water	1·5
		Soft water	0
	Corrosion (Pump Stand) 1·5	Hard water	1·5
		Soft water	0
	Mechanical faults (Pumping Element) 3	Clean water	3
		Sandy/silty water	0
	Mechanical Faults (Rising Main) 0·5	Clean water	0·5
		Sandy/silty water	0
	Mechanical Faults (Pump Stand) 3	Clean water	3
		Sandy/silty water	0
	Wear (Pumping Element) 2	Clean water	2
		Sandy/silty water	0
	Wear (Pump Stand) 2	---	
SAFETY 3		---	

FIGURE 3

WEIGHTING TREE

DESIGN OF ABOVE GROUND COMPONENTS 37	Manufacturing Equipment	10	Foundry	2
			Machining	2
			Cutting, drilling, welding	0
			Presswork	2
			Sheet metalwork	0
			Protective coatings	1
			Mouldings (Polymeric)	1
			Woodworking	0
			Fitting skills	2
	Adequacy of Design	3	Tolerances	0·5
			Clearances	0·5
			Dimensions	0·5
			Manufacturing requirements	1·5
	Design Complexity	4	---	
	Materials Selection	3	Engineering	1·5
			Corrosion	1·5
	Simplicity of Repair	3	Hand/foot pedal	1
			Bearings	1
			Other components	1
	Sanitary Considerations	2	Spout design	0·5
			Resistance to contamination	1·5
	Robustness	6	General	1
			Resistance to impact loads	2·5
			Resistance to pilferage	2 5
	Maintenance	6	Extent of maintenance	4
			Ease of maintenance	2
DESIGN OF BELOW GROUND COMPONENTS 30	Manufacturing Equipment	10	Foundry	2
			Machining	2
			Cutting, drilling, welding	0
			Presswork	2
			Sheet metalwork	0
			Protective coatings	1
			Mouldings (Polymeric)	1
			Woodworking	0
			Fitting skills	2
	Adequacy of Design	3	Tolerances	0 5
			Clearances	0 5
			Dimensions	0 5
			Manufacturing requirements	1·5
	Design Complexity	3	---	
	Materials Selection	3	Engineering	1·5
			Corrosion	1·5
	Simplicity of Repair	4	Valves	1·5
			Seals	1·5
			Pumping element	1

FIGURE 3 (Cont'd)

WEIGHTING TREE

DESIGN OF BELOW GROUND COMPONENTS (cont)		Ease of Installation	4	General	2
				Likelihood of damage	2
		Maintenance	6	Extent of maintenance	4
				Ease of maintenance	2
ERGONOMICS AND USER TESTS	8	Spout Design (Ergonomic)	1	Height	0.6
				Exit water pattern	0.2
				Water turbulence	0.2
		Handle Height Suitability	3	Men (tall)	0.2
				Men (short)	0.2
				Women (tall)	1
				Women (short)	1
				Boys	0.3
				Girls	0.3
		Handle Comfort (Overall)	1	----	
		Ease of Operating Pump (20 m)	3	Men (tall)	0.2
				Men (short)	0.2
				Women (tall)	1
				Women (short)	1
				Boys	0.3
				Girls	0.3
PERFORMANCE	6	Leakage Rate When New	3	High head	1.5
				Low head	1.5
		Efficiency	3	High head	0
				Medium head	2
				Low head	0
				Stroke speed variation	1
ENDURANCE	15	Corrosion (Pumping Element)	1.5	Hard water	0
				Soft water	1.5
		Corrosion (Rising Main)	1.5	Hard water	0
				Soft water	1.5
		Corrosion (Pump Stand)	1.5	Hard water	0
				Soft water	1.5
		Mechanical faults (Pumping Element)	3	Clean water	0.5
				Sandy/silty water	2.5
		Mechanical Faults (Rising Main)	0.5	Clean water	0
				Sandy/silty water	0.5
		Mechanical Faults (Pump Stand)	3	Clean water	0.5
				Sandy/silty water	2.5
		Wear (Pumping Element)	2	Clean water	0
				Sandy/silty water	2
		Wear (Pump Stand)	2	---	
SAFETY	3			---	

ASSUMPTIONS USED IN FORMULATING WEIGHTING "TREES"

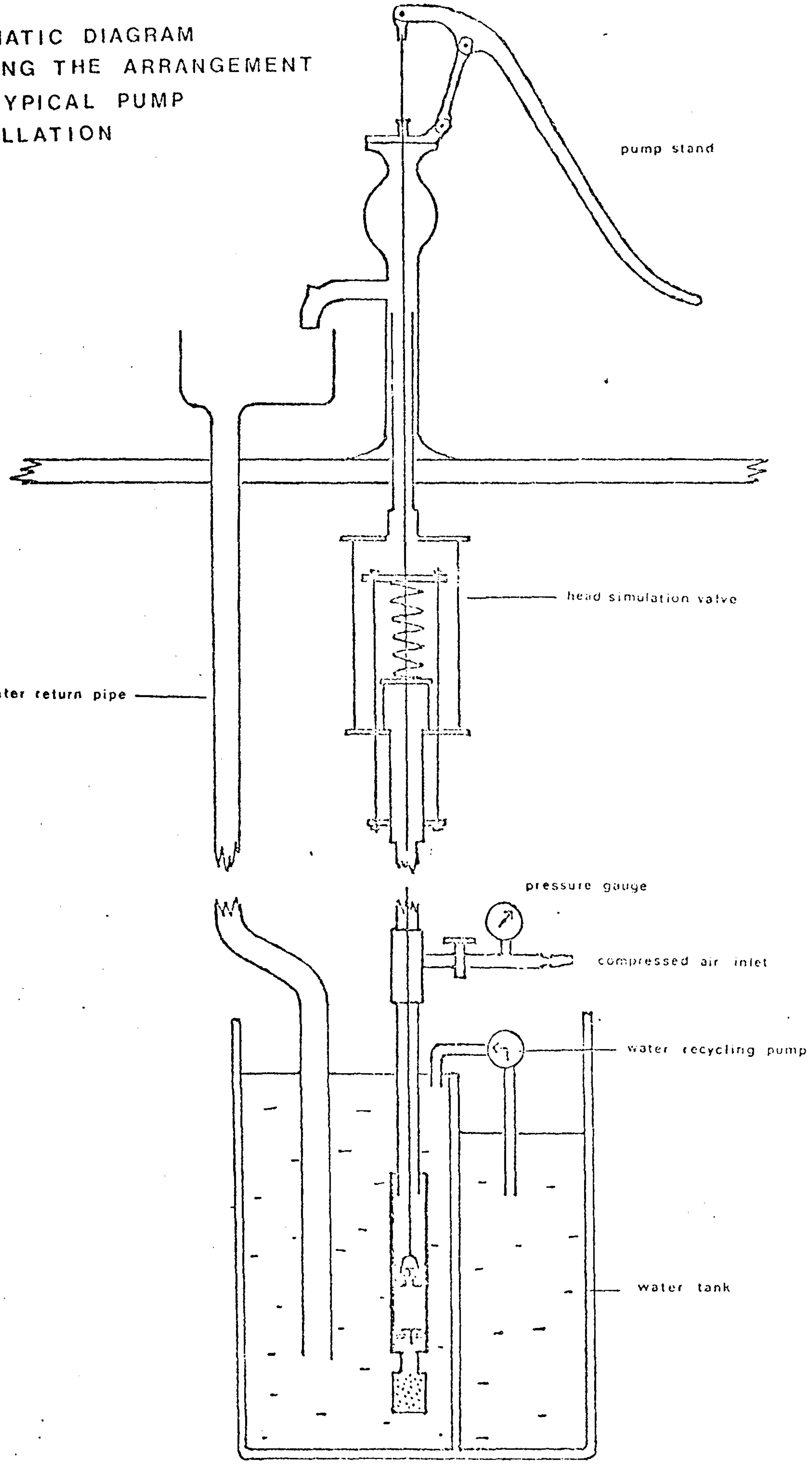
1. (a) Pump bought in from abroad
   (b) Maintenance difficult, level of technological know-how is generally low
   (c) Pilferage and vandalizing of pumps unlikely
   (d) Women are the main pump users
   (e) Deep well installations, > 30 m
   (f) Water is acid
   (g) No sand/silt in water

2. (a) Pump made in LDC
   (b) No foundry available and only limited skills
   (c) Pilferage and vandalizing common
   (d) Women are the main pump users
   (e) Simple maintenance is fairly easy
   (f) Well depth 15 m
   (g) Hard water
   (h) No sand/silt in water

3. (a) Pump made in LDC
   (b) Women are main pump users
   (c) Maintenance is difficult
   (d) Pump likely to be maltreated and pilfered
   (e) Well depth 20-25 m
   (f) Acid water
   (g) Some sand/silt likely to be in water
   (h) Only fairly simple manufacturing processes - no foundry and very little machining or press work.

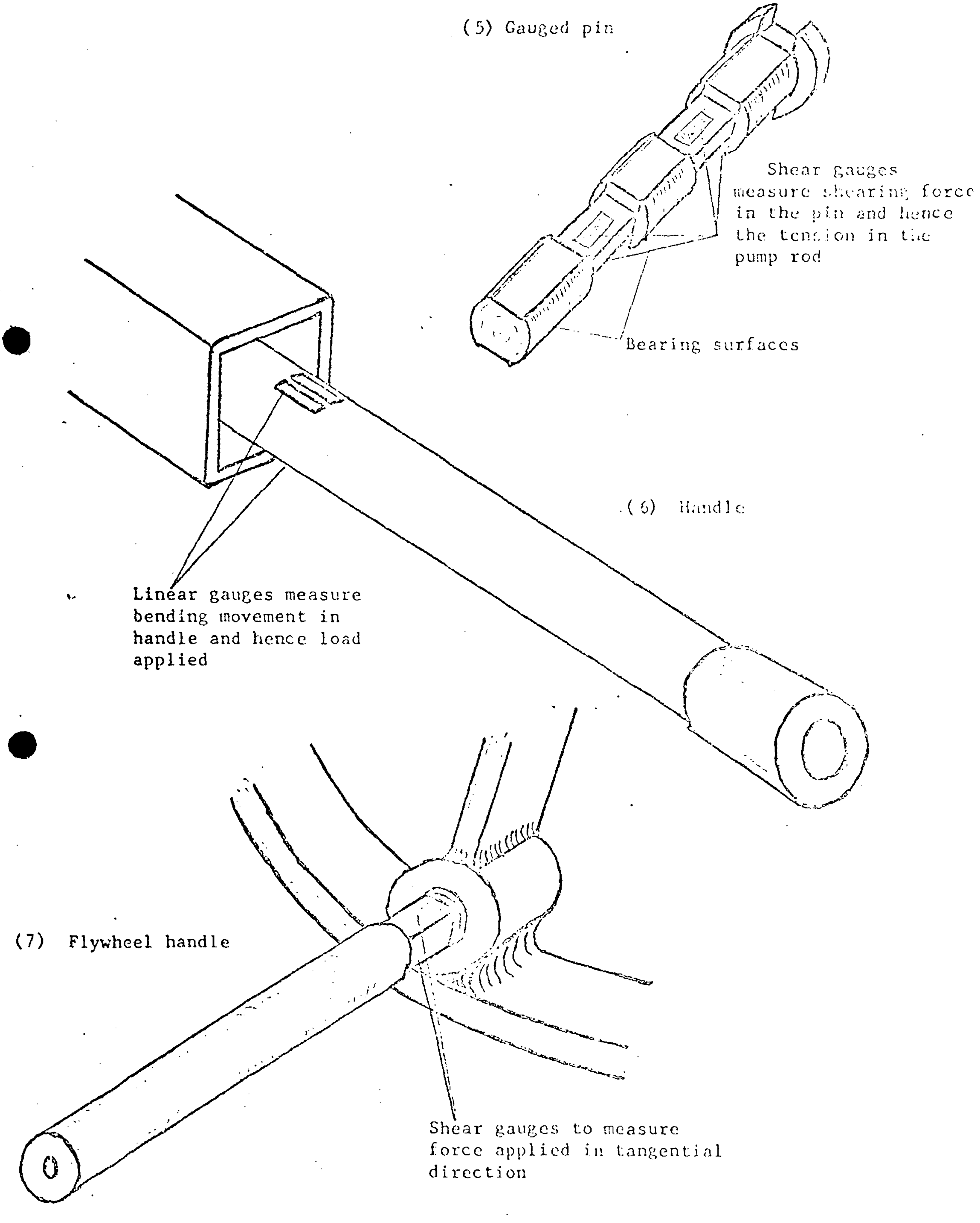
FIGURE 4

SCHEMATIC DIAGRAM SHOWING THE ARRANGEMENT OF A TYPICAL PUMP INSTALLATION

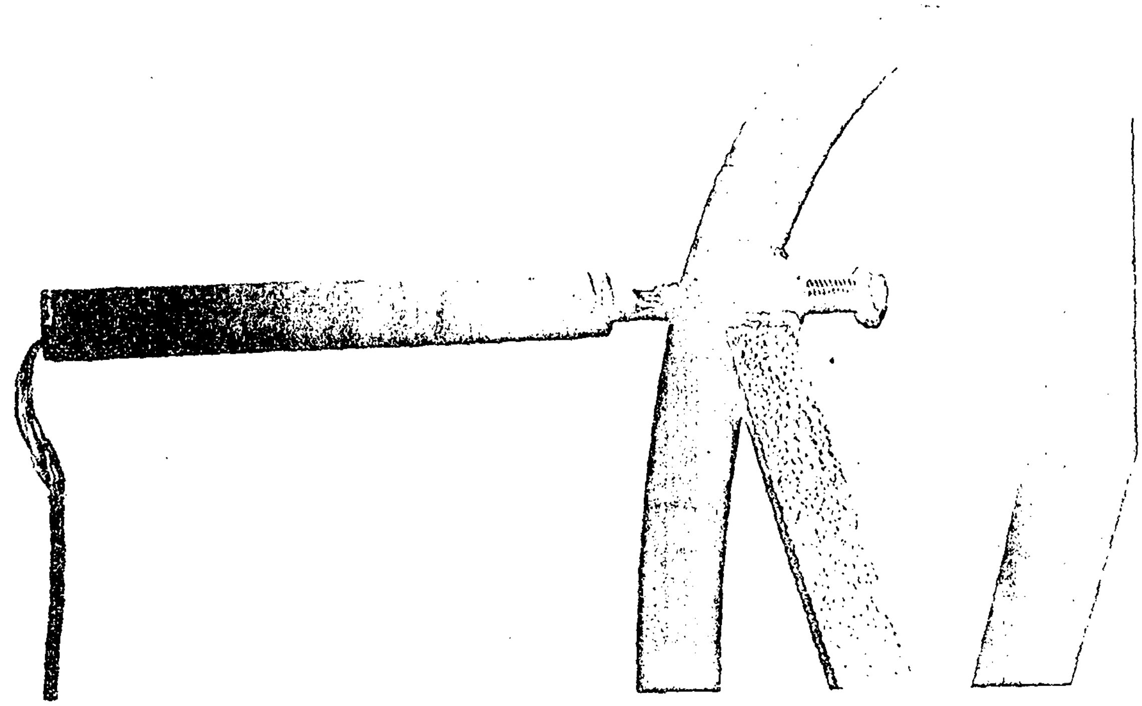


FIGURES 5-7

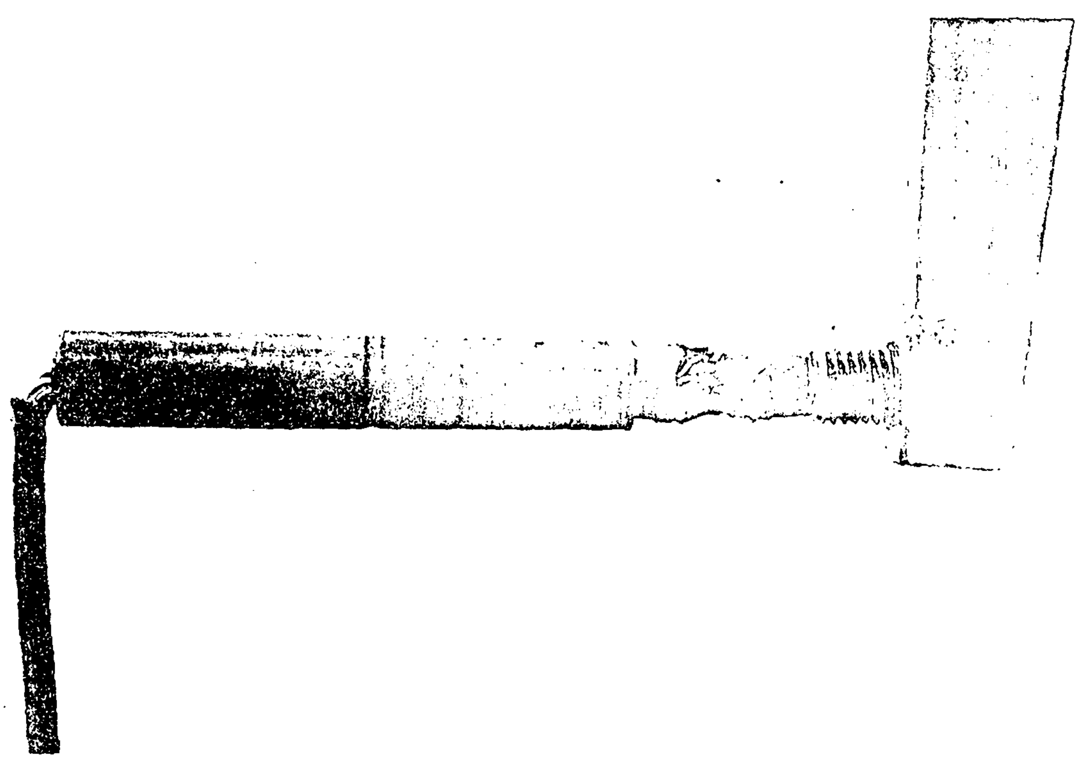
Examples of Strain Gauged Components Used to Measure Forces in Various Parts of a Pump



<u>Examples of Components Fitted with Strain Gauges</u>

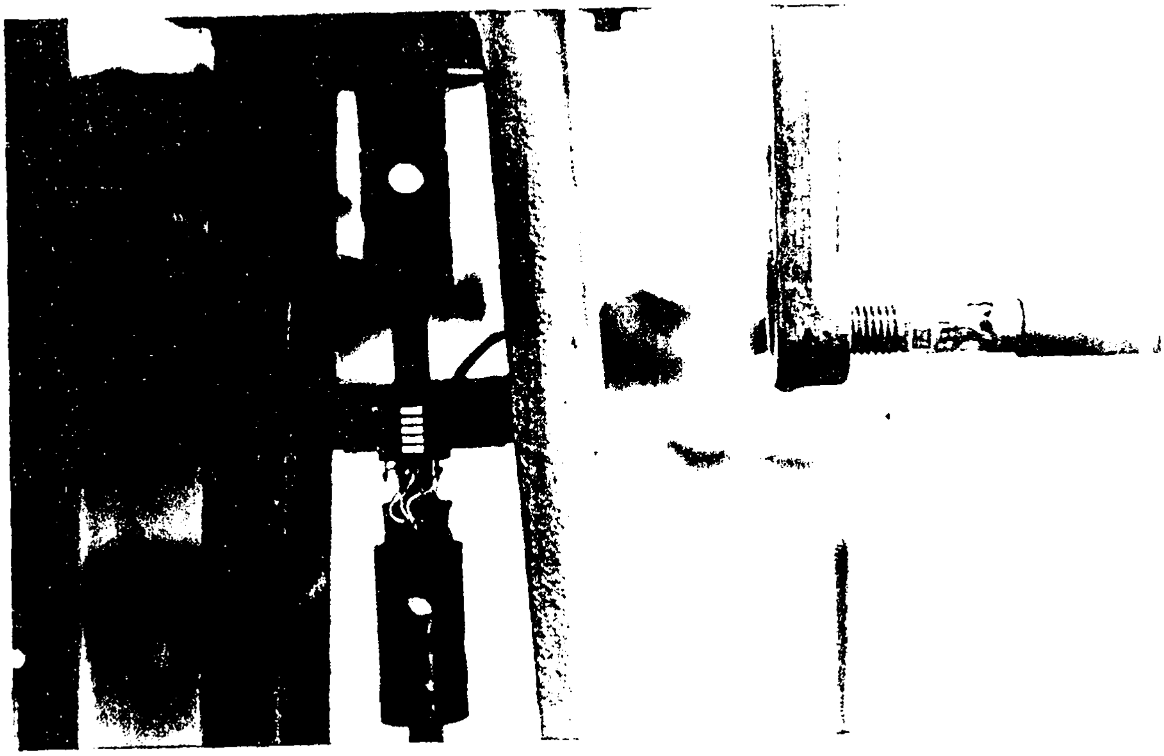


8. Flywheel pump with gauged handle for measuring handle loads (Godwin W1.H51)

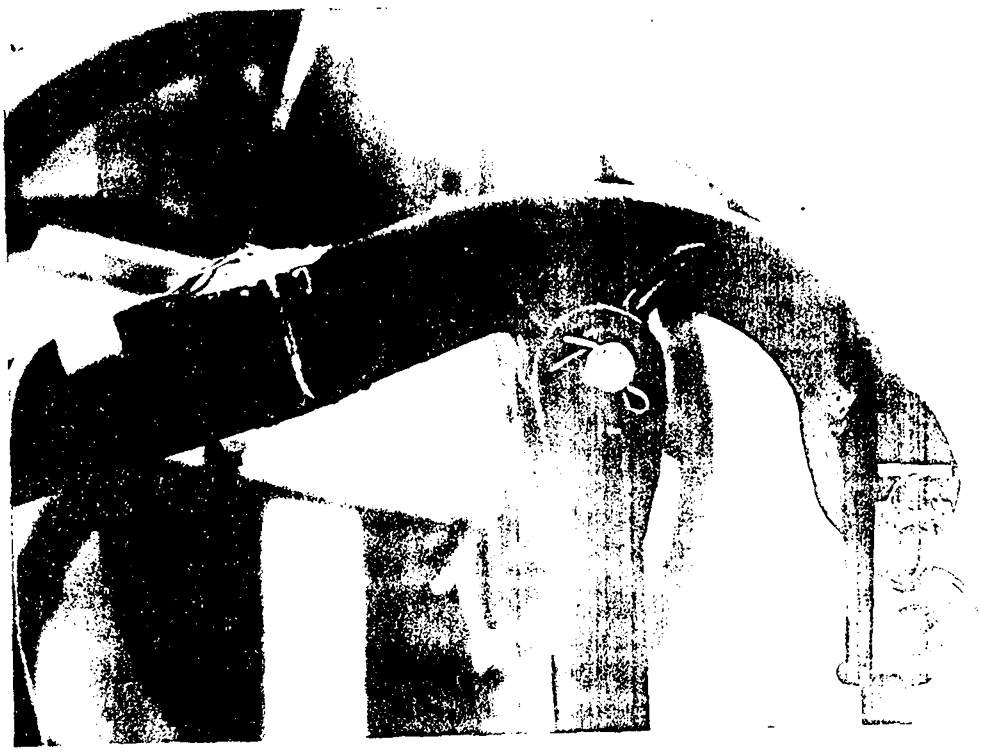


9. Gauged handle on rotary pump (Mono ES30)

Examples of Components Fitted with Strain Gauges

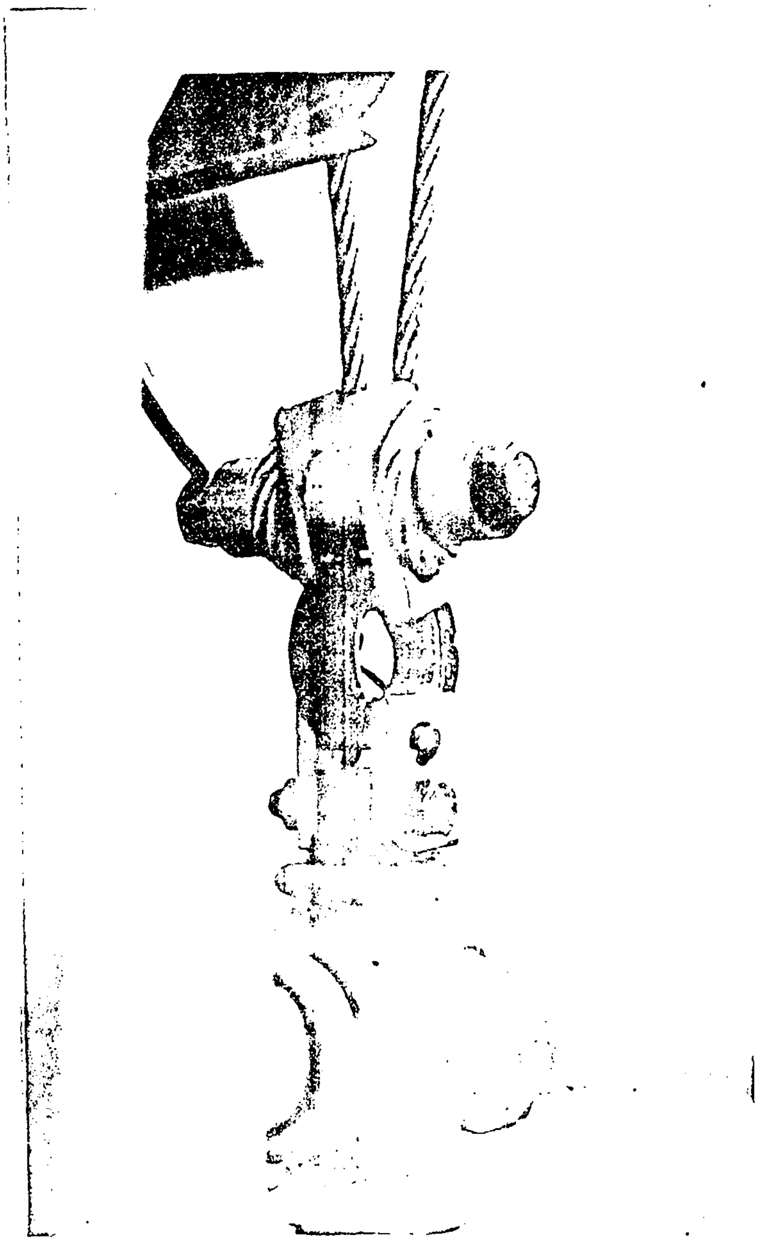


10. Gauged rotating shaft and handle (Mono ES30)



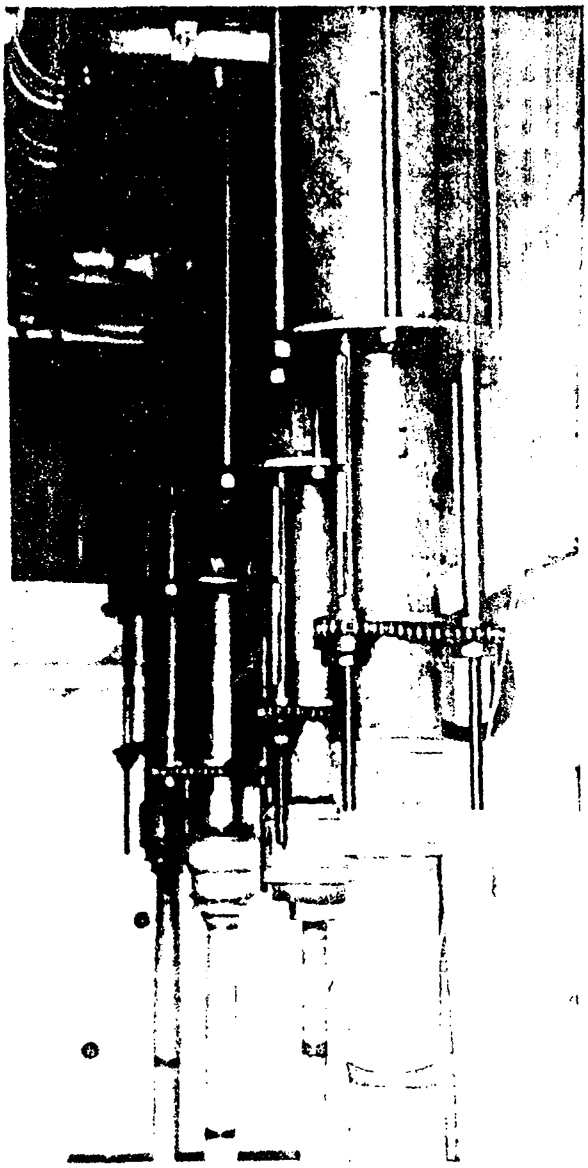
11. Gauged pin (for measuring force in the pump rod) and handle (Dempster 23 EX (CS))

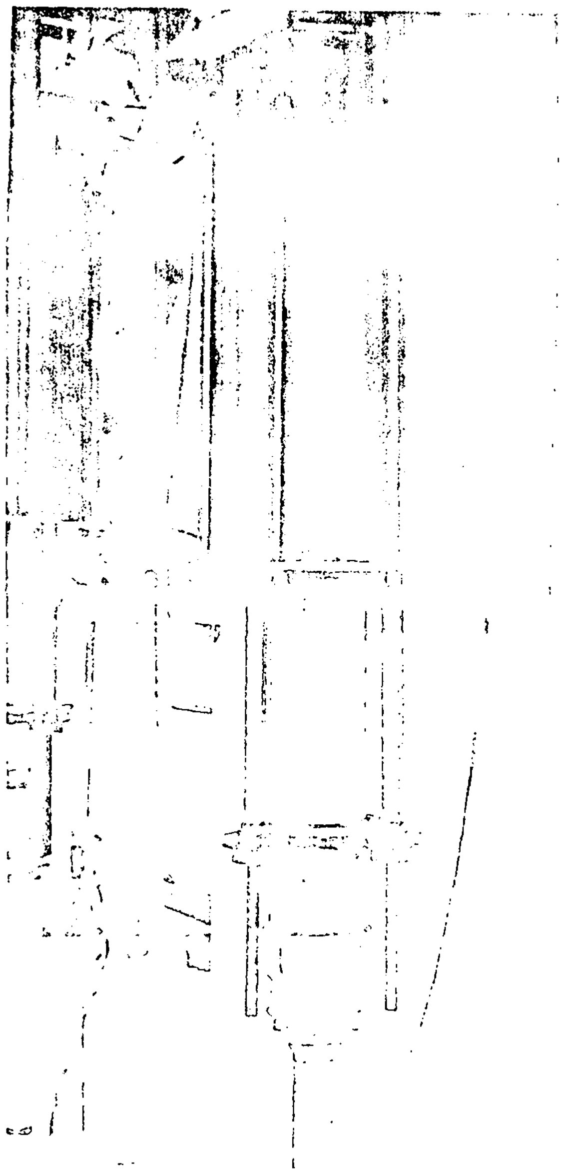
Examples of Components Fitted with Strain Gauges



12. Stress proving ring fitted to a Petropump type 95

Photographs Showing the Head Simulation Valves





14.

II - GUIDELINES FOR COMPARATIVE TESTING OF PRODUCTS

C O N T E N T S

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GUIDELINES FOR COMPARATIVE TESTING OF PRODUCTS

1. INTRODUCTION

1.1.1 The best method of determining how particular brands of a product will perform and endure, in practice - and, therefore, of deciding which is the most suitable for purchase - is be to buy and use them in the normal way.

There are some major problems in such an approach, however If it is to avoid artificiality and produce real, useful answers, the users must know that the investigation is designed to simulate "real life". They will then treat the products normally - especially if reality is such that they have chosen and paid for the products in the normal way. Unfortunately, however, the answers will not be available for a long time, if they can be obtained at all.

1.1.2 Thus there arises the first dilemma of anyone who faces a buying decision - whether it be a personal choice about a product for personal use, or for use by family or friends, or a corporate/business decision about many products for use by others.

The problem is to obtain sufficient useful information about the brands available so that a sensible buying decision may be made. The dilemma is to obtain this information before committing one's finds to buying. The question is "where and how to get such information?"

1.1.3 At first sight it might be supposed that manufacturers are prime sources of the information one needs. What does the product do, how much, how well, and at what running cost, how safe is it, how easy is it to use, how noisy is it, how long will it last, what does it cost to buy/to repair etc.? Manufacturers who make their brands in thousands or millions must surely know the answers (?)

We all know that manufacturers' advertising literature, perhaps without being untrue, often avoid telling the whole truth; even technical brochures for engineering products, sent out by manufacturers' technical departments to the technical departments of buying companies, although more factual, tend to mention the more attractive aspects of a product rather than its drawbacks.

1.1.4 So, while we conventionally (and somewhat easily) reject manufacturers' published information as inevitably not-independent, and somewhat biased, what use is the fund of information which manufacturers must surely have from their customers through sales and field-service departments?

That information is certainly valuable but can it solve the problem? Is it for example, comparative, verifiable and usage-orientated? Unhappily, usually it is not. Not comparative because one manufacturer will seek, obtain and file different information in a different way from his competitors. Not verifiable because it often consists of opinions of users - genuine opinions, but often not helpful to potential purchasers (we are all familiar with the over-optimistic "testimonials" which are sent to manufacturers by users; no doubt there are equally over-pessimistic complaints and abuse received by manufacturers). Often this information is helpful, but incomplete and not a balanced picture.

1.1.5 So, we end up with a need for - Independent
Objective
Unbiased
Accurate
Reliable
Verifiable
Meaningful
Comparative
Usage-orientated

information about products.

This then, is the reason for the foundation of Consumer Unions throughout the World, and for the establishment of the technology of comparative testing : many users can band together to fund research into products-in-use which will provide answers to the above questions, and at a cost which is only a fraction of the cost of buying the products needed by these users. There is then a viable comparative testing organisation (CTO). Consumers' Unions perform that function for individual consumers (hundreds of thousands or millions of them in Europe and N.America). Governmental and international agencies may perform the research co-ordinating and funding role for their taxpayers or beneficiaries.

2. ORGANISATION OF COMPARATIVE TESTING

Comparative testing work in laboratories, or in the field, needs to be

2.1 Independent of manufacturers, of politics, of pressure groups, the Press, etc., for obvious reasons. The need for independence has implications when the choice of a testing organisation to carry out a project is being made. It also has implications for the staff of the testing organisation who themselves must not be subject to influences of the sort mentioned. Difficulties can also arise if the testing organisation itself is so small relative to a project that the organisation's financial viability rests on one project.

2.2 Objective

In that the results of any test must not depend on contingencies such as the place, time, and persons doing the job, except insofar as location is part of the test and particular skills are needed. The same testing procedure carried out by a different (but equally competent) team in a different place at a different time should produce the same results.

2.3 Unbiased

By memories of previous results and observations, whether these were obtained in the same project, or in previous projects, or even by other researchers. One helpful technique which can assist (but not ensure) lack of bias especially in recording and analysing data, is to code the brands with numbers or letters and refer to them only by codes and not by brands.

2.4 Accurate

Test methods must be designed and checked to ensure that results are correct enough and precise/reproducible enough to justify their use in evaluating the attributes of the product which the data purport to represent. Note that there is no need to measure anything more accurately or more precisely than necessary but that it is essential to know what the precision and accuracy of a test result is and that they are the same in all cases. It will be essential for test organisations to have regular procedures for checking the accuracy of their measuring instruments - including simple measuring rulers - against their own reference instruments and/or against national reference instruments.

2.5 Reliable

Attention to all the other points plus the reputation and experience of the CTO will generally assure reliability in its work.

2.6 Verifiable

Usually a test report on a product can have an effect on its sales; therefore, a critical report, especially of a product's safety or durability, may be damaging to its manufacturer. If the test report is misleading or inaccurate, or if testing has not been done properly or by suitably qualified staff, the manufacturers may in most countries be able to get legal re-dress. It is therefore necessary that the testing organisation take clear, and publicly available, steps to ensure that its report can be proved. Such steps include -

(a) The need for all data to be recorded as and when it is obtained, and for it to be clearly labelled with the date and the signature of the person recording the data. This original documentation must then be preserved so that it can be produced if necessary to justify the reported conclusions.

(b) If data are obtained which are likely to lead to substantial criticism of any brand under test (or which are in some other way "odd"), steps must be taken immediately to check such data by -

(i) Repeating the test with other, more experienced/senior observers present.

(ii) Checking the calibration of all measuring apparatus used and the validity of the test method.

(iii) Obtaining further samples of the brand concerned and repeating the test on them.

(iv) Obtaining the manufacturer's comments on the factual data (as in (c) below), and investigating thoroughly any reasons for disagreement.

It is desirable to inform the client after steps (ii) and (iii) and (iv) - unless he wishes to subcontract all the responsibility for even the most unusual results to the testing organisation.

(c) Even if (b) does not occur it is desirable, before issuing a final evaluation report, to check factual data for each brand tested with the manufacturers of that brand. He should only be given the factual data on his own brands, without indicating evaluat ry judgements as comparisons with other manufacturers' brands, and he should be invited to agree/disagree or comment. If he disagrees with the test data he should be asked to supply his own data to the testing organisation in order to demonstrate that its results were incorrect or that the test methods were unsuitable. Very often disagreements are minor and unimportant (e.g. a ~1% difference in the measured external dimension of a product compared with the manufacturer's specification). Even when there are substantial differences in test results these will often be found to be due to different test methods, and, provided that the testing organisation can confidently justify its test methods and procedures in relation the criteria set out in this section (2), it need not be in any way bound by the manufacturer's measurements or views.

(d) Retaining test samples after presentation of the test report for a long enough period to deal with queries which may arise.

It is important that a comparative testing organisation has a full quality assurance system - which, as in good manufacturing industries, should report to the organisation's chief manager independently of managers responsible for finishing projects on time and within cost

2.7 Meaningful

Data should be analysed thoroughly and the significance evaluated - this includes assessment of accuracy and precision and other appropriate, statistically-based techniques. Only data which make sense to potential users/buyers should be included in the test report and indications should be given of the differences which will be perceptible to users and which matter in practice. These data - and, indeed, the whole report - should be presented in such a way that readers can understand and use the results. Without too much scientific detail it should be made clear how a reader can appreciate the results, in order to see for himself what his best choice of action is.

2.8 Comparative

The range of products/brands included in a test should be comparable - at least the brands included should be used realistically for comparable ends and they should present a real choice to users/buyers. Moreover all tests in the research programme must be equally applied to all brands without any differences in method or procedure.

2.9 Usage-Orientated

The test programme, the test methods and the evaluation methods should take into particular account the conditions in which the products are to be used, the level and nature of the users' skills and expectations, and the likely or inevitable abuse ("normal abuse").

3. THE TEST PROGRAMME

The attached flow chart gives an outline of the main steps in the execution of a comparative testing programme. Some points which should be noted are -

3,1 Choice of Brands

The budget may be a limiting factor but every effort should be made to include as many of the brands as are available on the market concerned, in a fully comparative test. However, there will also be occasions when one or two brands of special interest (innovatory designs, for example, or new local production in the country of interest) should be tested. It is also often helpful to include one or more brands of a different type or different price range in order to obtain comparisons and see whether, for example, price differentials or innovation are worthwhile.

3.2 Shopping

Should be done anonymously and through channels which are normal for sales of the product concerned. Care should be taken to ensure that samples for testing have not been specially prepared by some of the manufacturers since this would obviously invalidate test results. Shoppers should also collect, wherever possible, user and installation instructions, service manuals, guarantees and any other relevant documentation.

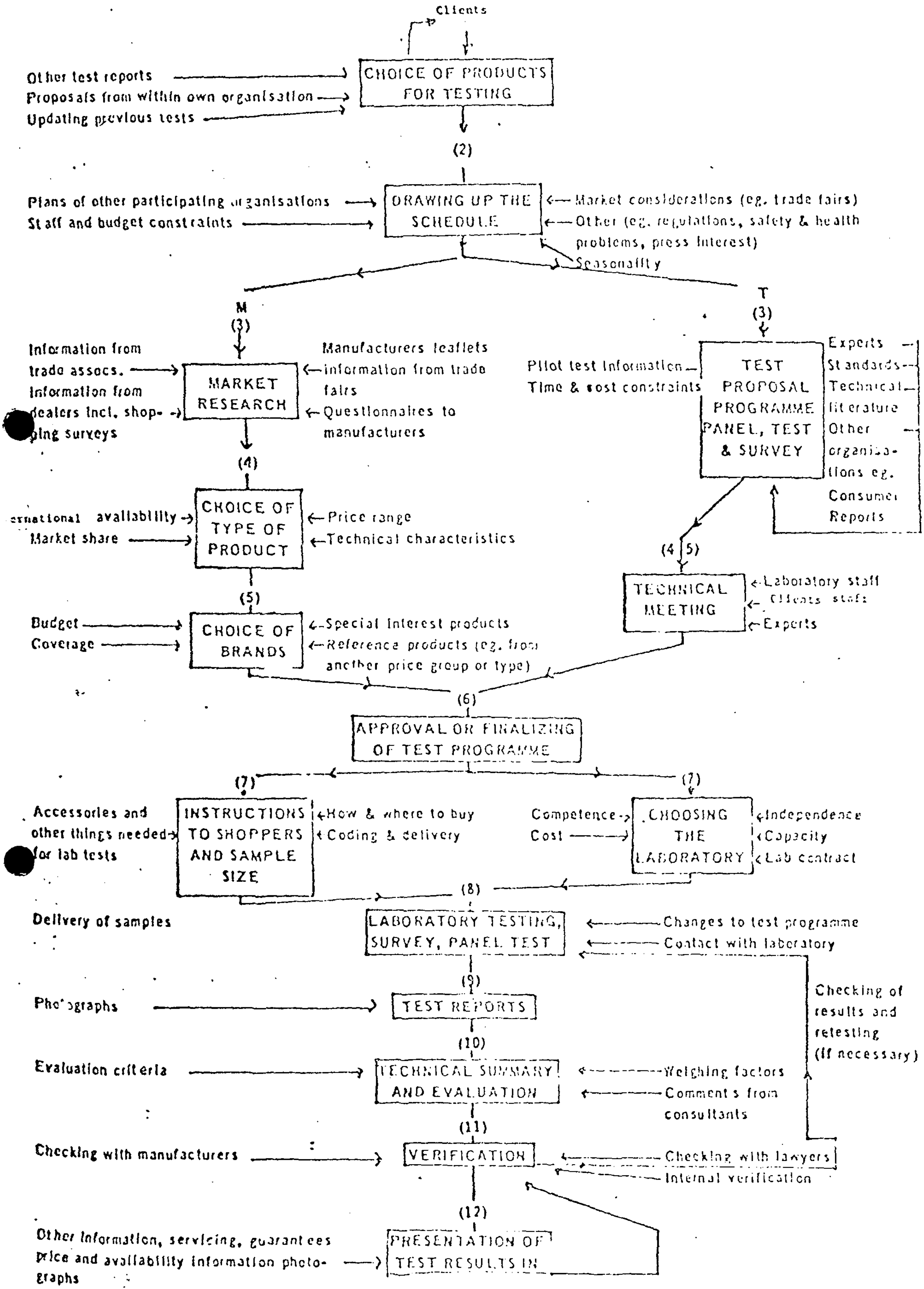
After delivery, samples and their associated literature should be checked thoroughly to ensure that what was ordered was, in fact, obtained, and also that the multiple samples of each brand are, in fact, similar.

3.3 Sample Size

It is rarely possible to take a purely statistical approach when determing sample size but, as indicated above, it is important to ensure that the way the samples are bought is much the same as the way in which users normally buy these products. Later one, precautions should be taken to ensure that the results obtained are not atypical of the products on the market. Such precautions may include an assessment of whether a fault is due to poor design or due to an exceptional product failure, the checking of results against manufacturers' specifications, the substitution or repair of a sampl the presentation of certain test results individually to manufacturers, and the experience of consumers themselves.

With certain products, such as perishable goods, particular attention should also be paid to the trading channels used for the purchase of the items, condition of sampling, transport and storing before test, in order to ensure the comparability of test results.

Samples obtained directly from manufacturers or wholesalers by the test organisation are unlikely to be typical unless a selection of samples from a large number is permitted.



Clients
Other test reports
Proposals from within own organisation
Updating previous tests
CHOICE OF PRODUCTS FOR TESTING
(2)
Plans of other participating organisations
Staff and budget constraints
DRAWING UP THE SCHEDULE
Market considerations (eg. trade fairs)
Other (eg. regulations, safety & health problems, press interest)
Seasonality
M
(3)
T
(3)
Information from trade assocs.
Information from dealers incl. shopping surveys
MARKET RESEARCH
Manufacturers leaflets
information from trade fairs
Questionnaires to manufacturers
Pilot test information
Time & cost constraints
TEST PROPOSAL PROGRAMME PANEL, TEST & SURVEY
Experts
Standards
Technical literature
Other organisations eg. Consumer Reports
(4)
ernational availability
Market share
CHOICE OF TYPE OF PRODUCT
Price range
Technical characteristics
(4 5)
TECHNICAL MEETING
Laboratory staff
Clients staff
Experts
(5)
Budget
Coverage
CHOICE OF BRANDS
Special interest products
Reference products (eg. from another price group or type)
(6)
APPROVAL OR FINALIZING OF TEST PROGRAMME
(7)
(7)
Accessories and other things needed for lab tests
INSTRUCTIONS TO SHOPPERS AND SAMPLE SIZE
How & where to buy
Coding & delivery
Competence
Cost
CHOOSING THE LABORATORY
Independence
Capacity
Lab contract
(8)
Delivery of samples
LABORATORY TESTING, SURVEY, PANEL TEST
Changes to test programme
Contact with laboratory
(9)
Photographs
TEST REPORTS
Checking of results and retesting (if necessary)
(10)
Evaluation criteria
TECHNICAL SUMMARY AND EVALUATION
Weighing factors
Comments from consultants
(11)
Checking with manufacturers
VERIFICATION
Checking with lawyers
Internal verification
(12)
Other information, servicing, guarantees price and availability information photographs
PRESENTATION OF TEST RESULTS IN

4. THE CONTENTS OF A TEST PROJECT

4.1 Assumptions

All comparative test programmes make assumptions about the identity of the user population, the nature of the usage and abusage applied to the products, and the value satisfactions to the user population of product attributes.

These assumptions are most often implicit rather than explicit, and an incomplete statement of the assumptions is one of the most prevalent reasons for disagreement (between users and comparative testing organisations, between one CTO and other.)

Users are populations; so are the characteristics of usage/abusage; so are product ranges. So comparative testing organisations are faced with investigating a statistically complex situation and presenting results in such a way that they are useful (typically to readers who are less sophisticated in comparative testing). Usually it is necessary to simplify the investigation by considering the most likely usage/abusage, the 'average' user, and the most available product range. However, it is desirable to indicate the limitations of these simplifying assumptions (e.g. how prevalent are 'fringe'/'alternative' patterns of use, or user groups?) and it is sometimes also desirable to consider evaluations of the same data relating to different profiles of user needs. The objective of a comparative testing programme is to work within a defined set of assumptions about users/usage and to disprove the hypothesis that there is no significant difference in value of the different brands of product examined in the testing programme.

4.2 Attributes Normally Considered

It is not the object here to prescribe comprehensive Terms of Reference for a product. Nonetheless some guidance can be given on those attributes of a product which are most often considered important.

4.2.1 Size, weight and shape : in some cases these are important to the user, because some brands may not fit the space available. The size and shape of any containers which are part of the product should also be measured and related to users' needs.

4.2.2 Delivery : Appraisals of transportability can be made, and related to packaging supplied, whose degree of protection should be assessed.

4.2.3 Installation : where the product requires installation, a description of the materials, skills, tools needed should be given together with an appraisal of the ease of installation, and whether it is reasonable to expect the user/purchaser to be able to do it. Instructions for installation which are supplied should be assessed for content, layout, intelligibility and clear separation of multiple languages (if relevant).

4.2.4 Design, construction and materials : where appropriate good and poor features of the design should be examined and explained. The manufacturing process, its degree of sophistication, the precision required in making various parts and whether it can readily be attained in batch or mass production (as appropriate) should be considered. Materials of construction should be identified and their appropriateness assessed to the design, to the manufacturing process and, especially, to the purpose and function of the product. The ability of materials to withstand the expected use/abuse should be assessed - the most frequent example here being corrosion resistance.

4.2.5 Running costs should be calculated based on the consumption of electricity, oil, water, gas, detergents, batteries etc. but actual consumption figures should always be reported so that readers can calculate running costs specific to their own area. It is important to comment on the nature of the energy input implications especially in relation to renewable energy sources.

Costs of regular maintenance and of likely repairs during the product's lifetime ought also to be calculated.

4.2.6 Performance is normally measured under carefully controlled conditions which are representative of normal use (finding such conditions can be quite arduous and may well involve surveys or field experiments e.g. in testing tools it is necessary to survey how people actually use them and, perhaps, to measure the loads which they apply). Often performance of products is measured under a single "standardised" set of conditions; when operating conditions are known or expected to vary substantially in practice, the performance should be measured over a range of appropriate conditions in order to find out what range the products can tolerate before giving poor results. (An example would be varying the voltage applied to electrical goods to see what line supply voltage variations they can tolerate). If people are needed to operate the product they should be skilled staff for performance tests (not "users" - see section 4.3); very often automated simulators are used (see section 4.4).

Any legal requirements that relate to the product should be taken into account. Standards organizations and manufacturers are understandably keen that where methods of measuring performance have been published in Standards, they should be used by comparative testing organizations.

Where possible, such Standards should be used: often, however, Standards Methods for Measuring Performance do not exist, and even if they do, it is possible that they consider only "average" usage conditions, perhaps determined by manufacturers. It is, however, recommended that testing organizations should be quite clear as to their reasons why any test method is used.

4.2.7 As well as measuring the desirable outputs of the product which the user wants (and for which he buys the product) it is necessary to measure the "negative' aspects of performance". These are undesirabl outputs, such as noise and pollution (or factors such as the (undesirable) mechanical and chemical wear of the users' clothes which may accompany the (desirable) cleaning they receive in a washing machine). Adverse effects on non-users - e.g. neighbours - should also be assessed, and here again noise and pollution are the commonest factors.

4.2.8 Resistance of the product to normal abuse requires that it also be tested under conditions representing the inevitable, or likely, abuse to which users will put it. The fact that manufacturers may say that such use is extreme, or that the product is not designed for such use should be ignored, if it can be shown that users do actually so use the product. Examples of "normal abuse" include using screwdrivers to open paint tins (thereby tending to bend them), hitting wood chisels with a hammer instead of a mallet (thereby risking shattering the handle), using screwdrivers as cold-chisels (risking shattering the handle or blade tip), not levelling refrigerators, running small electric drills with sanding attachments for the time taken to sand the paint on a door, stalling electric saws, using too much detergent in washing and dishwashing machines.

Resistance to normal abuse includes the ability of the product to withstand extreme climatic and environmental conditions which are either inevitable or likely.

4.2.9 Safety of the product for its users and surrounding population must be investigated thoroughly. Safety aspects must include electric, mechanical, chemical and potential dangers arising from heat, etc., All types of abuse must be considered. Safety under probable fault conditions should be reported and if users are likely to maintain and repair the product themselves, its safety under maintenance and repair conditions must also be reported. It is obviously desirable that products should be safe under all conditions but this is an ideal which may be unattainable in practice - safety being relative, not absolute.

Safety can be assessed both in terms of the likely damage to people, and in relation to the best available protection - for example in the case of electrically-powered hedgetrimmers, the moving blades represent a serious hazard in use which could result in loss of fingers but they are unlikely to kill, as inadequate electrical insulation could; moreover inadvertent starting of the hazardous blades can be prevented by interlocked switches and "deadmans" handles and any brand which fails to provide such precautions should be strongly criticised.

4.2.10 Convenience in use, and ease of use should be assessed. Any special demands which are made on the user in terms of anthropometrics and ergonomics should be highlighted. Such information is available for many if not most, countries and this should be considered before assessing ease of use and convenience. Ergonomists and experts on the product should collaborate in providing informed opinion. Hypotheses thus developed can be tested by user tests (See section 4.3

In these assessments/tests it is obviously necessary to consider the control knobs/handles etc., which a user must operate, and any other parts with which (s)he will come into contact. The intelligibility of instructions, of labelling on the controls or other parts, and of the design itself should be assessed. Convenience and ease of use should be assessed/tested for the range of users likely to operate the product. It is often relevant to consider minority groups here, such as children, the aged, disabled or handicapped people (including pregnant women as a particular case of temporaily "handicapped" users) and the left-handed; with appropriate knowledge manufacturers can often design and make products which can be used by these minorities, but many of them often fail to do so. If there are even one or two brands in a comparative test which can be used more conveniently by some or all of the likely minority groups it is worthwhile to report this fact.

4.2.11 Durability testing often involves lengthy automated operation of the product, perhaps accelerated in time, in order to see the effects of substantial use of the product. Durability does not mean reporting only the life of the product: it should include finding out what factors limit the life (under use and abuse conditions), the most likely causes of failure (with an indication of expected frequency), how failures manifest themselves or can be detected and their consequences. The desirability and feasibility of users repairing failed parts should be assessed in terms of the supplies, tools and skills required and compared with repairs by regular service organisations (from the manufacturers or independent professionals).

It is most important that automated durability testing should represent as faithfully as possible the actual conditions of usage. An example of the differences which this can make was found in testing bicycles: in the past, durability testing in Europe had consisted of mounting the bicycle, with a weight on its saddle, on a moving "road" ("carousel" or "rolling road"), the surface of which was representative of real roads and kerbs/potholes. When Harpenden Rise Laboratory developed a machine which not only loaded the saddle-tube, but also pushed on the pedals to drive the bicycle (and the "rolling road") and also pulled and pushed on the handlebars and seat-tube as a rider would, results were obtained corresponding more to failures found by actual cyclists. As for performance testing, actual conditions of use probably have to be discovered by surveys and measurements in the field.

Corrosion resistance should be included in durability testing.

4.2.12 Although this is not intended to be an exhaustive, or prescriptive list of attributes to test, it is recommended that careful thought be given before omitting any, since an incomplete report may mislead readers (potential buyers). This could lead to inappropriate choices and loss of confidence in comparative testing (understandably, but undesirably from the readers point of view).

4.3 User Tests

Many attributes are complex and may not be easy to measure. For example, noise is usually important as the perceived nuisance: visibility from a car is a complex function involving subjective impressions, as well as the topology of the design. Taste and other culturally dependent sensory perceptions usually cannot be measured objectively. Comfort and ease of doing something cannot be measured directly. Anthropometric and ergonomic studies, while necessary, provide only guides to the design of proper user tests.

Uuser tests are, therefore, designed to test the attributes, which cannot be measured objectively, using panels of people. Data are obtained by measurement and observation of the person/product system, by the users' answering pre-designed specific questions (e.g. on a prepared questionnaire, or under interrogation during or just after the test) and/or by collecting "free-form" responses from the users. User tests may range from carefully supervised operations in a laboratory to usage by individuals or groups in their homes. It is easiest to analyse data obtained from 'blocked' experiments in which each user uses each brand under comparable conditions and in the same way, (the brands being used in different orders by different users). If the tests have been designed by a team including an appropriately experienced and specialised statistician and survey sociologists, they should be able to eliminate the variance due to users/user groups.

Field tests can be particularly difficult because it may not be possible to change user group/brand combinations sufficiently and, therefore, it will be more difficult to distinguish between user group differences and real brand differences. User tests, unlike objective measurements, are subject to the same problems of reproducibility and accuracy as surveys. They are, in fact, sociological experiments as much as, if not more than, they are measurements.

It is necessary that the sample of people recruited as users is representative of the population of actual users; for most products the user-population is not the same as the population of the nation. The sample recruited for a user test must therefore take into account the characteristics of the real-user population (which can often only be discovered by a preliminary survey).

In the case of water pumps for LDC's recruiting a representative sample of people for a user test presents substantial difficulties. If the test is being done in a country other than that in which the results will be of interest, there are problems of matching the user-population anthropometrically as well as for sex and age.

A further requirement in user tests, as in surveys, is the avoidance of bias. Bias is not just a bad, subjective characteristic, (e.g. opinion) of the user which (s)he brings into the test. Bias occurs whenever some sub-groups of the user population are represented on the samples more than others (e.g. in a comparative test of cookers if there were substantially more owners of one brand than of any other brand the samples would be biased in terms of that brand - not necessarily in its favour). Bias may occur due to faulty sampling techniques on the part of the organiser, but is more likely to be due to limitations outside the organiser's control, since, for obvious reasons, his knowledge of the population is limited.

The organiser selects his sample of users from a section of the user population which (s)he knows and has access to. The assumption is that this section of the user population is itself representative of the total user population, and sometimes this assumption can be tested.

For example, at Harpenden Rise Laboratory, we normally select samples of users from a list of over 2000 Consumers' Association members who live within a few kilometres of the Laboratory. We are tacitly assuming, firstly, that Consumers' Association members are representative of the British users of the products being tested and, secondly, that those living in N.W, Hertfordshire are representative of the country as a whole. (The first assumption is not so important when we are testing products for reports in our own magazine to our own members). The assumptions could be tested by selecting samples of non-members in our area, and samples of members and non-members from areas far away, or likely to be different: such testing would be more difficult and costly and usually it is not judged to be necessary for CA projects, but the nature of the bias of our basic list of users must be considered in other projects.

Another common source of bias arises from self-selection: not everyone who is invited to respond to a survey or to help with a user test wishes to do so, and there is a possibility that the characteristics of being willing/unwilling to help in these tests may be associated with differentiation in user/usage characteristics. For most surveys in the UK it has generally been found that willingness to answer does not result in bias, but for some user tests (and, particularly for "free form" field trials) more caution is necessary in interpreting the results.

4.4 Accelerated Testing and Simulations

Often it seems desirable to simulate normal usage of products using mechanical/electrical/electronic machinery to 'operate' the products. One reason for this is the inherent irreproducibility and arbitrariness of human operators which might lead to non-comparable usage between the different brands being compared, (a simple example being the effects of fatigue on a human operator in testing the sharpness of saws, or the psychological effects on human operators in measuring the maximum braking performance of two-wheeled vehicles). The machine or 'rig' which replaces human operators needs to be well designed, taking account of the characteristics of human operation (e.g. a metal rod driven by a rigid ram does not adequately simulate the resilience of a hand pushing controls): if this is well done, a rig can adequately simulate normal usage and ensure that all brands are treated comparatively. It must also be remembered, however, that real usage of some products will be brand dependent (e.g. some cars will be driven 'harder' than others due to the psychological response of the driver to their combination of performance, ride, visibility etc.): in such cases the characteristics of the rig should be varied to match the expected human operation, while retaining the indefatigability, precision, reproducibility and comparativity of a rig.

Another frequent reason for using simulation is the variability in environmental and load characteristics of real usage; controlled environments and standard loads can be devised provided they can be shown to be representative of actual conditions (e.g. controlled climate chambers) or to give test results which are representative of real usage (a situation most thoroughly worked out for American/European domestic appliances).

The need to accelerate usage in order to examine wear, breakdowns and durability frequently leads to the use of continuous/programmed automated rigs. In some cases products can be operated in this way for 168 hours per week, but before doing such accelerated intensive testing it is important to consider whether rest periods between usage cycles in normal situations are actually important in contributing to longevity (e.g. when the rest period allows the product to 'cool off' as, for example, in an electric drill intended only for occasional, amateur usage) or to deterioration (where the rest period permits wear and degradation to set in as, for example, the corrosion which seems to occur in many machines while they are idle and static); in either of these cases, a too intensive durability test will produce unrepresentative results, and a 168 hour per week test may only answer the question 'What happens to the product (and its parts) in intensive use?

5. EVALUATION OF RESULTS

There are many short cuts to processing the data from appropriate tests to arrive at evaluated conclusions. But there is no substitute for the initial thinking about the product in its situation of usage, about the needs and values and (dis)satisfactions of the users, about methods of evaluating the product.

Ideally comparative testing results should be subjected to multi-attribute utility analysis though usually there is insufficient data to do a full analysis; for this reason we normally use a Simple Multi-Attribute Ranking Technique (see Appendix III), which facilitates going from the data obtained by measurements and tests to a ranking order for the brands tested.

Any evaluation makes assumptions about the needs of users; for this reason the future evaluation method must be considered when deciding the content and methods of the project, although modification may well occur as results become available.

6. ACKNOWLEDGEMENTS

Although I put together this particular text, I acknowledge my indebtedness to the accumulated experience and knowledge of those engaged in comparative testing, throughout the World. I would like to mention particularly colleagues on the Testing Committee of the International Organisation of Consumers' Unions, including -

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Oscar Grosch (until recently Head of Technical Department, Consumentenbond Netherlands)

Roland Huettenrauch (Director, Stiftung Warentest, West Germany and present Chairman of the Testing Committee)

Peter Sand (Head of Research, Consumers' Association, UK)

and

Armand de Wasch (Head of Technical Department, Verbruikersunie Belgium)

Nonetheless I also acknowledge that this paper reflects my own views, and neither it nor the previous one is a normal CA Testing Report (which would be based on verifiable evidence).

APPENDIX I

Definitions

Test Programme	:	Combination of particular terms of reference applied to particular products for use in particular situations.
T/R = Terms of Reference/Protocol	:	Document outlining the extent and limitations of the testing.
Methodology	:	Theory relating the ways of obtaining data to their significance.
Methods	:	Description of how each attribute will be examined and measured.
Procedures	:	What the people examining the tests actually do, in detail.
Attribute	:	A property/parameter belonging to the product which relates to its usage.
Evaluation	:	The process of arriving at conclusions representing the value of products to the user (and also the conclusions themselves)
Ranking	:	A list of the brands examined placed in order of in/de-creasing value of defined attribute(s).
Weighting	:	The relative importance/value of an attribute (often quoted as a % of the value of the whole product).
Scoring	:	A measure of the degree to which one brand meets the ideal specification for an attribute.
Brand/Model	:	One particular design of the product (different models from the same manufacturer/distributor are normally treated as different brands).
Sample(s)	:	An individual example of a brand/model.
Expert Opinion	:	The unbiased views of an independent assessor possessing the necessary qualifications, skills and experience relating to the products/attributes.
Rig	:	Semi-or-fully-automated test equipment/machinery which operates the product and/or measures/observes the performance.

APPENDIX I (Cont'd)

'User' or Panel Tests	:	Practical tests carried out under controlled circumstances on products by a group of users.
Survey	:	The collection of information from a sample of users (members, subscribers, or the general public) either by interview, discussion, or postal questionnaire (See IOCU Guide on Survey Work).
Test Programme	:	The overall plan for comparative testing including choice of brands, test proposals, and proposals for panel test and survey work.
Expert	:	Anyone with specialized knowledge of the subject being investigated.
Test Report	:	Report of results of laboratory findings.
Project Controller	:	Person with responsibility for managing, co-ordinating, and seeing through the work on an individual project to its conclusion, including reporting the results and drawing evaluated conclusions from them.
Shoppers	:	The people employed by the testing organization to buy samples for testing.

APPENDIX II

CONDITIONS FOR TESTING BY CA TESTING DEPARTMENT

(HARPENDEN RISE AND GOSFIELD LABORATORIES)

1. We are able to perform INVESTIGATION AND TESTING OF PRODUCTS for some organisations other than CA (with the exception of manufacturers and traders), and this document summarizes the way in which we normally work with such clients.

2. Before starting any tests it is necessary to discuss and agree TERMS OF REFERENCE, which are the detailed instructions from the Client to the Laboratory, on which the work will often be based. Terms of Reference are written by the Client, but we can propose Terms of Reference for discussion. An appreciable part of the Laboratories' work is testing to relevant national or international Standards (e.g. BS DIN IEC CEE ISO), to manufacturers' specifications or against claims.

3. The Laboratory can give preliminary estimates of the COST OF TESTING to any Terms of Reference, but such estimates are not to be understood as firm quotations unless they are issued on a TESTING AUTHORISATION FORM or QUOTATION FORM over the signature of a Section Manager, and the initials of the Head of Testing. Quotations will normally only be given against specified, and agreed, Terms of Reference, for a specified number of samples of each of the specified number of brands to be examined, and for agreed dates for delivery of samples at the Laboratory and completion of the Laboratory Report. Obviously changes in any of these conditions may alter the actual cost of performing the work.

4. A QUOTATION issued and later accepted by a representative of the employing organisation (e.g. by signing Section 4 of the TAF) will be regarded as an official commissioning for the work to be performed and, unless there is any exceptional circumstance, this commission will be accepted when the Head of Testing signs Section 5 of the TAF, and acknowledged by return of a copy of the TAF to the client. There is then a CONTRACT between the employing organisation and the Testing Department. Payment for the work will normally be expected within one month of presentation of an Invoice (after delivery of the Laboratory Report, or other agreed termination of the Contract).

5. GOODS FOR TEST will normally be purchased by the Client and delivered to the Laboratory at the Client's expense, although we may be able to give advice and sometimes assistance in arranging transportation. Any spares, accessories or replacements which are necessary to fulfil the tests according to the agreed Terms of Reference, or because of faults in the samples as supplied, will also be supplied by the Clients and delivered to the Laboratory.

Appendix II (Cont'd)

All goods for test remain the property of the Client and we will ensure that all goods are returned to the Client after testing (unless otherwise instructed by him); (cif will normally be charged to the Client). The condition of tested goods will be notified to the Client as soon as possible after completion of testing, noting whether they are :

As new, Good (minor blemishes only), Repairable, Unsafe or Scrap.

Goods originating from outside the UK must be consigned to Consumers' Association, 14 Buckingham Street, London WC2N 6DS, and all transportation documents (delivery notes, bills of lading, customs declarations) and all packaging of the goods themselves must bear the legend 'Imported under Consumers' Association General Bond No : SOLR 2368/73).

6. The Laboratory will preserve until three months after delivery of the Report all packaging, instructions, labels, guarantees and other material that may be needed to identify products or to show the way in which they are intended to be used or prepared for use.

The Laboratory will, so far as it can consistent with the testing programme, take good care of and not make use of goods which are in its possession for testing. While on Laboratory premises, Goods for Test are covered by the Laboratory's insurance against fire and theft. The Laboratory does not accept any liability for risks inherent in the nature of the testing or which cannot reasonably be foreseen.

The Laboratory will, unless otherwise requested, keep tested goods until three months after delivery of the Report on its premises in the condition they were in immediately after testing, together with all component parts of tested goods, as well as the remnants of any goods damaged or destroyed in the course of testing, and will preserve appropriate means of identification of particular products in relation to the tests and the published report.

Appendix II (Cont'd)

7. It is usual for DISCUSSION to occur between representatives of the Client and the testing staff of the Laboratory as appropriate during testing and after completion and delivery of the Laboratory Report. Any significantly unusual results or occurrences during test, or points of principle about test methods will normally be notified to the Client as soon as possible, especially if criticism of product safety or performance is likely to ensue or if there is a likelihood that the Terms of Reference for testing might be changed in consequence.

The Laboratory will also inform the Client if any goods submitted for test do not appear to be as specified in the Terms of Reference or if there are any obvious similarities between different brands, or dissimilarities between samples of the same brand. The Client will be notified if any tests specified in the Terms of Reference appear to conflict with manufacturers' recommendations or instructions for use, or with relevant national or international standards.

Wherever possible the Laboratory prefers to use the Telex for such communications in order to combine speed with the availability of a written record.

(The Laboratory can accept letters or telex communications in French, German or Dutch as well as English. Other languages will require time for translation).

8. The Laboratory will carry out the tests described in the agreed Terms of Reference mentioned on the TAF and the results will be delivered to the Client in a CONFIDENTIAL LABORATORY REPORT (written in English), the copyright of which will remain with CA.

The Laboratory Report will contain estimates of the accuracy of all measurements and, where appropriate, statistical analysis of the results (e.g. in User Tests). Any major criticisms of products which during testing were notified to the Client will be marked in the Laboratory Report as 'Purple Alerts'; in such a case the appropriate original observations or measurements made by a Tester will have been checked by the Section Manager, the Quality Assurance Officer and, in the most serious cases, by the Head of Testing.

Appendix II (Cont'd)

9. ALL ORIGINAL OBSERVATIONS, MEASUREMENTS and RECORDS of communications between the Laboratory and the Client during testing will be retained in Laboratory Project Files for at least twelve months in order to provide original documentary evidence if required by the Client; this file will be treated as Confidential to the Laboratory and the Client. All original observations and measurements are recorded in Laboratory notebooks and are initialled and dated as the records are made. Measuring instruments are calibrated regularly against appropriate standards and full records of such calibrations are maintained.

The Laboratory Report is prepared from a draft which is examined and corrected by independent Checkers wholly employed by the Laboratory, whose comments are also retained in the Project File.

10. We will keep CONFIDENTIAL all matters relating to testing and reporting. This covers every aspect of the relationship between the parties, and nothing will be published or divulged to anyone (including, obviously, the press and broadcasting authorities) without the Client's specific consent each time. This confidentiality will be kept both before and <u>after</u> publication of <u>any</u> report by the Client (where applicable).

Examples of things which we will keep confidential are -

(a) The fact of having been commissioned to do the work.

(b) The products tested.

(c) The methods of testing.

(d) The results of the testing, or of any other observations, of the goods for test.

(e) The contents of the test reports.

(f) The contents of any draft report for publication (where applicable).

(g) The nature of and reasons for revisions in the draft report.

These standard Conditions of Contract require the Client to maintain the same degree of Confidentiality. Either the Client or the Laboratory may break this confidentiality only by express agreement of the other, or if compelled to do so under, or by virtue of, an order or rule of court of law.

Appendix II (Cont'd)

11. When the TESTING is commissioned by the Client IN ORDER TO PUBLISH a report on the goods, either to the general public or to subscribing members of the employing organisation, the Laboratory can often help if a copy of the draft publication report is sent to the Laboratory as soon as possible for comments. In this case the Laboratory will comment on the factual statements, and interpretation; if the Client wishes the Laboratory to check any factual statements in the draft publication report, the words 'Please Verify' should be written on the draft clearly against the parts which are to be checked. The Laboratory will then indicate agreement disagreement on the draft and return it to the Client initialled and dated. If the Laboratory thinks that statements or interpretations in the publication report are accurate or reasonable but cannot take responsibility for them it will write 'Not Checked', '?', or some similar indication. Anything in the draft report left without comment is to be regarded as not checked specifically.

12. The Laboratory may be able to supply 'expert witnesses' and would normally expect to be able to verify the statements in the Laboratory Report. However the results of investigations and tests may not be used for the purposes of any civil dispute or criminal prosecution without the prior written agreement of the Head of Testing. If the Client requires the tests to be carried out in connection with any dispute (existing or contemplated) the details must be disclosed to the Laboratory before the Contract is signed. If Laboratory staff are required to prepare, or present, evidence in connection with any dispute or legal proceedings, whether instigated by the Client or anyone else, the Client will be charged for the costs of additional time and expenses involved over and above the original Contract for test work.

13. If any DISCOVERIES are made by Laboratory staff during an investigation or test we reserve the right, after consulting the Client, to secure ownership of the discoveries by patent, registered design or copyright in any countries. In this case the Client will be entitled to a free, non-transferable UK licence with limited period of exclusivity, and other licences on terms to be agreed.

14. The Laboratory is not obliged to allow Clients to witness the tests, or any experiments related to them, and reserves the right to exclude VISITORS, although this right will not be unreasonably used. If representatives of the Client do visit the Laboratory they will be restricted to the areas and staff concerned with work being done for them, in the interests of preserving the confidentiality of other work.

APPENDIX III

"SMART"

EVALUATED CONCLUSIONS FROM COMPARATIVE TESTS

(Multi-attribute utility analysis)

1. Comparative testing, whether it takes place in a laboratory, in users' homes or 'in the field' aims to assess products in relation to the needs of their users/prospective users.

2. In order to make the results of the tests meaningful and useful to the reader of the reports it is very necessary

   (a) to make the process of arriving at conclusions clear, objective, and reproducible.

   (b) to present the conclusions to the reader so that he can see how the conclusions follow from the objective data plus our assumptions about users' needs. Then, if he wants to change his own understanding of these needs it is not necessary for him to wade through all the mass of detailed evidence - he will be able to 'dial in' a new set of needs and obtain new conclusions.

3. Obviously we need to do two things :

   (i) think about our assumptions of the user's needs, expose them so that they are useful to the reader.

   (ii) develop and use consistently an objective 'calculator' for deriving evaluations of products.

   These need to be done at Terms of Reference stage, so that we can see that project resources are being put into obtaining data which is judged to be useful to readers.

4. We cannot draw any conclusions at all from our work without making some assumptions about the needs of a user; this follows from the aims of our work which are to evaluate and compare products in relation to their real usage and abusage. Obviously we should try to find out what real users actually want and expect from a product and how they will use and abuse it. Sometimes there is survey information, sometimes we depend on our client/project officer, (rarely) there is a specification for use, sometimes we are relying on our own experience as users (and perhaps our own prejudices and peculiar needs).

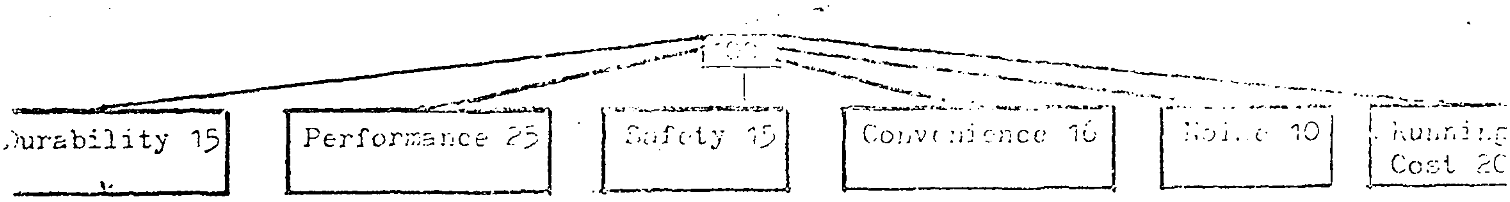
5. For a long time some consumer organisations (notably VU CB SW) have used an evaluation system which is relatively objective. While it is not totally beyond criticism, it has many advantages and is, in any case, one of the methods tried and proved by many non-domestic purchasing organisations on both sides of the Atlantic - the Americans refer to the problem of evaluating products for purchase as multi attribute utility analysis. This particular method is a simplified version called SMART (Simple Multi-Attribute Ranking Technique).

6. Starting with the whole product evaluation as 100, divide this into the main attributes which will be tested and assign weightings to each.

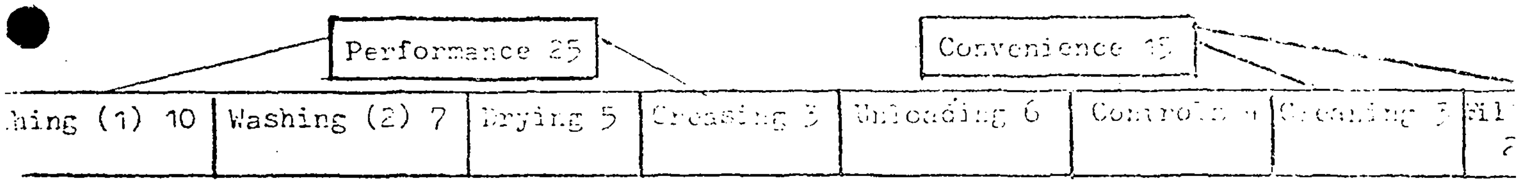
(It is helpful here to remember that attributes of most products can often be divided into size, and shape, features, performance in normal use, negative aspects of performance (cost, noise, vibration, environmental damage etc)., safety normal abuse, ergonomics, durability, and maintenance.

Obviously normal usage/abusage/users do cover a wide range of situations : in many cases it will not be sensible to decide on one "average" evaluation, and perhaps several different evaluation "trees" should be used to draw conclusions, for different segments of the user/usage population.

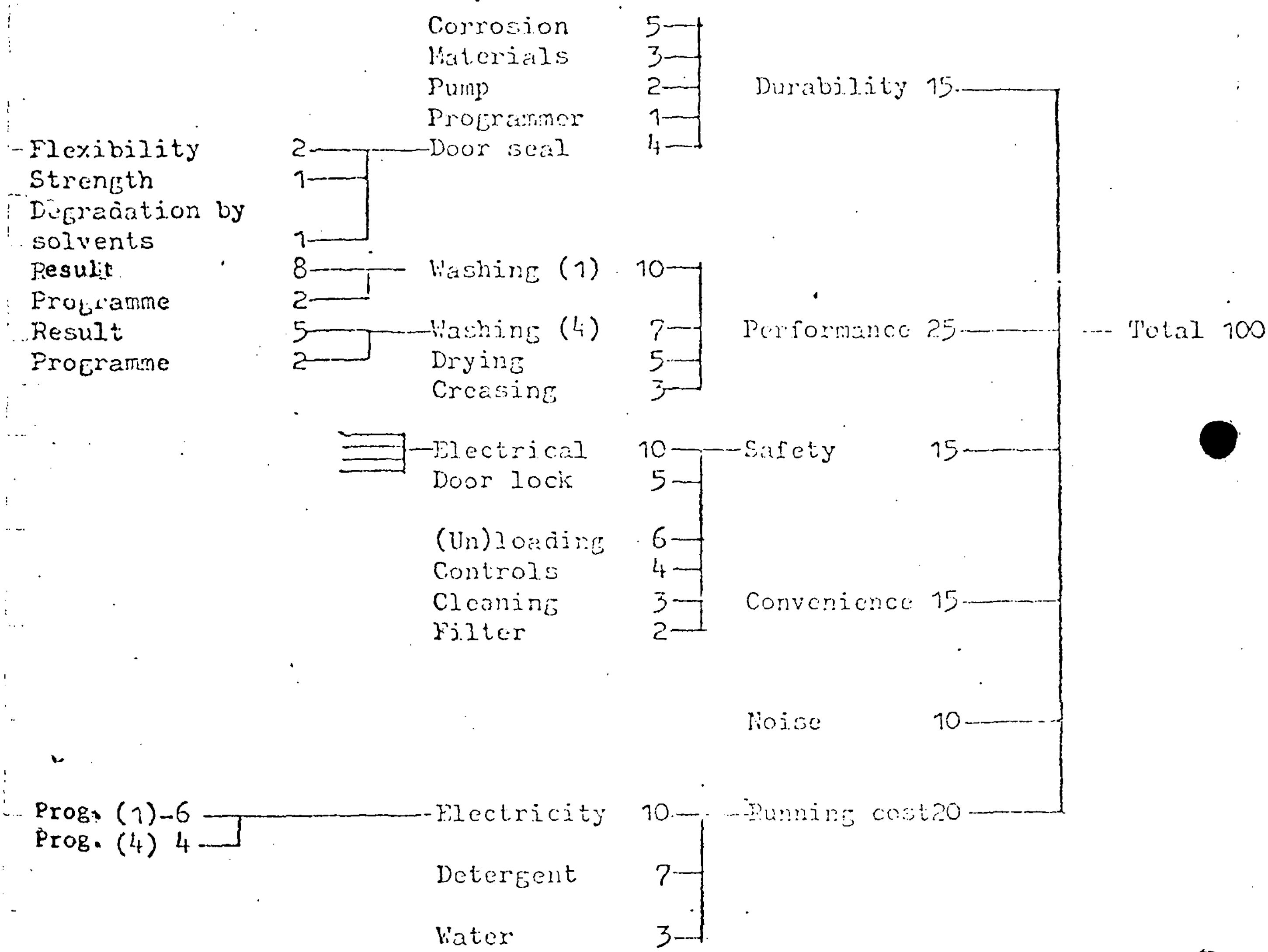
e.g. for Washing Machines



and subdivide these where necessary and appropriate e.g.



Further subdivision follows where necessary and possible, and the complete tree should be drawn (see over).



(This is an artificial example which leaves out some attributes and the weightings are not right; it illustrates the principles however).

Method and scoring of results are inextricable.

7 - Deriving the conclusions from the results is then relatively straightforward.
Starting from the left hand side (or more detailed branch of the tree) one takes the test results and assigns a score on a ten point scale to each product.

(a) for some tests which are inherently scores (e.g. user tests, convenience assessments, instructions etc) it is obviously simple : if the original assessments by the tester/user are only on a five point scale (and should be) then just multiply by two to get a 2, 4, 6, 8, 10 scale.

(b) for other tests which produce an apparently continuous scale of measurements (e.g. 0-100 washing index, size, electricity consumption) it is necessary to think about a reasonable range over which a 10-point rating scale could sensibly be applied : also the widths of the 10 sectors of the rating scale do not have to be the same e.g.

0 10 20 30 40 50 60 70 80 90 100 working index

(40 to 100) probable range of result

0 — 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 possible scoring (but value to the user and the needs of the user must be considered)

(c) there are some attributes which are measured on a continuous scale which actually is proportional (or inversely proportional) to value to the user (e.g. fuel consumption).

8 - There are some attributes which can rule out a product totally from further consideration (e.g. lack of adequate safety, or even very poor performance in some respects). In order that this real situation can be modelled correctly in the evaluation, the appropriate values of these attributes which would rule the product out of consideration can be given a score of -1000: the final score of the entire product will then be negative. For example, a scoring system for safety of :

Hazardous	=	-1000
Potentially hazardous	=	-1000
Unsatisfactory	=	0
Satisfactory with minor criticisms	=	6
Satisfactory within limits of tests	=	10

would delete all products found to be actually, or potentially, hazardous and highlight those which are unsatisfactory (perhaps for further examination).

9 - For each brand have a photocopy of the tree (section 6) with the weightings omitted. Starting from the branch ends enter on each 'twig' the score on the 10-point scale (section 7) multiplied by the weighting of the master tree (section 6). This is the brand's score on that particular attribute. Work up the branches, adding all the numbers from the previous sub-branches, to arrive at a total score out of 1000 (100 x maximum of 10 on 10-point scale).

10- It is now possible to draw up a ranking table for all the brands. Divide their final scores by 100 to get rankings on '10-point scale Obviously further condensation to a 5-point scale is possible, but not recommended for laboratory reports.

Including all the individual brand score sheets (section 9), the master weighting tree (section 6) and the bases on which measurements were converted to a 10-point sacle (section 7) as Appendices to the Report, will enable any reader who wants to use different weightings, or different scaling of particular measurements to do so quickly without having to read laboriously through every page of the Report each time.

11- The key task is to prepare the master weighting tree (section 6). This is where all available information (from surveys, client, consultants, previous experience, other publications) has to be incorporated and a judgement has to be made. Substantial discussion will be neccessary and is desirable (at least with the Client).

12- There is a difficulty about attributes which are judged to be important to the user (probably with good reason and evidence for the judgement) but for which there are no data available (either because the necessary tests have not been done or cannot be done within the limits of time and resources available). In these cases it is not satisfactory to omit these attributes from the weighting tree because that gives a falsely reassuring picture of the completeness of the information. These 'difficult to assess' attributes should be included in the weighting tree even though all scores for these brands will be zero, for all brands. At least all brands will be treated comparatively, though they will only be assessed against a maximum possible score of 10 - (0.1 x weighting of unmeasured attributes). For example, if the durability of dishwashers will is judged to be 30% of the value to the user, and we do not test durability (as is the case up to 1977) then dishwashers will only be scored against a maximum score of 7.

13- Finally it is worth stressing that, whether it is spelled out or not, the ways in which results will be appraised is inherent in the Terms of Reference and methods being used in the project - better, then, to be explicit so that Report readers may more easily see clearly what has been done.

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WORLD HEALTH ORGANIZATION

REGIONAL OFFICE FOR SOUTH-EAST ASIA

Research Study Group Meeting on Appropriate Technology for Improvement of Environmental Health at the Village Level, New Delhi, 16-20 October 1978

Restricted

SEA/EH/RSG Meet.1/4.1c
13 October 1978

NOTES AND REFERENCES ON DRINKING WATER UTILIZATION IN RURAL BANGLADESH AND SUGGESTIONS FOR RESEARCH

By

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John

5560

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The opinions expressed in this paper do not necessarily reflect those of the World Health Organization nor of the UNICEF.

NOTES AND REFERENCES ON DRINKING WATER UTILIZATION IN RURAL BANGLADESH AND SUGGESTIONS FOR RESEARCH

1. Water Utilization:

A survey was made in 120 villages in Bangladesh in November and early December 1976 (see ref. no. 1) which found that over half of the households (52%) were using handpump tubewell water for drinking and that 27% were using lined dug wells. Thus a great majority (79%) were using groundwater for drinking at the time of the survey. The survey found that 73% of the households were within 700 ft. of a handpump tubewell and 40% were within 300 ft. The attack rate for diarrhoea or dysentery in the week preceding the survey as reported by the households showed that those using groundwater (either handpump tubewells or lined dug wells) had only about half as many attacks as those using surface water.

The survey found that in most cases the villagers used the handpump tubewell water only for drinking and not for bathing, laundry or washing of cooking utensils. Although the survey was done during the dry season the villagers were questioned as to their source of drinking water throughout the year. Only about 1% of the households answered that they changed their practise from season to season. In other words, the use of handpump tubewell water for drinking appears to be quite consistent from season to season. This is not the case in other parts of the world (see for example ref. no. 2 regarding changes in water usage habits from wet to dry season in Dongore, Ethiopia).

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2. Chemical and Bacteriological Water Quality Problems:

Much of the groundwater in Bangladesh is quite high in iron and this appears to be deterring installation and use of tubewells particularly in those areas having iron concentrations in excess of 5 ppm (see ref. no. 1). In a preliminary study in which 64 wells were checked 30% showed signs of faecal contamination (ref. no. 1). Subsequently (see ref. no. 3) two rounds of tests were done on a sample of 80 tubewells. The first round showed 24% unacceptable (according to Bangladesh water standards) and the second round showed 13% unacceptable. The first round was done during the wet season and the second one during the dry. Another interesting finding is that there is an increase in percentage of tubewells producing contaminated water as the number of users increases beyond 200. The typical public well in Bangladesh is, however, only used by 100 or so people (ref. nos. 1 & 5).

3. Maintenance of Handpump Tubewells in Bangladesh:

In the last two months of 1977 a survey was made of about twelve hundred tubewells in the same villages where water usage had been surveyed the previous year (see ref. no. 4). This survey found that almost 80% (the figure being higher for newer installations and lower for older ones) of the handpumps were being kept in running order. A similar percentage were found in running order in a survey done elsewhere in Bangladesh (see ref. no. 5) about two years earlier. One of the interesting factors to come out of the most recent survey (ref. no. 4) is that almost half of the wells which are being maintained are done so through local caretakers/mechanics or through some combination of government and village cooperation. This is attributed to the fact that the handpump tubewell has been known for several decades

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throughout Bangladesh and thus quite a large number of people are able to do the necessary maintenance. Furthermore spare parts are available in most of the local markets and thus government was only relied on for parts in about half of the cases.

4. Discussion and Suggestions for Research:

From the data taken in the 1976 survey in Bangladesh mentioned above, the percentage of households within a given distance using tubewell water appears to indicate that fewer, high yielding wells might achieve the desired coverage. However, subsequent studies (see ref. no. 3) regarding the bacteriological quality of tubewell water indicate that when the number of users of a tubewell handpump installation in Bangladesh goes beyond about 150, there seems to be a greater chance that the well water will become polluted.

Locally available materials, such as leather and jute are desirable because of their low cost and availability; however, they are not so desirable in that they can decompose and provide nutrients for bacteria which might accidentally enter the pump in falling dust or polluted priming water. Another indigenous factor is the common use in Bangladesh of cow-dung mixed with clay and water to form a sort of drilling mud for the sludger sinking method. Prolonged pumping to develop the well and heavy use seems to flush the system sufficiently as far as it is known, but no detailed study over time has been made which would definitely indicate how much flushing is needed or what specifically are the health risks associated with this technique.

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An effective maintenance system requires good communications which, in turn, imply a fairly good level of education and physical infrastructure. As Bangladesh does have a network of roads and river transport and other communication facilities, a maintenance system is easier to set up and run there than would be the case in a country with less adequate communication capabilities. This requirement may hold even where much of the maintenance is to be done by the villagers themselves as they need access to information and material supplies from outside the village. Thus, one may find the somewhat odd situation that more trouble-free, and hence often more sophisticated and expensive, pumping equipment is favoured in backward areas where communications are most inadequate.

One undesirable feature of many of the handpump tubewells in Bangladesh is that though the majority probably give safe water, a sizeable percentage would probably not pass the local bacteriological water quality standards. Of the many possible reasons for this, the use of contaminated water for priming is undoubtedly one of the important factors. This could be circumvented by doing research and development to produce a shallow well pump that either requires no priming or has a built-in means of decontaminating whatever water is put in the primer.

Though no detailed investigation has been conducted which would conclusively prove that leaking joints near the surface of the well are allowing polluted water to enter, this is a possibility. Certainly in piped distribution schemes much good water is wasted and contamination also takes place through leaky joints. The common use of biodegradable fibres, such as jute, to pack or wrap around threaded joints is not to be encouraged as it is ineffective

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in sealing the joints and will ultimately rot away. It would seem that there is room for improvement in the area of production and distribution of inert sealing compounds and training of fitters in their use.

Inasmuch as high iron content in the ground water in many parts of Bangladesh (and perhaps other neighbouring countries as well) appears to be holding back installation and use of wells for drinking water, research and field testing of appropriate iron removal facilities and/or other alternatives are needed for these areas.

As noted (ref. no. 1), there is a great need for sanitation in the densely populated rural areas of Bangladesh. The family type of latrines used in rural areas with lower population densities requires a greater amount of land than is generally available to each family in the very densely populated areas. This is specially a problem in Bangladesh during the monsoon when much of the land is under water. Either facilities which require even less land per household and/or facilities which can be shared by several households are needed.

Just as very simple, low-cost, hand-pumped water systems, put to heavy use by the communities, require a capacity for frequent maintenance (both preventive, as in lubrication, and corrective as in repair of broken parts), so environmental health systems with minimal or inadequate coverage require considerable capacity for prophylaxis and cure. As the necessary education, appropriate design and complete coverage regarding hygiene, water and sanitation will probably take several decades to achieve, the need for prophylaxis and cure of diseases associated with contaminated water, lack of hygiene and sanitation is also likely to be keenly felt for decades to come. The capacity for appropriate prophylaxis and cure routinely required will have to be supplemented to allow for special needs for natural disasters or other contingencies.

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WORLD HEALTH
ORGANIZATION

REGIONAL OFFICE FOR
SOUTH-EAST ASIA

Research Study Group Meeting on Appropriate Technology for Improvement of Environmental Health at the Village Level, New Delhi, 16-20 October 1978

Restricted

SEA/EH/RSG Meet.1/4.2a

COMMUNITY ASPECTS OF RURAL WATER SUPPLY AND SANITATION PROGRAMMES AT VILLAGE LEVEL

By

Ir. E.L.P. HESSING

and

Ir. P. Kerkhoven

The opinions expressed in this paper does not necessarily reflect those of the World Health Organization.

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"Any intelligent fool can invent
further complications, but it
takes a touch of genius to
attain - or recapture - simplicity"

Dr. E.F. Schumacher

INTRODUCTION

This paper has been prepared for the purpose of serving as an input for the discussions at the Meeting of the Research Study Group on Appropriate Technology for Improvement of Environmental Health at Village Level.

In general, when considering the promise of appropriate technology, one often thinks of innovative technical solutions. However much needed in current conditions of shortage of resources, for this paper to emphasise technological novelty would be to divert attention from more vital issues relating to water supplies.

In this connection reference is made to a statement by David Bradley in the preface of "Water for the Thousand Millions":

> "We have set out to discuss technology of an appropriate sort and ended up considering organization and maintenance, this is not to belittle technology (and many and better devices are needed to improve water supply), rather we wish to emphasise that organization and maintenance are of at least equal importance".

It is against this background that this paper deals with community aspects of rural water supply and sanitation programmes and calls for attention to an integrated action research and development work in support of the planning and implementation of such programmes.

In preparing this paper extensive use has been made of the work done by Dr. Alistair White, Donald Curtis and Dr. Richard Feacham, respectively on Community Education and Participation, and Socio-economic and Health Impact Studies, in the context of the Integrated Research and Demonstration Project on Slow Sand Filtration.

I COMMUNITY ASPECTS AND APPROPRIATE TECHNOLOGY IN PROGRAMME DEVELOPMENT

1. To accelerate the developments in the community water supply and sanitation sector in developing countries, it is necessary to improve those structural conditions, which are beneficial to an effective planning and implementation of water supply and sanitation programmes.

2. Increasing attention is being given to the development of an appropriate strategy for the planning and implementation of programmes and projects. In this connection, reference is made to the integrated programme development concept, which is based on the recognition and the discernment of the inter-related character of the technological, organizational and socio-cultural aspects of community water supply and sanitation programmes. The crux of this concept is the integrated development of various components in such a way that a synergetic effect is achieved. The major components are: planning, institutional and organizational infrastructure, research and development, technical engineering, management and organization, economics and finance, manpower development, community development and evaluation. The assesment of the relative importance of these components and the interactions between components and related elements may help arrive at a more effective and efficient programme planning and implemtation. A more detailed review of this concept is given in annex I.

3. Community development can be considered as one of the major components of a rural water supply and sanitation programme. According to the integrated programme development concept, the various community aspects are to be considered in relation to other components and elements of a programme. In rural areas, and in villages with a close community structure, the socio-cultural aspects are of the utmost importance when introducing new water supply and sanitation facilities. This is especially applicable to smaller supplies and for devices, such as, handpumps and public standposts, where the human factor physically comes into contact with the technology. It is obvious that community aspects are less important when considering the construction of a large scale coagulation water treatment plant in a metropolitan area. So, depending on the kind of technology and the demographical setting (rural or urban), the importance of the community development component in the programme may be assessed.

4. Appropriate technology is that form of technology which creates a maximum of local resources and requires only an intermediate or low capital investment, the benefits of which should be made widely available among the people who most need them and which should be capable of small scale application, and suitable for village use and local control (Schumacher, 1975).

5. When appropriate technology has to be socially appropriate, and when it is considered as an integral part of a broader system, this system should:
   - be responsive to community needs as perceived by its inhabitants;
   - be designed and implemented with active community participation;
   - have costs low enough to be afordable to low income rural and urban fringe area inhabitants;
   - include an adequate organization for operating and maintenance;
   - require minimal support by central government agencies and maximize the use of local resources;
   - have maximum impact on public health and socio-economic and -cultural development of the community.

6. Different objectives lead to different criteria of appropriateness (social, economic, organizational and technological). When water supply and sanitation projects are considered as a means of promoting community development and self-reliance in the villages, as well as improvement in health, a lot of attention has to be paid to appropriate organization of the project. this, in its turn, brings a whole range of social issues into the discussion of technology. In this relation reference is made to the ITDG publication: "Water for the Thousand Millions" and to the tables 1 and 2 which are presented as annex 2 to this paper.

II COMMUNITY ASPECTS IN RELATION TO OTHER PROGRAMME ELEMENTS

PLANNING AND MANAGEMENT

7. Active community participation guarantees a direct orientation on local circumstances of a cultural and socio-economic nature. The project design therefore has to be responsive to community needs as perceived by the villages. Community participation can be realized in the planning-operation, construction, operation, maintenance and management of rural water supply and sanitation schemes.
Particularly in the planning stage attention should be given as much as possible to the various community aspects. Therefore, it is advisable to involve the community in the decisions on the level of service, the site of the facilities, evaluation of alternatives on the basis of costs, development of local insitutional and organizational arrangement and especially with regard to the future operational and maintenance requirements.
The objective of the planning should be to chose the technology that is most appropriate from social, economic and technological point of view for the particular circumstances in the village concerned.

8. Community participation in the planning requires that the people appreciate and understand the value and the advantages to be derived from a water supply or sanitation scheme and that they are willing to contribute their own share for the construction, operation and maintenance of such a scheme. Following this, community participation will include that communities are actively involved in the planning and implementation of the project, that arrangements are made for the regular supply and for the maintenance and that the people to whom the scheme is meant consider it their property and feel responsible for the ownership.

9. Engineering is always related to social ideals and objectives, and the product being designed always becomes a part of the system which includes a large social component.
Any organization planning to implement a water supply and sanitation project should first clarify its objectives, especially with regard to community development. If the objective of the project is development on the broad front and the water supply or sanitation facility is intended to play a catalytic and educational role in that development process, community participation in the project will be most generally applicable.

10. Somebody must look after pumps, taps and pipes and this presents problems when the supplies have been installed in widely dispersed villages. From the administrative and technical point of view, the most direct system may be one in which the agency itself looks after the whole thing, constructing the supplies and sending qualified men at regular intervals to keep them in good repair. As another system, the agency may appoint water supply attendents from amongst the local population, who can then be made answerable to the authority for keeping the supplies going and reporting on major difficulties. Whether either of these two options is feasible depends partially on costs and partially on the availability of local skills in the village.

But, another opportunity is to put more emphasis upon options involving local initiative or participation, for cost or other reasons, and many water supply agencies will find themselves involved with such schemes for reasons of costs, local participation may be heavily relied upon for maintenance and repair work. But here the agency faces a delema. Typically a public agency is designed to carry out routine activities while villagers may go into an occasional generous contribution towards self-help projects. But the converse is not true. Particularly for that reason it is highly essential to set-up an adequate local organization that can perform this function of public agency and can cope with the organizational and management aspects of regular operation and maintenance work. This local authority should be formally constituted and empowered to raise the necessary resources for the financing of the operation and maintenance.

11. The object is to find the best means of ensuring that small community water supplies are built cheaply and effectively, serve a public at minimum costs, and are maintained in running order. The water authority should attempt to work out the institutional arrangementes in villages which meet these objectives.
The approach taken will partially depend on which administrative strategy is favoured, community ownership or community involvement in formal management requires some kind of representative body in the community. If government policy does not commit the water authority to a particular alternative it should be possible to choose between:
1. ownership by the water authority (or local authority) with or without water charges or rates.
2. ownership by the water authority with or without some management powers delegated to a village level management committee.
3. ownership by an individual; with charges to members of the public.
4. ownership by private water users association from which non-subscribers are excluded.
5. ownership by the local community.

The alternatives are defined principally in terms of ownership of the supply, ownership implying responsibility more than legal ownership although the latter may be important also.

12. If the supply is owned, constructed and maintained by the water authority (1 above) then it is clearly a public service open in principle to all people in the area; though some may have better access than others depending upon ability to pay or other factors. The costs of both construction and maintenance may be higher than in other cases. As an alternative the water authoruty may chose to involve the public in the management of the supply while retaining ultimate responsibility (2).

13. If the supply is owned by a private individual, perhaps the village storekeeper, management costs and reponsibilities are removed from the water authority (3). The individual has an incentive to build efficiently and cheaply using competent local people and well known local materials and to maintain the supply in running order (An OECD publication suggests that the maintenance history of private supplies may compare very favourable with that of public supplies in rural settings). Water users associations (4) can be seen as a devise for avoiding the factionalism and conflict that is often found in rural communities and overcoming the problem of what to do with non-contributors to voluntary projects. As association regular subscriptions can be more easily collected from members since membership entails matching privilages and obligations with the ultimate sanction of withdrawal of the right of access to the supply.

14. Ownership by the community (5) can work well when the community has a small town local authority. Often however, villagers are expected to look after their own supplies. This may be the unforeseen result of a self-help process which has been encouraged by the government without making it clear who is responsible for the resulting scatter of supplies throughout the country. Voluntary bodies like village development committees may be able to raise money and enthusiasm for a public service but they are not able to provide routine management because they have no authority to enforce subscriptions. In most countries villages are not corporate bodies which can own property in a legal sense although there may be customary ways of looking after property, such as temples, fish ponds or irrigation ditches. In some instances it might be possible to adapt a traditional institution to take on a modern management role. For example, a village water supply supervisor might be rewarded for his services by granting him the use of a field that has been purchased for the purpose. This has been a traditional arrangement common to many different countries.

15. In this relation, it is necessary, to also pay attention to those social economic divisions which might make some members of the community look on the water project with less favour than others. These may be people who are currently paid to fetch and cart water for others, people with private wells who sell their water, people whose incomes are so low that they will be hard pressed or unwilling to pay the charge and visit the water supply. An equal contribution or charge represents the great proportion of a poorer family's income, and therefore a greater real burden.

DESIGN AND CONSTRUCTION

16. Essential in the design procedures is to look at the water supply from the users point of view, this recognizes that there may be cultural differences between the designer and the user, but it also recognizes that many factors influence the convenience of supply to the user. Apart from physical convenience, collecting and using water is a part of daily life, and has to fit into the pattern of daily activity and the pattern of relationships with other people that this entails. Very often people value socialbility at the tap while collecting water, but it is important to know that there are specific groups of people using the supply who are reluctant to mix with other groups at the taps, or whether there are certain groups excluded from use of the taps. In the case of clothes washing and bathing facilities, which one might wish to include in a water supply programme to obtain maximum public health and hygiene benefits, the picture will inevitably be exploratory but some probing as to what people would accept possible.

17. Some of the particular points on the design and construction that should be discussed in detail with the community will be:
- where the plant, the public standpost and the other sanitary facilities should be located and what form of fencing will be required
- whether it is necessary or desirable to provide a cattle trough for animals to drink out
- whether bathing facilities should be provided
- whether facilities should be provided for washing clothes (and what design)
- what use should be made of excess of water, which is not of sufficient purity to be piped as drinking water (such as discharge and drainage water)

18. The level of provision - the number of public standpost water points to be provided in a village - is closely related to the health and time saving benefits of the water supply, and particularly the benefits received by the users. However, these benefits depend on the typical distance from a household to the nearest water point, whereas the cost of this provision depends also on the number of them in a village. The relationship between these two measures will depend on the pattern of settlement.

19. The use of self-help as against direct labour or concentrated labour for water supply construction requires further study. Engineers in water supply programmes where self-help labour is used sometimes complain of frequent delays and unnecessary expense due to a poor turnout of the volunteer labour. The major costs associated with the use of self-help labour is the cost of supervision. It is therefore, advisable to assume that overheads are the same, whatever form of labour is used, but the advantages of using local labour are more in the sector of developing local skills and promoting community reponsibility and development.

20. To facilitate community participation, local consultants in developing countries should be trained and employed to design projects with the particiation of community representatives and/or staff of the selected implementing institutions, with expatriate consultants in an advisory capacity only.

OPERATION AND MAINTENANCE

21. It is widely accepted that the major reasons for the breakdown of water supplies in rural areas are social rather than technical. People do not look after supplies properly for a number of reasons, some of these are: people do not understand the technology, they may find the necessary procedures too demanding on time and resources, and they do not feel responsibility for a public system. However, the most common reason for breakdown is inadequate arrangements for operation and maintenance. Arrangements include both administrative procedures and community organization.
Therefore, management should ensure from the start of the programme that adequate arrangements are made for maintaining supplies and facilities, and in that stage of the programme: this may entail more work for the administration than for the village representatives.

22. Village level organization is obvioulsy needed, but so too is appropriate organization at local government level. Particularly with regard to operation and maintenance village people must play a part, if only by preventing misuse of equipment and keeping it clean. Yet to expect complete self-reliance of them is usually more than is reasonable. Maintenance involves action at local government level and at the village level: and it relies for long term success on the clearly defined share-out of the responsibilities between the two.

23. To overcome the gap which usually exists between the technoloigcal knowledge and the skills existing in the rural community and those which will be required to handle a complex innovation, which is introduced, the options are various combinations of: a captulating and the innovation in self-contained units by modules, the internal workings of which need not be understood by the users.

24. The extent to which training can prepare community members to carry out repairs will be small where technical skills in the community are low: the concentration must be on normal operation and <u>preventative</u> maintenance.
Attention should be paid in particular to ensuring that the operator takes adequate account of early signs of trouble and is able, if necessary, to summon help, obtain spare parts, or otherwise remedy the situation before there is a breakdown.

25. Serious consideration may also be given to the possibility of combining the position of operator or caretaker with that of village health worker; or the establishment of an inter-relation between the two functions. There is currently growing recognition of the need for some form of health worker in each community to provide simmple preventative and curative care. It may, in fact, be argued that a full advantage of the pure water supply can only be realized if complemented by health services of this sort. A village health worker would in the first place, be able to stimulate sanitation and the hygienic use of water, and it would be appropriate if he or she were also responsible, directly or indirectly, for the water supply

FINANCIAL ASPECTS

26. The collection of water rates from rural consumers is notoriously difficult, particularly where water is supplies from public standposts. A village cannot collect recurrent funds in the long term without the legal sanctions of a cummunial income, but legal sanctions against non contributors may be politically impossible to enact, and practically impossible to enforce. Some villagers may refuse to pay on the grounds that the water points are too far away or out of order, other may simply plead that they are too poor to pay.

27. There are two major reasons why wide spread non payment of water rates may occurr, although both may apply simultanioulsy. The first is a lack of recognition of the water rate as legitimate. This is particularly the case where consumers consider that they are being inadequately served by a water point which is too distant or a supply which is too intermitant. In this case the way to improve the way of collection will be to encourage recognition of the rate as a legitimate charge, by laying down legal powers, improving the service, or reducing rates where necessary.
The second possible reason for non-payment is an inadequate system of collection. Inadequately paid rate collectors may be subject to bribary, inefficient accounting systems which may enable households to default on payment without being noticed, and so on. It may be possible to improve collection performance by tightening up administrative procedures. The most crucial information to assist judgements on financial policies is the ability and willingness of the consumers to contribute towards costs. For rural areas such information is generally sparce.

28. There are two alternative approaches to the problem of setting water rates, the government can fix them at a level sufficient to cover the costs of the service, or it may aim at maximizing the benefits derived, bearing in mind the ability and willingness of the consumer to pay.
In rural low income areas this latter approach is more productive, because a water rate that is too high will simply not be collected, consumers will find ways to avoid payment or turn to alternative sources of water. In addition, there are good reasons for charging a subsidized initial price for subscribers with house connection, such as the significant health benefits and convenience of water piped to individual homes. It will often be possible to charge for the costs of this subsidy to be met wholly or partially by larger and wealthier consumers, by charging them more than the actual costs of supplying them.

29. Very often villagers are not aware of the hidden costs of their current habit of fetching water in economic terms. Specific information may help them to appreciate the economic advantages of a convenient water supply. The large reserve of funding capacity in the consumers willingness and ability to pay for selective services lies virtually untapped.
Labour intensive projects in preference to capital intensive projects should improve the internal funding capabilities.

30. Time savings result from the provision of water closer to the home, reducing the cost of water in time spent by the consumer collecting it. These savings may be considered as a benefit in themselves, but an additional economic benefit arises, if the time saved is spent in economically productive activities, such as, weeding of crops, or the setting-up of small scale industries.

31. The total costs of water supplies are made up of capital (investment) and recurrent costs. The capital costs of village supplies are often met by grants from central or local government, and by once-off contributions of cash or construction labour from the consumers. Recurrent costs have an element which is fixed (no matter how much water is actually sold), and an element which is variable (e.g. fuel for pumping, chemicals for treatment). The payment of these costs may be shared in a variety of ways between some or all of the consumers, and the various arms of the local government. It will often become apparent that different classes within the village do not pay in proportion with the costs of providing them with water, and the aim of evaluating a water rating policy is to ensure that these differences are in line with the objectives of a water supply programme.

III COMMUNITY EDUCATION AND DEVELOPMENT

32. Among the majot problems in rural water supply and sanitation programmes at village level are the social constraints and the organizatio of operation and maintenance. Active community participation in the context of a community development policy may help to overcome these constraints.

33. It has become increasingly clear that some degree of community involvement is essential to the succes of water supply and sanitation projects in rural areas of developing countries, as it is to grass roots development in other sectors. Amid the general agreement on the desirability of community participation, there is a danger of overestimating its potential as a technique to solve the problems which have been encountered in the past, for instance, the problems of maintenance and management. In different countries, community participation has taken different forms. In particular there is a wide variation in the intensity of involvement. Terms like "self-help", "self-reliance", even "indigenous development" as well as "participation" and "involvement" are often used interchangeable to refer to the different approaches which are adopted. There is, therefore, a need to clarify what is meant when one of these terms is used. In this connection, reference is made to the list of alternative meanings of community participation, prepared by Alistair White and attached to this paper as annex 3.

34. The relevant features of the social structure will differ in each country; it may be possible to draw up a typology of a half dozen typical community social structures for each country, in terms of the types of groups or individuals holding power and the basis on which that power rests, the extent of channals and whether it is factional or grassed base, etc. A different way of approaching the fostering of cooperation, even for such a politically neutral purpose as a water supply or sanitation project, may need to be developed for each type. A typology may help to formulate the description of the informal social structure in a community and can be regarded as necessary base line information for the establishment of an appropriate community participation system.

35. The major targets of the community education and development component of an integrated programme are the following:

1. to develop and maintain favourable attitudes throughout the community towards water supply or sanitation systems being introduced, and the enchancement of cooperative approach to community problems in general.
2. to promote community organization to coordinate community efforts with respect to water supply and sanitation, possibly including community participation in construction, and dealing with problems and finance.
3. To teach and supervise one or more operators in the operation and maintenance of the supply-system: to settle the question of external and community support.
4. To ensure that the actions of the community members promote personal hygiene and sanitation, specifically serve the purity of water from delivery points to ingestion (use of clean recepticles etc.) and facilitate easy access to the water supply by others, avoid waste of water and nuicesance arround delivery points, and cause no damage to the water system.

36. It is necessary to educate the people in matters of proper use of water, hygiene and sanitation. This health education could be conceptualized as fostering "knowledge, attitude, and practice" for the desired behaviour, but such an approach presupposes a one way communication of a fully pre-determined message.
Alternatively, it might be conceptualized as "starting from existing knowledge and felt needs, engaging in dialogue, and developing critical consciousness", but there are dangers of over estimating the relevance of indigenous knowledge, and of uncertainity as to what direction the dialogue should take.

37. The major assumptions involved in this conceptualizational of community education are that it is feasible to achieve an improved understanding of sanitation in a largely unskilled population, and that improved understanding will motivate more effective changes in behaviour that can be achieved by recommendations or precepts not supported by improved understanding.

38. The attempt to involve most actively those sections of the population, the poor and the women, where they have been negated to a subordinate role in the past will meet the incomprehension and very likely hostility of the dominant groups. In the case of a water supply system it will not be a question of working exclusively with the poorer sections of the population; the point is only to ensure that the projects benefits and actively involves the poor as well as the rich.
However, there is the case for trying to work mainly with women since they are the main carriers and users of water in most communities. The attempt to do so will undoubtly meet with great problems, since women are generally regarded as incompetent to deal with a modern technology introduced from outside the community, or even to deal with formal relationships with ousiders on behalf of the community and women largely, attract exclusion from these roles. A water project may, help however, for a handle for confronting such exclusion, as it may be argued that it is a matter for particular concern to women.

39. The crucial question is whether it is possible to access the potential impact of community participation and development on the accellaration of programme planning and implementation in the community water supply and sanitation sector. Would it, for instance, be possible to transfer socio-cultural aspects that are experienced as constraints into factors supporting the programme development? And what ways and means exist or are to be developed to make optimal use of local social characteristics for the planning and implementation of rural water supply and sanitation programmes?

IV RESEARCH AND DEVELOPMENT ACTIVITIES ON APPROPRIATE TECHNOLOGY IN SUPPORT OF RURAL WATER SUPPLY AND SANITATION PROGRAMME PLANNING AND IMPLEMENTATION

40. The Research Programme that is to be prepared for the coming five years should be in line with the relevant recommendations of the U.N. Water Conference and with the new plan for the management of WHO's Research Activity.
In this relation reference is made to the recent background paper prepared by the Director General of the WHO: "Study of WHO's structure in the light of its functions" (DGO 78.1), and in particular to the items 15 and 86 - 89. For easy reference both statements are annexed to this paper (Annexes 3A and B)

41. Quotation for the statement on TCDC:

> "The development of technical cooperation programmes implies the identification of needs in the countries, by these countries, as well as the identification or generation of appropriate methods for solving these needs. It is necessary to develop technical methods that take full account of the social and economic context in which they are to be applied. These social and economic factors emanate from the countries. Suitable methods can also emanate from the countries, and it is WHO's duty to spot these methods, to analyze them and to transfer the appropriate information to all countries which require them. It is also WHO's duty to generate appropriate technical methods that take account of the social and economic factors factors involved in their application, if existing methods are inadequate or non-existent. The development of these methods has to be arrived at through cooperation among countries, WHO acting as a stimulator, catalyst and coordinator".

42. The new management plan for research activities is based on the following principles:
   - research activities should form an integral part of programmes and should therefore be managed in the same way as all other programme activities:
   - emphasis must be laid on the development of national research capabilities, on national determination of research priorities in the light of social health policy, and on national implementation of research activities.

   These principles apply to research at whatever operational level it is planned and conducted.

43. In addition to this, emphasis may be given to the function of research and development in support of the acceleration of national programme planning and implementation. Programmes are developed through action; research is needed in support of this action. When talking about an integrated programme development, basically, research support is needed with regard to the various components, elements and inter-relations as well as with regard to the integrated development of these factors. In this connection reference is made to the discussion paper on the Integrated Programme Development concept Against this background, the need for integrated action research and development work is emphasised.

ALTERNATIVE STRATEGIES FOR RESEARCH AND DEVELOPMENT WORK

44. Basically, there are three different strategies for research and development:
    1. Integrated action research and development work; this is research carried out in the context of an operational water supply and sanitation programme; in direct and immediate support of programme planning and implementation; directed to the actual needs and based on the direct feedback from the field.
    2. Applied research and development in support of programme planning, implementation and evaluation, but not directly connected with an operational programme; in the context of the present paper this research mainly deals with appropriate technologies and socio-economic and cultural aspects; as much as possible this work should be carried out on local level.
    3. Evaluation studies; also in the context of an operation programme and including impact studies on the socio-economic and health aspects.

45. Programmes set-up according to the integrated programme development concept provide good opportunities for integrated action research and development work. In this connection, it is emphasised that community development is just one element of a rural water supply and sanitation programme. Although in this paper the main emphasis has been on the community aspects, it is now stressed that research on these aspects should prefereably be carried out in direct relation with the development of other components and elements of integrated programmes.
As the set-up of appropriate organizational methods and systems for operation and maintenance is to a large extent determined by local conditions and circumstances of a socio-cultural nature, there is an obvious need for integrated research and development work on this subject at local level.

46. In the field of applied research on socially appropriate technology interesting experiments have been carried out during the past few years, now it should be investigated as to what more should be done and how the research and development work in this field may be promoted and guided.
The importance of community development and the various community aspects in rural water supply programmes has already been recognized. An exploratory study to investigate the potentials of community participation may be set-up, as well as studies for the development of methods and technologies for making the community participation approach more effective.
Also the possibility of testing different approaches to health education could be considered. Is it possible to have non-educated villagers (even illerate ones) to understand the concept of bacteria (and is it necessary to make them understand). Are there other methods to create awareness and a better understand of methods of hygiene and are there other methods to achieve behavioural changes with regard to the use of water, personal hygiene and sanitation. What methods eixist to make villagers accept their own responsibility for their sanitary environment.
Answers are also needed on questions, such as: has a particular project led to a reduction of the time taken up by carrying water, what have been the main effects, has it meant that women that previously had to carry water now have more time, or that persons who were paid for carrying water have lost a source of income? As an illustration of this type of question, a list has been annexed to this paper mentioning ways in which water supply projects might possibily lead

to a worsening of the relative position of the poor (Annex 5). Other examples are given in the list of suggestions for research and development on socially appropriate technology.
Finally, it should be mentioned that there is a special need for manuals on the various aspects of rural water supply and sanitation programmes. The availability of such manuals in local languages would make a significant contribution towards proper design, operation and maintenance of water supply system and to the training of personnel required.

47. In programme evaluation special attention may be given to various community aspects and their influence on the implementation of the water supply and sanitation programme. In this connection, special impact studies on the health, socio-economic, socio-cultural and socio-organizational aspects could be carried out.

ALTERNATIVES FOR THE IMPLEMENTATION OF RESEARCH AND DEVELOPMENT WORK

48. Various alternative mechanisms exist and may be developed for the implementation of research and development work; amongst these are:
1. Programmes set-up according to the integrated programmed development concept; these programmes are suitable for the carrying out of integrated action research and development work on the various inter-related community aspects and socially appropriate technology.
2. Integrated research and demonstration projects; although basically implementation programmes, these projects are developed according to a concept that allows for more attention to action research and development work than is acceptable under normal situations; the same goes for pilot projects.
3. Regular programmes of research and development institutes.
4. Development and demonstration centres; these are appropriate technology development units on local level; preferably connected with and supported by a mother institute on research and development.

49. Integrated research and demonstration projects are developed on subjects, such as, handpumps, slow sand filtration, public standposts etc. These technical subjects serve as a cehicle for the integrated development of the technological, organizational and socio-cultural components of these programmes. This means that in developing these projects, a variety of aspects is taken into account, such as: planning, operation and maintenance, financial arrangements and administration, and organization and management, as well as various institutional and infrastructural aspects, such as manpower development and community participation; all complementary elements and equally important to the technological component of water supply and sanitation programmes. Bacially, these projects aim at demonstration of the inter-related character of the various aspects and the synergetic effect of the integrated programme development component. This is demonstrated by and in the developing countries involved in these projects.

50. All research and development activities that will be developed in the context of the present five year programme should be implemented and organized on the basis of close collaboration between operational agencies and research and development institutes. The latter may accept responsibility for the scientific foundation and implementation of the research and development work. The operational agency may take care of the interaction of this work with the actual problems and needs experienced in planning and implementing rural water supply and sanitation programmes

ANNEX 1

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CHECKLIST FOR SET-UP OF DEMONSTRATION PROJECTS ACCORDING TO THE INTEGRATED PROGRAMME DEVELOPMENT CONCEPT

COMPONENTS	ELEMENTS
PLANNING	integration in national programme programme planning budget and funding feasibility studies surveys progress control
INSTITUTIONAL and ORGANIZATIONAL INFRASTRUCTURE	institutional framework organizational infrastructure administration internal collaboration legislation international cooperation
RESEARCH and DEVELOPMENT	field investigations testing pilot studies
TECHNICAL ENGINEERING	design construction operation maintenance standardization manufacturing
MANAGEMENT and ORGANIZATION	administration charges policy revenue collection system operation and maintenance indigenous manufacture
ECONOMICS and FINANCE	economic viability investment cost/recurrent costs cost effectiveness analysis price fixing financing arrangements
MANPOWER DEVELOPMENT	recruitement training supervision courses, manuals, facilities
COMMUNITY DEVELOPMENT	socio-cultural aspects public information community participation sanitation education
EVALUATION	programme evaluation impact studies demonstrations
ADDITIONAL ACTIVITIES	international collaboration information exchange support studies Steering Committee

ANNEX 2

Table 1. Goals and objectives for water supply improvements in rural areas of developing countries

Immediate Objectives	*Further goals—stage I* (these follow as consequences when the immediate objectives have been met)	*Further goals—stage II* (these follow from previous stages if complementary inputs are provided)	*Further goals—stage III* (these are consequences of reaching the previous goals ... which follow if there are also inputs on many other fronts)
FUNCTIONAL: to improve the quality, quantity, availability and reliability of the supply OTHER: to carry out this improvement in a manner which (a) secures the support of users; (b) conserves scarce resources (e.g. capital); (c) avoids adverse environmental consequences (e.g. lowering water tables, encouraging mosquitoes)	HEALTH: to reduce incidence of water-borne and water-based disease ENERGY/TIME (ECONOMIC): to save time and energy expended in carrying water SOCIAL: to arouse interest in the further health and economic benefits which may arise from the water supply ECONOMIC: to provide more water for livestock and garden irrigation; (water may be used for this even if it is intended solely for domestic supply)	HEALTH: to reduce incidence of water-washed infections (*inputs required*: improved hygiene, health education, improved sanitation) SOCIAL/TECHNICAL: to ensure good long-term maintenance of water supply and sanitation facilities (*inputs required*: training, clear allocation of responsibility, build-up of local maintenance organization) ECONOMIC: to use energy/time savings and increased water availability to achieve better agricultural output (*inputs required*: extension work, fertilizer supply, etc.)	to achieve the greater well-being of the people through: (a) social change—greater self-reliance in the community, better organization, better deal for the poor, women, etc. (b) improved standard of living - health, nutrition, income, leisure

Table 2. Some criteria of appropriateness in relation to the water supply objectives from which they are derived (Stage III goals are not considered)

Criteria derived from IMMEDIATE OBJECTIVES	Criteria derived from STAGE I GOALS	Criteria derived from STAGE II GOALS
1. Criteria of TECHNICAL APPROPRIATENESS:		
Functional appropriateness fitness for purpose *Environmental appropriateness* fitness for hydrological conditions, avoidance of environmental damage	*Health and Sanitary appropriateness* water-borne disease data and water quality	*Health and Sanitary Appropriateness* water-washed disease data and water quantity and availability
2. Criteria of SOCIAL APPROPRIATENESS:		
Community appropriateness felt needs and stated preferences in the community, scale in relation to community size and organization. *Work appropriateness* organization of labour force (whether self-help or paid)	*Consumer appropriateness* changes in water carrying and in water use patterns *Educational appropriateness* degree of interest created in health, hygiene and other development	*Maintenance appropriateness* organization, administration, village/government responsibilities, spare parts supply, training, record-keeping
3. Criteria of ECONOMIC APPROPRIATENESS:		
Resource Utilization appropriateness capital and labour intensity, import bill, fuel consumption; scale economies		*Production appropriateness* amount of time/energy saving and volume of water available for productive purposes

FROM: "WATER FOR THE THOUSAND MILLIONS"
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Community participation may mean:

1.a. Consultation with community representatives or leaders, to ensure that the programme introduced by the outside agency is adapted to meet the needs of the community and to avoid difficulties in implementation.

1.b. Consultation with other members of the community, or specifically the poor, to ensure that the programme meets <u>their</u> needs.

2. A financial contribution by the community to construction.

3. Self-help projects in which <u>a specific group of beneficiaries</u> contribute labour (perhaps also materials), especially in constructio work, to reduce financial costs. Large input from external agency.

4. Self-help projects in which <u>the whole community</u> collectively contributes labour (perhaps also materials), especially in construction work. There is also a large input from an external agency.

5. The training of one or a few community members to perform specialised tasks (e.g. as village health worker, or operator of a slow sand filtration system of water supply).

6. Mass action: collective work aimed directly at an environmental change of general benefit, e.g. to drain the waste water (distinguished from self-help by the relative unimportance of any input by an external agency).

7. Collective commitment to change in personal behaviour, and collective social pressure for the realisation of such changes, (e.g. construction and use of a latrine, frequent hand-washing with use of soap).

8. Self-reliance in the sense of the autonomous generation within the community of ideas and movements for the improvement of living conditions, as opposed to stimulation by outside agents. But the community may well have recourse to external agencies to help with implementation.

9. Self-reliance in the sense of using only the efforts of the community members themselves, not appealing to outsiders for help.

10. Self-reliance in the sense of using local materials and manpower directly, rather than collecting funds internally in order to purchase goods and services from outside; including increasing local capacities with this kind of self-reliance as a goal.

15. Technical cooperation, on the other hand, implies that no matter at what operational level programme doctrines have been generated or programme activities implemented, the programmes have to be concerned with solving specific priority national health problems. The development of technical cooperation programmes implies the identification of needs in countries by these countries, as well as the identification or generation of appropriate methods for meeting these needs. It is necessary to develop technical methods that take full account of the social and economic context in which they are to be applied. These social and economic factors emanate from the countries. Suitable methods can also emanate from the countries, and it is WHO's duty to spot these methods, to analyse them and to transfer the appropriate information to all countries which require them. It is also WHO's duty to generate appropriate technical methods that take account of the social and economic factors involved in their application, if existing methods are inadequate or non-existent. The development of these methods has to be arrived at through cooperation among countries, WHO acting as a stimulator, catalyst and coordinator. Thus, the most suitable technical cooperation programmes are likely to be arrived at through a process of mutual influencing of socioeconomic and technical factors, the former deriving mainly from the countries, the latter often deriving from WHO through the coordination of activities in countries for the development of the technical methods concerned. This is one way in which the exercise by WHO of its coordinating role should lead to relevant programmes of technical cooperation.

16. Programmes of technical cooperation in and among countries can also be made more effective through support from various regional mechanisms. These include, for example, regional multidisciplinary panels of experts; Regional Advisory Committees on biomedical and health services research, which bring individual expertise from various countries to bear on research requirements and questions of research policy in each region; and national centres that are recognized as regional centres for operational research, development and training in specific programme areas, where countries work together to solve common problems and to build up cadres of national personnel trained for self-reliance in developing the programme concerned in their country.

17. The more general application of technical cooperation programmes at all operational levels should result from discussions in the Regional Committees that give rise to the realization of the need for inter-country cooperation. The proper manifestation of such cooperation should also be through national rather than Secretariat mechanisms. In like manner, global technical cooperation programmes should result from the realization of the ...ldwide nature of the problem and the need to solve it through cooperation among countries ... transcends the boundaries of individual regions. The evolution of technical cooperation programmes in such a way is the best guarantee that the real needs of Member States will be reflected in their demands on WHO, and that their specific requests for technical cooperation will conform to the policies they have adopted in the resolutions of the Health Assembly and other deliberating organs.

THE NATURE OF GLOBAL PROGRAMMES

18. The Assembly resolutions mentioned in paragraphs 1 and 7 above imply the formulation of global programmes as a result of integrated programme planning. It is necessary to clarify what is meant by integrated programme planning. At the Thirty-first World Health Assembly, it was made clear that two distinct yet closely interlinked processes are at work, the one a process for national health development and the other a process for the development of WHO's programme in response to national health development. The national health development process consists of country health programming, national health programme budgeting, national health programme evaluation and national health information systems support. The WHO programme development process consists of WHO medium-term programming, programme budgeting, health programme evaluation and information systems support. Ideally, integrated programme planning will result from the proper application of the national process for programme development in all WHO's Member States, and the corresponding response of the WHO process for programme development. In practice, there are multiple entry points to each of these processes.

84. When the above processes take root, along with the consistent application by countries of the national health development process mentioned in paragraph 18 above, WHO will have gone far in implementing resolution WHA28.30, according to which the Organization's mechanism for the allocation and reallocation of resources should comply with the principle of responding to integrated programme planning.

THE INTERACTION AND INTERDEPENDENCE OF ALL ORGANS AT ALL OPERATIONAL LEVELS AS ILLUSTRATED BY THE MANAGEMENT OF WHO'S RESEARCH ACTIVITIES

85. Whatever the degree of fruitfulness of the interrelationships between the various operational levels of the Secretariat, it cannot be sufficiently stressed that the key to the success of WHO's activities lies in cooperation among Member States. The Secretariat has to service the best interests of such cooperation. Maximum involvement of Member States, their institutions and their personnel in the work of the Organization is therefore essential. Nowhere are the above principles more apparent than in the new mechanism for the management of the Organization's research activities which are about to be introduced for a trial period of two years. This mechanism illustrates well how the Organization's structures are being reorganized in the light of its functions. It is therefore presented in some detail below.

86. The new plan for the management of WHO's research activities is based on the following main principles:

- research activities should form an integral part of programmes and should therefore be managed in the same way as all other programme activities;

- emphasis must be laid on the development of national research capabilities, on national determination of research priorities in the light of social health policy and on national implementation of research activities.

These principles apply to research at whatever operational level it is planned and ...ted. From the perspective of Member States there can be only one integrated WHO ...gerial system.

87. In the plan, two vital issues are closely interlinked, namely the development of research capabilities in Member States, in particular in developing countries, and the conduct of research for the immediate solution of health problems. Impatience for immediate results could lead to imposing research activities on countries before they are ready for them, or to attempts at solving problems for countries instead of with them. At the same time, the best way for countries to develop research capabilities is to participate in the planning and conduct of research.

88. Additional complexifying factors are the need for managerial consistency coupled with scientific cohesion and effectiveness at all operational levels, and this in an area in which there are all too few people with the necessary research and research management knowledge and experience. Yet, it is just such competence that is so important not only for research as such, but also for the improvement of health management in the broadest sense.

89. The plan is based on a number of fundamental concepts and guiding principles. The new policy laying primary emphasis on technical cooperation with and among Member States, and the ...egy being evolved for its implementation, have profound repercussions on WHO's research ...ivities. Research in WHO is now more intimately identified with health development in general, and responsibility for its planning and execution spread over the national, regional and global levels of the Organization. The promotion of national self-reliance in health research is fundamental. Countries have to develop their own health research capabilities and to cooperate among themselves for the benefit of the less privileged. Since WHO's research activities should be an intrinsic element of health development, they have to be undertaken in relation to socially relevant health goals, and not for their own sake.

ANNEX 4

Checklist No. 4

Ways in which water supply projects might possibly lead to a worsening of the relative position of the poor

1. Dominant groups might get a subsidised service which the poor do not receive, e.g. individual supply to their homes.

2. Access to the new water supply might be restricted or monopolised. This danger includes cases where the design of the project appears to cover the poor too, but actual flow is limited or diverted, so that only the dominant group benefits, e.g. by use of water for farming purposes, in such quantities that the supply does not reach the homes of the poor.

3. Water used for agricultural or commercial purposes by dominant groups may increase their income in ways which are not available for the poor; this can then lead to changes which worsen not just the relative but also the absolute position of the poor - changes in land tenure and others, such as the discontinuance of arrangements to share food in times of disaster.

4. Removal of an employment opportunity in water carrying.

5. Equal contributions exacted from all inhabitants for the construction or running costs of the water supply may mean a charge which poor families are in no position to afford.

6. Voluntary work demanded at peak times in the agricultural work cycle may lead to substantial loss of production.

7. The power of dominant groups may be increased by patronage available, e.g. in the form of selection of a water supply operator on a salary. At the least, the village-level organisation of the programme, in collaboration with a powerful external agency, will be a political resource in terms of prestige.

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SUGGESTIONS FOR RESEARCH AND DEVELOPMENT WORK

1. The further development of the integrated programme development concept (IPD) by planning, implementing and evaluating rural water supply and sanitation programmes according to this concept and studying the integrated development of the various components, elements and inter-relations. In this connection, also a series of guidelines for programme planning and implementation may be developed.

2. The set-up of a series of integrated research and development projects, on the basis of the IDP concept, and using technical subjects, such as, hand pumps, public standposts and simple treatment systems as vehicles for the development of these projects. Socio-economic and health impact studies as well as studies on the impact on community development and participation may be carried out as an integral part of these projects.

3. Assessment study on the potential of community development and participation in relation to the acceleration of programme planning and implementation in the community water supply and sanitation sector. The imapct of various levels of community participation may be compared.

4. Development of a typology of a series of typical community social structures for each country, in terms of the types of groups or individuals holding power and the basis on which that power rests, the extent of challenge and whether it is factional or class based etc. A different way of approaching the fostering of cooperation, even for such a politcally/neutral purpose as a water supply project, may need to be developed for each type.

5. Study on appropriate methods and techniques for mobilization of community efforts sometimes difficulties with the promotion of self-help activities have been found to entail greater costs for water supply authorities, as well as adding to the administrative burden. Usually, however, the difficulties can be traced to inappropriate ways in which the cooperation with communities has been approached, there has usually been insufficient understanding between project authority and community. In the context of the IRC slow sand filtration project, experiments are carried out with more extensive communication efforts which hopefully may lead to improved understanding.

6. A study on the basic features of an effective organizational set-up for maintenance, including aspects such as, institutional organization, responsibilities, administration, training and supervision.

7. The testing of alternative strategies and methods for community education which may contribute to improve the understanding and motivation and changes in behaviour. In this connection it is recognized that there are various reasons why people may adopt a change in behaviour related to health, such as: understanding acceptance of authoritive assurances, adoption of change by a reference group or person of higher or similar status, social endoursement, informal social rewards and formal sanctions. These reasons are not, of course, mutually exclusive and they do shade into one another, but they provide a basis for thinking about the ways in which behaviour may be influenced.

8. The role of women in rural water supply and sanitation programmes may be an interesting subject for a study. For programme planning and implementation it would be useful to know whether and how the active participation of women in rural water supply and sanitation projects affects the development of such projects, and to what extent this participation effects the role of women in the community. In this relation reference is made to a research project on this subject that Professor Scarlett Epstein of the University of Sussex, England, is developing in close collaboration with about a dozen research Fellows from countries in the South East Asian region.

9. A study on a series of inter-related subjects, such as, the ability and willingness of consumers to contribute towards the cost, pricing policies, charges and rate structures, and appropriate methods for revenue collection.

10. Several technological topics in the field of water supply and sanitation require further study and research, such as:
    - handpumps; design and manufacturing;
    - public standposts, including appropriate taps; desing and construction;
    - pipe materials (PVC);
    - methods of treatment without the use of chemicals;
    - simple chemical feeders;
    - cheap treatment methods for brackish water and reduction of fluoride, manganese and iron;
    - standardization and type design;
    - pre-fabrication of components.

    In this relation reference is made to the recommendations presented in the report of the Global Workshop on Appropriate Water and Waste Water Treatment Technology for Developing Countries, held at the IRC, The Hague, the Netherlands, November 1975 (IRC/Bulletin Series No. 7).

11. Special attention should be given to the ergonomic aspects of various water supply and sanitation equipment and devices, such as, handpumps, public standposts aqua privies, squatter plates etc.

12. There is an increasing interest in handpump testing and evaluation. In order to facilitate the comparability of testing and evaluation studies and to promote this work on a larger scale, the development of a standard protocol for field testing and a code for laboratory testing are considered useful activities in support of the research and development work in this field.

13. A study on the optimization of the relation between the number of house connections and the public standposts, both in a rural and sub-urban setting; and from technological, organizational, economic, financial and social point of view.

14. The development of manuals on various water supply and sanitation engineering topics.

15. The development of a series of rural water supply and sanitation programmes evuation studies, giving attention to various technological, organizational and social aspects. In this connection, also socio-economic and health impact studies may be carried out, provided that an appropriate base-line survey has been carried out in the beginning of the programme. In the context of these evaluation studies attention may also be given to the reduction of the water collection journey, the imapact of the resulting time savings, whether persons who were paid for carrying water have lost a source

of income, whether the time gained is used for the development of new economic activities, possible negative effects on the relative position of the poor, and whether the community participation activities have led to a greater liklihood of further cooperation on other community projects in the future.

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Research Study Group Meeting on Appropriate Technology for Improvement of Environmental Health at the Village Level, New Delhi, 16-20 October 1978

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SEA/EH/RSG Meet.1/4.2b
10 October 1978

COMMUNITY PARTICIPATION IN WATER SUPPLY AND SANITATION PROGRAMMES: SUGGESTIONS FOR PRIORITY RESEARCH AREAS AND STRATEGIES

By

Ok! Jerry, "excellent paper".

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The opinions expressed in this paper do not necessarily reflect those of the World Health Organization.

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1. Introduction

The purpose of this brief paper is to draw attention to some of the priority issues in community participation in water supply and sanitation activities at the village level within the context of primary health care (PHC) and rural development (RD); to suggest guidelines for the types of research questions which may be included in a Regional research programme on the above topics; and, to identify research strategies to maximize the relevance and utilization of research results.

The intention here is to raise issues rather than attempt to deal with them exhaustively, and no claim is made to including or even touching upon the many references and topics that could be brought into such a discussion. Hopefully, discussion during the Research Study Group will respond to issues raised here and will broaden the set of ideas presented in this paper.

2. Problem

In grossly oversimplified terms, the problem is that far too few people - especially poor and rural people - have access to reasonable water supplies and excreta disposal facilities; those supplies and facilities which do exist are frequently out of service and repairs are slow; and, when supplies and facilities do exist and are operable, they are not utilized to the degree expected. Furthermore, it is generally believed that appropriate technologies can be identified and/or developed to meet technical aspects of these problems, but that major behavioural and operational problems and constraints should be defined and overcome to achieve what is believed will be a major component of improved health care.

These two aspects of appropriate technology have been referred to as the "hardware" and "software" of appropriate technology[1] and this general distinction will be maintained here. Of prime importance is the interaction or relationship between AT "hardware" and "software", and not whether one is more important than the other. Most experts in this field (and at this meeting) are well-versed in the "hard ware" aspects. (I am not.) Some are knowledgeable in both areas. My problem is to try to put forward a clear case for the relationship between water and sanitation appropriate technology "hardware" and "software" within the context of PHC and RD.

ok!

3. Water supply and sanitation at village level within the context of PHC and RD

Primary Health Care has been identified as the framework within which village level water supply and sanitation should be developed. Appropriate technology is seen as an essential element of PHC and is consistent with PHC principles. These emphasize accessibility, acceptability, and technical appropriateness of health care, and also give prominence to community participation. Some people have unfortunately tended to interpret community participation as "cheap labour", as a form of taxation to manipulate communities and pass the burden for support of rural health care to those who presently do not benefit from urban-oriented national health care schemes. While it is true that "a key factor in this approach is the enlisting of community participation to reduce the cost of installation and ensure the proper maintenance and utilization of these facilities"[2], community participation

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[1] SEA/RACMR/78.1/5 p.12.

[2] Development of a Programme for Diarrhoeal Disease Control: Report of an Advisory Group, Geneva, 2-5 May 1978. p.10.

has much more far-reaching implications. These especially relate to participation in response to community needs and priorities.

As Scotney points out with respect to community participation and village technology, it is essential for each village technology that:

"... it should arise from, and meet the needs of, the society so that it could be maintained, restored, duplicated and improved by local people from their own resources... The one sure basis on which any innovation can occur in the village situation is that it [redacted] them. The gap between our view as "outsiders" of what people need and the "insider's" own perception of the nature of the problems pressing upon his family and community, needs to be closed. Our "gifts" can only become acceptable if they are felt by the receivers to harmonize with their priorities, to fit the skills and resources they are able to call upon, and to conform with their way of arranging their lives."[1]

The failure to appreciate this aspect of community participation within water supply is stressed by Briscoe who says:

"In water supply policy the fundamental need appears to be a reorienting and restructuring of the decision-making process. The continuation of traditional water use habits when the people of poor countries are presented with alternative sources of pure water is generally ascribed to the ignorance of the uneducated masses. The prescription then becomes education of the ignorant and the identification of communication barriers. In this paper it has been suggested that the fault

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[1] Village Technology in Eastern Africa: A Report of a UNICEF-sponsored Regional Seminar on "Simple Technology for the Rural Family", Nairobi, 14-19 June 1976. p.12.

lies not so much with the recipients of these programs as with the process whereby these programs are conceived. An understanding of the water use habits of the majority and the factors which affect these habits is necessary, as is the incorporation of the potential users into the process of decision-making in water improvement programs."[1]

These statements advocating priority-oriented and community-based planning and intervention, clash with the majority of traditional intervention strategies, which are technically-oriented and centrally-based. Typically, several reactions occur at this stage, e.g. "communities don't really know what they need or what is good for them; they will list all kinds of foolish/impossible/unnecessary 'priorities'; water supply/waste disposal/medical care/etc. is highly complex and has a real technical basis; villagers cannot be expected to understand, plan or implement these activities;" or, more cynically "so leave the villages alone then and let them solve their problems their own way."

And this is the very heart of the PHC approach. As with the case of "hardware" and "software", there is not an either/or conflict between technically-oriented, centrally-based water and sanitation programmes and those which are priority-oriented and community-based activities. Both must be there, but an entirely new relationship has to be achieved. Communities do not exist in self-sufficient isolation, nor have they independent means to develop the bifurcated needle, to sustain a chold chain for vaccines, or - in most circumstances - to independently develop and sustain appropriate technologies in water supply and waste disposal. But, however necessary "outside" technical

[1] Briscoe, "The Role of Water Supply in Improving Health in Poor Countries (with special reference to Bangladesh), Cholera Research Laboratory, Dacca, Sept. 1977. p.26.

expertise may be, it must be made to harmonize with community priorities and needs. The PHC approach calls for a partnership between the participating community and extra-community resources and support. This is a key element of SEARO's draft Medium-Term Programme for Primary Health Care for 1978-83, which is oriented to community participation and decision-making, and lists among its activities to "work out national procedures for technical support and guidance to strengthen local community organization for various aspects of PHC...".[1]

More will be said about research questions within this partnership later, but here I wish to suggest some other corollaries of the priority-oriented, community-based approach.

While the topic of this Research Study Group is a "sectoral" one, communities ought not to be expected to identify their priorities in a similar sectoral way and research and implementation activities ought not to be sectorally isolated, but should be broadly based and/or closely linked with other "sectoral" activities (e.g. nutrition, MCH, immunization, family planning, education, agriculture, housing, etc.) within PHC. The primary school curriculum, for example, provides an excellent opportunity for the introduction of concepts favouring a proper understanding and use of water supply and sanitation facilities. It is important to know more about the actual perceived needs or priorities of communities, including those of water and sanitation, and to know how these priorities are articulated and communicated within village decision-making organizations. This would have implications for the type of mix of extra-community, supportive activities that

[1] Draft SEARO Medium-Term Programme of Primary Health Care, 1978-83, July 1978. p.23.

should be made available to communities, and for the nature of resources that communities might generate in local support of these same activities.

While I am advocating research attention to community priorities - clearly assuming that communities do have a good idea of what is important to them, and that these priorities do relate to real community development - I am not equally positive towards most individual attitude-type studies about water and sanitation. This approach is often equated with attempts to change attitudes or "educate" the population when their attitudes may be quite reasonable within their situation. Moreover, this approach is sometimes close to "blaming the victim" as Briscoe, Bannerji and others have described.[1,2] This is especially inappropriate when it has been concluded that "stripped of statistical evidence, the stark global facts are that: people need and want water; ... and where installations have been provided, they have been left with distressing frequency to fall into disrepair and disuse through faulty operation and maintenance."[3] With large percentages of pumps out or order, it seems more reasonable to focus first on problems of providing and maintaining pumps, than on attitudinal questions of why people may not use pumps if and when they are provided.

[1] Briscoe, op. cit.

[2] Bannerji, D., "Health as a Lever for Another Development." Development Dialogue, 1978, 1, pp. 19-25.

[3] SEA/RACMR/78.1/5 p.9.

4. Guidelines for Research in Community Participation in Water Supply and Sanitation

In the previous section, some suggestions were made concerning possible research on general community priorities, including water supply and waste disposal. Here I should like to focus more specifically on priority research issues related to appropriate technology in water and sanitation.

As mentioned earlier, the extra-community/community partnership in PHC requires considerable attention to the kinds of necessary support to community efforts. This includes training for technical staff to work with communities; planning methods which can be used by communities; guidance and assistance in construction and operation which fits community time frames and work habits rather than only fitting central/technical schedules; loans and financial support mechanisms which correspond with community financing patterns and which extend beyond construction to operation and maintenance phases; and management/collection/financial schemes which would be applicable at the community level. Perhaps most importantly, research attention must be directed toward community-oriented operation and maintenance schemes. Water facilities are too often inoperable because of faulty maintenance or shortage of parts. As Shawcross points out with respect to handpump maintenance, "a searching examination of the entire maintenance delivery system, its equipment, its financing, its management and the suitability of the environment" is required.[1] It is necessary that community members be trained to operate and maintain the appropriate technology, and attention should be directed to developing the necessary training and maintenance schemes, with all of the necessary extra-community support.

[1] SEA/RACMR/78.1/J. p.54.

In the same way in which many technically-sound medical procedures have been "de-professionalized" so that village health workers, following diagnostic flow charts or standard operating procedures, can apply these procedures at the village level, technically appropriate engineering procedures must be made available to village level water and sanitation workers. Some examples already exist[1] but much more attention should be devoted to finding practical answers to these needs.

5. Research Strategy

Research on the topics identified here should not be carried out in isolation. Multidisciplinary teams are required to assure that behavioural questions and problems relate to the technical work being performed by engineers and others. Research on community operation and maintenance of hand pumps, for example, should be carried out in direct connexion with engineers developing and testing physical components of the same pumps and other elements of the system. Furthermore, these close relationships help to assure relevance of the questions asked and utilization of the research results. Wherever possible, and in keeping with the above, research should be directly connected with implementation programmes, and not carried out as an isolated or separate activity.

Emphasis should be placed on obtaining research results which can be directly shared within the country, the Region, and between Regions, and attention may even be directed to improving this process

[1] "The Training and Utilization of Rural Water Technicians in Guatemala", Background paper for 22nd JCHP study on Water Supply and Sanitation Component of PHC, 1978; and Cardenas, Margarita, "Community Participation and Sanitary Education in Water Supply and Sanitation Programmes in Rural Areas of Paraguay", Background Paper for above study, 1977.

of information exchange, especially as it relates to the acceptance and adaptation of new technologies.[1]

Finally, it is important to build up multi-disciplinary institutional strengths so that changing research and development questions can be continuously addressed by a core of researchers possessing an "institutional memory" which builds on previous experiences rather than starting anew with each research problem.

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[1] See, for example, Andreas Fuglesang, Doing Things Together: Report on an Experience in Communicating Appropriate Technology, Dag Hammarskjöld Foundation, Uppsala, 1977.

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OPERATIONS RESEARCH APPLIED TO APPROPRIATE TECHNOLOGY FOR IMPROVEMENT OF ENVIRONMENTAL HEALTH

By

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(Operations Research Specialist)

5560

To introduce my comments on operations research as that discipline may apply to appropriate technology for environmental health, I quote from Mother Goose as adapted by Stacer Holcomb as reported by Cleland and King.

Jack and Jill went up the hill
To fetch a pail of water
Jack fell down and broke his crown
And Jill came tumbling after.

Jack could have avoided that awful lump
By seeking alternative choices
Like installing some pipe and a great big pump
And sending Jill the invoices.*

That quote seems particularly appropriate both to the substantive issue of environmental health and the methodological issue of operations research. For the most part, alternative choices, how to identify them and how to make them is the subject matter of operations research.

Nearly every book on operations research begins with a statement of what operations research is. Each of these statements tends to have in common the basic idea that operations research is research applied to the solution of management problems in the deployment of given technology. The notion of applied is critical to operations research. As Wagner says of operations research, "The principle results of the analysis must have direct and unambiguous implications for executive action".** Research undertaken without this direct implication to executive action, no matter how elaborate or costly, is not operations research. Many elaborate research projects are designed, funded and carried out with little thought given to the application of results. In some cases, it is readily acknowledged that the research results will come in after decision making has taken place. In other cases, the decisions have been made prior to the research effort which is merely cosmetic. It will be referenced if it supports the decisions and buried otherwise. Whatever else such activities may be, they are not operations research.

The deployment of given technology is also central to the concept of operations research. Operations research attempts to utilize the existing technology in the most effective and efficient way, but is not basically concerned with the development of the technology, per se. The construction of a better pump or a more effective composting procedure is the province of the engineer rather than the operations researcher. This does not mean that OR cannot contribute to both the evaluation of and application of new technology, but simply that technology development is outside the OR range.

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*David Cleland and William King, Systems Analysis and Project Management, Mc Graw Book Co., New York, 1968, p 40.

**Wagner, Harvey M, Principles of Operations Research, Prentice Hall, 1975, P3

A second characteristic common to most statements of what OR is, is the notion of objective and measureable pay-off. The purpose of OR is to show the way by which some objective pay-off (often economic) can be maximized (or alternatively, costs can be minimized given a set of output goals). In applications in the private sector, this is a relatively easily adopted perspective. The objective pay-off is very often organization profit. In the public sector it is much more difficult to specify objective pay-offs. Public sector organizations are not profit making, but rather service organizations. Very often it is difficult to quantify the service to be provided or even to obtain agreement on what the service is. Still, for a successfull application of OR, such quantification is necessary.

A third characteristic of OR, is that it relies on formalized mathematical procedures or models. Wagner* again says that the procedures for manipulating the data to which OR is applied should be so explicit that they can be described to another analyst, who in turn would derive the same results from the same data. This does not mean that the procedures must at all times rely on what Singh** has called the "abracadabra of higher mathematics". He points out that "operations research is, like the tusks of an elephant, of two types: one for grinding and the other for display". Published OR work is often quite mathematically sophisticated, but that which is applied in practical situations may be so simple, even crude, that it would not provide a publishable paper. Yet it has been sufficient to solve the problem at hand in an acceptable manner.

The real point of the reliance on formalized procedures is that the results of the Research effort not be so subjective as to be wholly dependent on the perspective and hunches of the researcher. Any researcher using the same techniques (however crude) should be able to reach substantially the same results.

A detailing of these characteristics of OR still does not suffice to let the person unfamiliar with the subject know, in fact, what it is. Those activities which most often go under the name of OR are a fairly specific, though diverse, set of mathematical procedures which are considered almost always to include Decision Analysis and Decision Theory, Linear and Non-linear Programming, Network models including PERT and CPM, Markov Analysis, game theory, inventory models, queuing theory and simulation. Singh also considers statistical inference, including hypothesis testing, statistical model building and analysis of variance as part of operations research although most authors do not include these topics. While the distinction is not perfect, it might be said that the difference between those techniques which are generally perceived to fall under the heading of operations research and those which are more often considered as primarily statistical inference is that operations research represents evaluation before the fact based on best estimates of various model parameters while statistical inference represents evaluation after the fact. Both can be usefull management tools, but the "after the fact" nature of statistical inference often makes it a less usefull management tool in public sector activities.

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*Ibid P3
**Singh, Jagjit, Great Ideas of Operations Research, Dover, 1968, P6

How can OR be applied to the practical problems of appropriate technology for environmental health? Environmental health is not without OR applications at the present time. D. Hindle, who has written a problem based OR training manual for developing countries provides a simplified description of an OR treatment of the problem of river water management.* The problem included how best to extract water from the river in order to meet water supply needs, what strategies for treatment of waste water should be utilized and where to build processing and treatment plants. The OR approach taken, which was highly pragmatic, showed that the lowest cost strategy for assuring an adequate supply of safe water depended on the cooperation of water supply and sewage treatment authorities and could not be reached if each authority attempted to minimize its own costs.

In another area of OR application, John Briscoe has developed several mathematical models for simulating hookworm infestation.**

As a means of better conceptualizing the possible use of OR in addressing practical problems in environmental health, let us consider three hypothetical (and relatively simple) applications, a decision analysis problem, a linear programming problem and a problem involving Markov analysis. In undertaking such a discussion, however, two points should be clear at the outset. First, environmental health is not my field. Because of this, the examples I have chosen to discuss may or may not appear naive. If they are naive, at least let us hope that the possibility of the use of OR techniques in environmental health will not be rejected solely on that account. Second, the examples are purposely simple for the purpose of discussion. In a serious application, the order of complexity would be many times greater. Again, the point is to demonstrate an approach to problem solving without getting bogged down in detail.

In a 1977 report Briscoe has discussed a number of studies bearing on the spread of cholera in Bangladesh.*** On the basis of these he examined several hypotheses concerning the spread of cholera.

Three of the hypotheses he examined include, in a slightly reworded form, the following

1. Cholera is transmitted only by drinking water
2. Cholera is transmitted by all contacts with water including drinking, cooking, bathing and washing cloths
3. Cholera is transmitted through oral-fecal contacts unrelated to water

Briscoe shows evidence that essentially casts doubt on all of these hypotheses (as well as others) as accounting for the spread of cholera. But

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*Management Science for Health Services, an OR/SA Training Course for Developing Countries, (no further reference).
**Briscoe John, Public Health in Rural India: The case of Excreta Disposal.
***Briscoe John, The Role of Water Supply in Improving Health in poor countries, Cholera Research Laboratory, Dacca, September 1977.

let us suppose that a country wished to launch some type of cholera preventive programme and believed these three hypotheses to be the most plausible. Further, let us assume that the country is contemplating five different possible programmes. The first programme would be the widespread expansion of tubewell availability, which they estimate to cost rupees 16 million. The second is a tubewell project plus education about cholera estimated to cost rupees 24 million. The third alternative is a combined tubewell and excreta disposal project estimated to cost rupees 32 million and the fourth alternative is an excreta disposal programme alone estimated to cost rupees 16 million. Finally, the country could elect to do nothing, a policy we will consider to be free. This is a classic example of a decision analysis problem. There are several alternative strategies (the five possible programmes) and several alternative states of nature (the possibility that either hypothesis one, two or three is true). What strategy should be chosen to gain the maximum benefit?

To answer this question, two other types of information must be available. The first is the benefit derived from selecting any given strategy if any given state of nature obtains, and the second is the likelyhood or probability that a given state of nature will obtain. Consider first the question of benefit derived. Figure 1 represents what might be considered a plausible pay-off matrix for the three states of nature and the four alternative strategies under consideration.

Figure 1

Pay-offs for Alternative Strategies and States of Nature
Cholera Control Programmes

	States of Nature A	B	C
Strategies 1	75	50	25
2	80	50	25
3	80	75	50
4	50	50	50
5	25	25	25

States of Nature

A. Cholera transmitted only by drinking
B. Cholera transmitted by all water contacts
C. Cholera transmitted by other oral-fecal contacts

Alternative Strategies

1. Tubewell project
2. Tubewell plus education project
3. Tubewell plus excreta disposal project
4. Excreta Disposal Project alone
5. No programme

It may be necessary to suspend disbelief for a moment, but let us consider that the number in each cell of the pay-off matrix represents an expert's, or panel of experts' best guess as to the proportion of the population of a country which will be protected from (that is not exposed to) cholera for each strategy given each state of nature. For example, if cholera is spread only by drinking water (State A) and the country chooses to launch a major tubewell project (strategy 1), seventy five people out of every one hundred will be protected from exposure to cholera. (Remember, these are only exemplary figures based on my personal brief exposure to environmental health). If on the other hand, the country decides to concentrate its efforts only on excreta disposal the effect will be the same (50 percent unexposed) whether the true state of nature is that cholera is transmitted by drinking only, by all water contacts or by other oral-fecal contacts. The other numbers in figure 1 represent the belief that a tubewell project or a tubewell project plus education will have some effect (50%) if cholera is spread through all contacts with water but little or no effect (25%) if cholera is spread by other contacts. A tubewell plus excreta disposal effort will have substantial effect if water is the transmission medium (80 and 75%) and some effect if not (50%). Finally if nothing at all is done, it is estimated that 25% of the population will remain unexposed to cholera.

Briscoe shows evidence to refute all three hypotheses about the spread of cholera. But let us assume we can get expert opinion which tells us that the probability is 40% that cholera is spread by drinking along, 50% that it is spread by drinking, bathing and all other water contacts and only 10% that it is spread in some other way. Decision analysis would then dictate that the correct programme to introduce is that programme which maximizes the sum of the product of the pay-off for each state of nature for each programme multiplied by the probability that each state of nature is the correct one. Thus, the pay-off for each strategy given the probabilities .4, .5 and .1 are shown in the top half of figure 2.

Figure 2

Computation of Pay-off and Pay-off per cost
Given fixed probabilities for
Alternative States of Nature

Probabilities of the States of Nature: A = .4, B = .5, C = .1

Strategy	Pay-off	Cost (million rupees)	Pay-off/ (million rupees)
1	(75)(.4) + (50)(.5) + (25)(.1) = 57.5	16	3.59
2	(80)(.4) + (50)(.5) + (25)(.1) = 59.5	24	2.48
3	(80)(.4) + (75)(.5) + (50)(.1) = 74.5	32	2.33
4	(50)(.4) + (50)(.5) + (50)(.1) = 50.0	16	3.13
5	(25)(.4) + (25)(.5) + (25)(.1) = 25.0	0	N.A.

Probabilities of the States of Nature: A = .1, B = .5, C = .4

Strategy	Pay-off	Cost (million rupees)	Pay-off/ (million rupees)
1	(75)(.1) + (50)(.5) + (25)(.4) = 42.5	16	2.66
2	(80)(.1) + (50)(.5) + (25)(.4) = 43.0	24	1.79
3	(80)(.1) + (75)(.5) + (50)(.4) = 65.5	32	2.05
4	(50)(.1) + (50)(.5) + (50)(.4) = 50.0	16	3.13
5	(25)(.1) + (25)(.5) + (25)(.4) = 25.5	0	N.A.

Under this fomulation, given fair certainty about the pay-offs but uncertainty about which will be the true state of nature, the best strategy to maximize the proportion of population protected is strategy 3, a joint tubewell and sewage project.

Consider now an alternative fomulation in which our expert opinion indicates that the likelyhood is very low (say .1) that drinking alone spreads cholera, .5 that all water contacts spread cholera and .4 that other oral-fecal contacts spread cholera. In this case, the pay-off of each strategy will be as shown in the lower half of Figure 2.

In this case, again, the maximum pay-off is obtained when the joint tubewell sewage project is undertaken; In fact, given this particular pay-off matrix, the best strategy for reducing exposure to cholera will be a joint tubewell/sewage project regardless of the probabilities assigned to the possible true states of nature.

But suppose that reduction to cholera exposure is not the only consideration. Suppose also we are concerned about the cost of the programmes and the need to get the most "bang for the rupee" so to speak. In that case the "best" strategy in terms of cost-effectiveness would be the first, (3.59 percent of the population protected per million rupees spent) if the probabilities of the states of nature were .4, .5 and .1 respectively and the fourth (3.13 percent of the population protected per million rupees spent) if the probabilities of the states of nature were .1, .5 and .4. These details are also shown in figure 2.

This is a relatively simple example of the use of decision analysis in planning a specific type of environmental health project. A more sophisticated application might include the staging of implementation so that decisions could be based on experience as well as a priori assumptions about pay-off and states of nature. Most standard texts in Operations Research provide examples of such decision staging.

Consider, now, another application of OR to the question of appropriate technology. Again, the example will be kept simple for the purpose of this discussion. Bangladesh, according to Shawcross* has 400,000 hand pumps in operation and an annual maintenance cost of $ 5 per pump or 2 million dollars. The pumps are currently maintained by the central government but there is a desire to transfer maintenance of possibly all, but at least some of the pumps from the central government to the people at the local level. Let us assume that there will still be a maintenance cost to the government of $ 1 per pump if they are able to shift the maintenance responsibility to the local level (perhaps they will have to hire people to act as advisors in pump maintenance) and let us assume further that the country is willing to continue to spend $ 1 million per year on pump maintenance.

Under the current system of pump maintenance approximately 75 percent of all pumps (about 300,000) are working at any one time. The government realizes that if they decentralize responsibility to the local level, probably no more than 50% of pumps will be operational at any one time. Yet they want to assure that the million dollars will be spent in such a way that the maximum number of pumps, whether government maintained or locally maintained will be working at any time. How do they best spend the $ 1 million to assure this.

The problem as stated is a straight-forward, if simple, linear programming problem. The issue is how to allocate resources between two competing destinations (government and locally maintained pumps) in such a way as to maximize some pay-off (the proportion of pumps working). If we designate X_1 as the number of pumps maintained by the government and X_2 as the number of pumps maintained locally the problem is to maximize Z where:

$$.75X_1 + .5X_2 = Z \quad \text{Total proportion of pumps working}$$

and

$$5X_1 + 1X_2 = 1{,}000{,}000 \quad \text{Total dollars to spend}$$

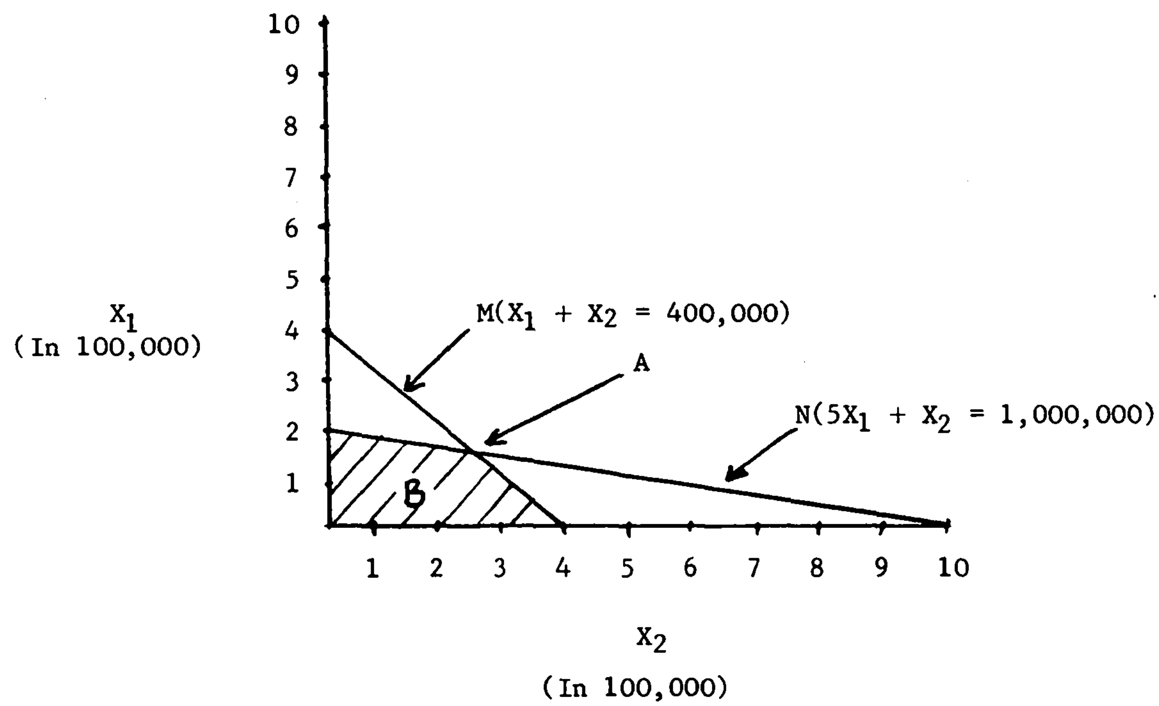
$$1X_1 + 1X_2 = 400{,}000 \quad \text{Total pumps to maintain}$$

These three equations indicate that we are trying to maximize an additive combination of 75% of all pumps maintained by the government and 50% of all

*Hand Pump maintenance, John F. Shawcross, Interim Report to the International Reference Center for Community Water Supply, Voorburg, The Netherland, 1978 pumps maintained locally (those that will be operational at any one time) subject to the constraints that the number of pumps maintained at five dollars and the number maintained at one dollar must result in expenditures not exceeding one million and more than 400,000 pumps cannot be maintained through either mechanism. With a little effort, this problem can be solved by trial and error. The best strategy is to maintain 250,000 pumps locally and 150,000 by government workers. This results in 237,500 pumps or 59.4% of the total being in working order at any one time. With a million dollar per year investment and only these two maintenance strategies, that is the best the country can do. The problem can also be solved graphically as shown in figure 3.

Figure 3

Graphical representation of maximization



In figure 3, the line M represents the constraint

$$X_1 + X_2 = 400,000$$

The line N represents the constraint

$$5X_1 + X_2 = 1,000,000$$

Any point in the shaded area B satisfies both constraints but it can be readily shown that point A, representing the intersection of the two constraints, results in the maximum of the objective function. (At point A, $X_1 = 150,000$ and $X_2 = 250,000$)

Most linear programming problems in practical applications are much more complex than this. They may have tens or hundreds of additive terms to be maximized and equal numbers of constraints. The simplex method, described in any OR text and available in a number of different computer programme formats will, in general, provide solutions to such resource allocation problems if the relationships can be stated in linear terms.

A final example of an OR Application involves the use of Markov analysis, and basically concerns the same problem of well maintenance. Markov analysis is concerned with the steady state characteristics of dynamic systems. We know, for example, that only 75 percent of Bangladesh wells are operational at any one time.* But if maintenance efforts are being expended then some of the pumps are being fixed while others are breaking down. The 75% represents a steady system state where as many wells breakdown as are repaired in any given time period.

Let us assume that the maintenance force visits each pump once each month and that they fix each pump which is broken. To simplify (hopefully not beyond the realm of belief) let us assume that all the pumps went into operation at the same time and were all operational at that time. So, for the first month of the maintenance programme we might be able to represent what happened with the transition matrix, shown in Figure 4.

Figure 4

Transition matrix for first time period

	working at T_2	broken at T_2
working at T_1	P	1-P
broken at T_1	1	0

If all the pumps are working at T_1, 1-P pumps will be broken by T_2 (working pumps at outset X 1-P + non-working pumps at outset X 0)

We know the system is in steady state when 75% of the pumps are working. In the case of a transition matrix which is 2 x 2, both rows in the steady state will be identical. If we denote the proportion of pumps working and not working at the outset by the vector w = (1 0) and the steady state matrix by S, the proportion of pumps working at any one time after reaching steady state is w S or as shown in Figure 5

*Shawcross, opcit, P_3

Figure 5

Proportion of pumps working after reaching steady
state - all
Broken pumps repaired each
month

w		S			
(1 0)	(.75	.25)	=	(.75)	(working)
	(.75	.25)		(.25)	(not working)

It is known that the steady state matrix S is in fact some power of the initial matrix shown in Figure 4.

In order to fix all the pumps that are broken, the repairmen would conceivably have to visit all pumps. The value of knowing the initial matrix is that it can help us to determine what the steady state of the system would be if our policy was changed to visiting only half the pumps each month so that only half the broken pumps would be fixed.

It is relatively easy to find the initial matrix above through trial and error which turns out to have P = .66 and 1-P = .34 as shown in Figure 6.

Figure 6

Original transition matrix for
75% steady state

$$\begin{pmatrix} .66 & .34 \\ 1 & 0 \end{pmatrix}$$

This matrix raised to about its 4th power gives the steady state matrix. Beginning with the matrix in Figure 6, what would be the result of a decision to visit only half the pumps each month (and hence fix only half the broken pumps) has been made.

In the initial month the transition matrix would be as shown in Figure 7 which reaches the

Figure 7

Original transition matrix if only half the pumps are visited each month and only half of broken pumps fixed (on the average)

$$\begin{pmatrix} .66 & .34 \\ .5 & .5 \end{pmatrix}$$

Steady state shown in Figure 8

Figure 8

Steady state for transition matrix shown in Figure 7

$$\begin{pmatrix} .60 & .40 \\ .60 & .40 \end{pmatrix}$$

Thus, by visiting only half the wells each month (a fifty percent reduction in work) the number of pumps working drops to 60%, only a 20% reduction in operating pumps. Or, viewed another way, for a 38% reduction in cost per working well there is a 20% reduction in working pumps. This type of information could be usefull in planning programme changes, especially in the presence of restricted budgets.

I have mentioned only a small number of possible OR applications to environmental health, and clearly they are highly simplified. Perhaps, like the visible tusks of the elephant they are more for display than for grinding. Still, I hope they provide some indication that OR techniques may provide information usefull to environmental health planning.

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WORLD HEALTH ORGANIZATION

REGIONAL OFFICE FOR SOUTH-EAST ASIA

Research Study Group Meeting on Appropriate Technology for Improvement of Environmental Health at the Village Level, New Delhi, 16-20 October 1978

SEA/EH/RSG Meet.1/4.3a

RESEARCH IN RURAL WATER SUPPLIES AND SANITATION

By

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The opinions expressed in this paper does not necessarily reflect those of the World Health Organization.

RESEARCH IN RURAL WATER SUPPLIES AND SANITATION

This note is written for use at the October 1978 meeting of the Research Study Group on Appropriate Technology for the Improvement of Environmental Health at the Village Level held in New Delhi under the auspices of WHO's Regional Office for South East Asia. Its purpose is to briefly set out IDRC's activities in this sector and discuss some of the priority needs for research in the excreta/wastewater disposal and reuse sector.

The Health Sciences Division began funding rural water supply and sanitation (RWSS) projects in mid-1975, to date 44 projects are underway or are in the initial stages of receiving support. A complete list is attached hereto. The total amount of funds committed thus far are in the region of $4,000,000. IDRC's policy is to support developing country national institutions and researchers and in doing so to respond to their priorities. Research funding has been geared to both:

1. the maintenance of high standards in research; and
2. the development of research capability within the third world.

Of the several criteria placed on research supported by IDRC/HSD are:

1. that it should respond to national priorities;
2. that the project should be in a position to influence government policies and practices should research results merit implementation;
3. that the target population group which would ultimately benefit from the research be of the rural poor or the low income urban squatter settlements; and
4. that the investigators be committed to the research activity.

Efforts by international agencies to develop the rural water supply and sanitation sector as a whole are hindered by several constraints.

These include lack of such fundamental prerequisites as central government motivation and rational implementation policies. Financial and administrative infrastructure are inadequate and co-ordination between the responsible agencies is poor. Communications between government and villages being serviced are generally weak, resulting in misunderstandings and the early breakdown of the equipment installed through lack of maintenance and support at the local level. The selection of technology has been dominated by foreign consultants; equipment has been applied with inadequate attention being given to local conditions. Of particular note of this respect are village handpump and latrine installation programmes. Handpumps require maintenance; however, most installations have been made without adequate maintenance back-up facilities and in such a way that the community being serviced regards the pump as the property, and hence the responsibility, of the government.

RESEARCH PRIORITIES WITHIN IDRC'S FUNDING ACTIVITY

Due to constraints on funds and the lack of relevant research capacity in the field, it has been necessary to select specific research areas as foci which represent a compromise between those that are felt to exhibit the greatest promise and the constraints imposed by the limited research capacity. These are listed below; they are not in any order or priority:

1. Ground Water Extraction: studies on the development of handpump technologies which are relevant to local conditions and have potential for local manufacture.

2. Surface Water Treatment and Delivery: studies on low-cost, low-maintenance water treatment (clarification, filtration, disinfection) processes. This research is aimed at minimizing equipment requirements and reducing capital costs of existing water treatment plant designs for the larger villages and rural towns.

3. Wasteswater Management: investigations into alternative modes of excreta and wastewater collection and disposal in both the urban and rural contexts but with emphasis on the densely populated areas of the squatter settlements, where conditions are most critical and lack of feasible approaches most severely felt.

4. Wastes Reclamation: the development of reclamation systems aimed at the treatment and reuse of wastes (in particular, human excreta) which are applicable to those derived of the rural town and agricultural community. Specific emphasis is be given to the production of fish and other forms of biomass in waste treatment ponds and to health aspects related to such processes.

5. Impact of Water and Sanitation Interventions: investigations into the effects of water supply and sanitation delivery on the village. This work includes field studies of the impact on public health of various types and levels of improvements which can be made with a view to their optimization and definition of the most cost-effective combinations of interventions appropriate to the variety of village conditions in which they are to be made.

6. Social and Managerial Aspects: studies on the social, organizational, administrative and financial aspects of rural water supply programmes including traditional technologies and water-use practices; village organizational capacity and interaction with the government as related to water supplies; community participation and self-help approaches; the design of government administrative and financial infrastructure for implementation of rural water supply and sanitation schemes; and functions of the primary health care systems in maintaining installations and providing sanitary education.

7. Manpower Development: investigations related to the design of manpower development programmes, including training for rural water supply and sanitation. These will include studies on the role of village-level maintenance personnel, middle-level technicians, and the central co-ordination and design offices,

with a view to defining the type and number of personnel at each level required for effective back-up for the continued use, maintenance and extension of the systems, once installed.

Researchers who are interested in requesting support for work in this sector from the Health Sciences Division should initiate correspondence directly with the writer. Proposal development is very informal. The first letter should set out the proposed project in a few paragraphs. It is used to obtain an informal reaction from IDRC. This is followed by more detailed correspondence and most likely a visit by a representative of IDRC which will conclude with submittal of the formal proposal. The formal proposal will give details of the background to the proposal, the specific objectives of the work, how the research will be carried out, how the results are to be disseminated, how they might be utilized within the government's development activities, the budget and the way in which the funds are to be transferred and administered throughout the project. It is possible that the proposal will require some formal clearance by the recipient's government. Such clearances would be necessary prior to IDRC's formally accepting the proposal and committing funds.

RESEARCH IN EXCRETA AND WASTEWATER DISPOSAL

In the past, there has been a natural tendency to focus on the "hardware" aspects of technology for excreta and wastewater disposal. This has been in response to the technology gap between the objectionable pit privy and the too-expensive sewerage network system. Now that research projects in the developing countries are generating technical solutions more emphasis will have to be placed on the "software" components of development programmes in this sector.

Listed below are several techniques and technologies requiring further research. The list is obviously incomplete but could serve as a focus for discussion.

ON-SITE EXCRETA DISPOSAL TECHNOLOGIES

1. Lower cost construction methods and materials for all parts of the privies, compost and water seal latrines which will permit the owner to construct the unit himself without reliance on factory made parts.

2. Practical methods for reducing fly infestation and breeding within the pits and vaults.

3. Techniques for desludging the pit privy which are acceptable to the owner and which permits decentralization of responsibility for latrine maintenance.

4. Improved venting systems to reduce odours in the "dry" latrines and composting toilets.

5. Water using latrine designswhich encourage hygiene and handwashing in particular after defecation.

6. Techniques for reducing the quantities of water reaching the vaults of compost toilets.

7. Methods for reducing refuse and grass requirements of compost toilets while ensuring adequate temperatures are maintained within the compost development and field testing the Vietnamese double vault toilet in other regions and cultures.

EXCRETA COLLECTION TECHNOLOGIES

1. Low-cost yet functional designs and their field evaluation for vacuum trucks and vaults.

2. Minimum water use water seal riser seats for use with the household vault where squat plates are unacceptable.

3. Design criteria and field testing of the upgraded PRAI latrines connected to low sloped, shallow buried, small bore, low water use sewers.

4. Storm drain designs which will cope with sullage and other wastewaters which cannot be treated or adequately managed by the on-site excreta disposal technologies

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5. Water use reducing devices and approaches.

EXCRETA TREATMENT AND REUSE

1. Field testing the Chinese and BARD systems of nightsoil composting with agricultural wastes and urban refuse.
2. Low-cost materials and construction designs for the biogas plant - such as the fixed top digester
3. Means by which digester temperatures can be raised and maintained during winter
4. More efficient gas burning devices (cookers and lamps) which can be fabricated within the village.
5. Improved operating regimes to raise the productivity of the biogas digester (gas/volabile solids introduced).
6. Use of excreta and sewage for aquaculture methods, increasing productivity including optimizing stocking rates, polyculture, algae production, culture of high yield, low quality varieties for fish meal and intensive aquaculture techniques.

The list is incomplete but illustrates the numerous opportunities and demands for research. There are even more solutions and information required in the non-technology areas.

Perhaps the most obvious questions centre around the health aspects of on-site disposal and reuse approaches. The transfer of pathogens through all the above processes need to be assessed. The spread of water related pathogens by introducing water coupled with excreta disposal technologies which cannot cope with sullage needs investigation. The potential for bioconcentration of pesticides and heavy metals through aquaculture reuse systems has not been quantitatively evaluated to date. Research which has been carried out in this area has tended to focus on pathogen transfer through the process itself and largely ignored their die-off or survival after harvest and through the market and food preparation processes.

Although costing exercises are relatively common little consideration has been given to the use of cost-effectiveness analysis to determine the overall least cost approaches from the national and user points of view. The householder's capacity to pay for or otherwise contribute to the technology and its maintenance remains a relatively untrodden area of research but is a crucial element in government programmes in this sector.

Institutional, manpower and management liminations remain as the greatest constraints on progress.

Manpower which is available for project implementation has been educated in sophisticated non-reuse technologies requiring excessive capital outlays. Manpower at the sub-professional levels is often non-existant and often needs to be trained on a project-by-project basis. There is an urgent need to transfer and adapt successful institutional and manpower development approaches from Latin America and Malawi for use in other regions and countries. What activity there is to counter this situation is still in its infancy. There remain urgent needs to develop relevant training programmes incorporating the lower cost technologies for manpower at all levels (professional, technician and village). There is however a dearth of innovative and evaluative capacities in the third world to meet these demands. Such capacities cannot be imported from abroad.

The lower cost technologies must be socially acceptable to the user. International agencies and even national governments are often ignorant of social factors in implementating their projects in their rural areas. It is often firmly stated that no reuse approaches would be acceptable to rural communities. Such broad-brushed negative reactions are often ill-informed. There are important examples of indigenous reuse practices such as the use of excreta in backyard fish production ponds in Indonesian Moslem communities. These point to the basic lack of understanding of motives and religious/aesthetic factors of rural peoples' response to the reuse technologies.

Internationally assisted projects have a tendency to focus on the delivery of a technology to the rural village - most often a handpump or gravity fed pipe system. Technology is not enough. It needs to be introduced along with a change in hygiene habits in the home before its full benefits are realized. Latrines and sanitary education tend to fall way down on the list of priorities. This is a result of their being non-technology oriented, awkward and time consuming in implementation. Ways by which sanitary education and latrines can be more easily introduced with water as a "sanitation package" need to be developed and evaluated in the field. There remains a dearth of sanitation education material which focusses specifically on water and sanitation and can easily be implemented in the field.

Third world researchers in this field have tended to be divided and focussed on research acceptable for publication in the industrialized states. Practical means of encouraging communication between researchers in the developing countries without domination or control by international agencies need to be devised and implemented. Finally effective means of information transfer between developing countries has been lacking. Fortunately, the Asian Institute of Technology is establishing a Sanitation Information Centre which will be a first step in alleviating the situation.

Michael G. McGarry, Ph.D.,
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IDRC FUNDED PROJECTS IN THE WATER SUPPLY AND SANITATION SECTOR

Groundwater Extraction

Manually Operated Low-Lift Pump Prototypes (Canada)
- University of Waterloo

Rural Water Technology Research (Canada)
- IDRC

Pump Windmill Systems (Canada)
- University of Waterloo

Pumping Technology Research (Ethiopia)
- Ethiopian Water Resources Authority

Windpower (Ethiopia)
- Ethiopian Water Resources Authority

Water Pumping Technology (Sri Lanka)
- Sarvodaya Shramadana Movement

Water Pumping Technology (Malaysia)
- University of Malaya

Shallow Well Pump Research (Malawi)
- Ministry of Finance - National Research Council

Water Pumping Technology (Kenya)
- Kano Water Development Trust

Water Pumping Technology (Thailand)
- Asian Institute of Technology

Water Pumping Technology (Philippines)
- University of Philippines

Windpower Pumping (Botswana)
- Rural Industries Promotions

Literature Review: Innovative Hand Pump Technology
- University of Waterloo

Water Treatment and Delivery

Water Treatment (Brazil)
- Campanhia de Saneamento do Parana/SANEPAR

Infiltration Galleries (Panama)
- University of Panama

Lapa Water Treatment Plant (Peru)
- Pan American Health Organization

Groundwater Iron Removal (Ghana)
- University of Science and Tehcnology

Wastes Management

Palm Oil Wastes (Malaysia)
- Asian Institute of Technology

Self-help Sanitation (Mozambique)
- Ministry of Public Works and Housing

Sanitation Technology (Zambia)
- National Housing Authority

Alternative Waste Disposal Phase II (Tanzania)
- Tanzania National Scientific Research Council

Environmental Health (Thailand)
- Applied Scientific Research Corporation of Thailand (ASRCT)

Alternative Waste Disposal Methods (Tanzania) Phase I
- Tanzania National Scientific Research Council

Squatter Settlement Sanitation (Botswana)
- Ministry of Local Government and Lands

Disposal of Human Excreta in Rural Areas (Ghana)
- University of Science and Technology

Piggery Waste Treatment (Singapore)
- Ministry of National Development

Reuse Wastes (Korea)
- Dong-A University

Excreta Reuse (Guatemala)
- Centro Misoamericano de Estudios sobre Tecnologia Apropiada (CEMAT)

Wastes Reclamation

Stabilization Ponds (Peru)
- CEPIS/PAHO

Waste Water Reclamation (Malaysia)
- University of Malaya

Waste Water Reclamation (Israel)
- Ministry of Agriculture

Waste Water Reclamation (Kenya)
- Ministry of Water Development

Waste Water Reclamation (Thailand)
- Asian Institute of Technology

Impact of Water and Sanitation Interventions

Gastro-enteritis (Guatemala)
- INCAP/PAHO

Water Impact (India)
- M.L.B. Medical College

Sanitation Impact (Bangladesh)
- Cholera Research Laboratory

Social and Managerial Aspects

Water Management (Nigeria)
- University of Ibadan

Maasai Water Impact (Kenya)
- University of Nairobi

Rural Water Supply (Korea)
- City College of Seoul

Water Management (Sudan)
- University of Khartoum

Gastro-enteric Diseases

Viral Gastro-enteritis (Caribbean)
- CAREC/PAHO

Rotavirus - INCAP (Guatemala)
- PAHO

General

Trust Fund Rural Water Supply and Sanitation
- World Health Organization

Handpump Lab Test (England)
- Consumer's Association

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WORLD HEALTH ORGANIZATION

REGIONAL OFFICE FOR SOUTH-EAST ASIA

Research Study Group Meeting on Appropriate Technology for Improvement of Environmental Health at the Village Level, New Delhi, 16-20 October 1978

Restricted

SEA/EH/RSG Meet.1/4.3b

WATER AND WASTEWATER TREATMENT AND DISPOSAL
SOME RESEARCH AND DEVELOPMENT IN THAILAND

By

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1 Introduction

Whereas authorities concerning the provision of clean water for various communities in Thailand have been clearly defined for a long time, the authorities responsible for sewerage and sewage disposal of towns and villages have not been so well defined, but it is generally accepted to be the responsibility of the Department of Local Administration.

The provision of clean water for rural areas in Thailand was initiated in 1964, when the Cabinet appointed an executive committe with members represented from various departments. The target to be completed was to provide clean water to some 50,000 villages throughout the country during the ten years to follow. The programmes included the following:

- The construction of shallow dug wells and jet wells with handpumps
- Small diameter wells with handpumps
- Deep wells equipped with handpumps
- Piped water supply
- Rain water collection reservoirs
- Standard ponds
- Improvement of existing ponds
- Dikes and reservoirs

2 Sources and Handpump Problems

However, during 1965-1975, only 40,000 villages had been provided with water supply of some sorts. At the end of the Third National Social and Economic Development Plan, the National Economic and Social Development Board requested the National Institute for Development Administration (NIDA) to carry out the evaluation of the programmes. It was found that only 9.3% of the rural population had water that could be considered to be clean (Kraivixien and Chulavachna, 1978).

Among the many problems confronting the implementation of the programmes the failure of handpumps was identified.

There are many authorities at national level vested with the responsibility of provision of clean water: the Department of Local Administration, the Department of Mineral Resources, The Office of Accelerated Rural Development, the Department of Public Works and the Department of Health.

Among those authorities, the Department of Health seems to be more concerned with the rural areas. Since 1966 up to the end of 1977, with funds from the National Budget, the communities participation, and also from contribution from international agencies, notably WHO and UNICEF, 539 piped water schemes had been constructed serving 1,438,100 rural inhabitants which, however, represented only a small portion of the total rural population. Realizing that new approach to the problems is needed to accelerate the implementation of the programmes, small diameter well programmes for communities between 500- 1500 population were introduced in 1976 with UNICEF assistance. At the end of 1977, 130 wells with handpumps were installed and another 350 wells with handpumps will be constructed annually from now on.

In all, approximately 19,000 handpumps were installed all over the country and, according to NIDA's Report, about 5,000 were out of operation at any one time. The failure was attributed to various sources; from the poor engineering designs, the low quality of production, to the problems of operation and maintenance. The spare parts problems were also of great importance, since those handpumps were imported from overseas.

The ARD and the UNICEF Bangkok, had conducted surveys of handpump designs with a view to develop a new design which can be manufactured locally with available materials, durable and easy to operate and maintain. It is planned to install handpumps with the improved designs and construction and to field test them over a period of time. The existing approach to the maintenance problems carried out in this country, notably by the Department of Mineral Resources, is to absorbed all costs by the Department. A new approach will be introduced by the Department of Health and the ARD where the local communities will be trained to participate in the maintenance programmes: the upper part of the handpumps by the villagers and the lower part by the town mechanics.

3 Treatment for Water Supply

The Department of Health has constructed a number of water treatment plants through out the country. They are invariably of conventional design: coagulation,sedimentation, rapid sand filtration and chlorination. The problems encountered lie in the areas of operation and maintenance because of the lack of the capability of local communities in terms of financial and technological resources.

3.1 Sand Filters

The Department of Health, the WHO and the International Reference Centre for Water Supply are collaborating with the Asian Institute of Technology and the Sanitary Engineering Department, College of Engineering, Chula longkorn University, in the study and assesment of the use of slow sand filters for rural water supply. Three slow sand filters plants are now being constructed and tested.

Sand filters for household use were also developed by the Sanitation Division, Faculty of Public Health, Mahidol,University, as shown in Annex 1 .

3.2 Iron Removal by Tray Aerator

Iron was found to be in concentration well beyond the WHO International Standard for Drinking Water in many parts of Thailand, especially in the Northeastern Region. Aerating towers were used in many places consisting of wooden or concrete towers, 4-5 meter high, from the top of which water was sprayed and allowed to drip down to sand and gravel filter basins constructed at the base of the towers. The Division of Rural Water Supply, Ministry of Health also used this process in many water schemes.

Limrat (1968) investigated the oxidation and removal mechanism of the process with different types of media and flow rates, and concluded that the optimum dosing rates were in the range between 10-15 gpm/sq.ft., and coke 2½-4½ in. size was the most efficient media. The percentage of iron removal and iron oxidation at 10 gpm/sq.ft. were about 16% and 11.5% respectively. To affect a high overall iron removal, the aeration process should be followed by coagulation and sedimentation. In this investigation the coagulants used were lime and alum, and the sedimentation was most effective in solid-contact tank with preformed sludge blanket, where up to 86% 96% removal could be obtained. See Annex 2 for more details.

4 Waste Treatment

There are not many domestic waste treatment plants constructed in this country, and it can be safely said that not a single town within the country has a proper sewage treatment plants for town wastewater. A few do exist at military installations and bases. In Bangkok, there are a number of treatment plants constructed at various housing estates, especially, those that come under the jurisdiction of the National Housing Authority. They are by far of conventional activated sludge systems, which are used also by large hotels and offices in Bangkok and in the resort areas such as Pataya.

The provision of sewerage and sewage treatment plant facilities has increased the cost per unit dwelling of many projects which forgo the septic tank and leaching pit system for the activated sludge or extended aeration system by some ฿ 5000 per unit dwelling. If the sanitary installations are for individual housing projects, the cost will be much higher in the region of ฿ 6,000 - ฿ 7,000 per unit dwelling. (Note: 1 US $ = 20 Baht).

The practice in this country is to separate wastewater from soil waste which will be in most cases treated by septic tank system in towns and cities.

In the rural areas, pit privies and water-carried latrines are the most prevalent. A typical Northeastern Region village, may be represented by Nong Hai in Ubol Rachathani, which has a total population of about 1600 and 236 households. There are 139 shallow wells, 37% of which are more than 100 meters from the houses. The number of households with latrines is only 26%. It would seem therefore that the immediate problems of many rural communities of Thailand should be the provision of latrines as well as the problems of water suplly.

However, as far as wastewater treatment and disposal are concerned, a number of research works and programme implementation have taken place which might be appropriately mentioned as follows:

4.1 Anaerobic Filters

Anaerobic filters have been shown to be very efficient for many kinds of organic industrial wastes with extremely high BOD loadings. The College of Engineering, Chulalongkorn University, through its Department of Sanitary Engineering, has been studying for more than 5 years in research and development concerning anaerobic filters for the treatment of agro-industrial wastewaters, notably the tapioca starch waste (Annex 3) the sugar mill waste (Annex 4), and the wastewaters from such canning factories as pickled vegetables canning and bean curd canning. Recently, Supavong (1978), completed a research study concerning the use of anaerobic filters for the treatment of septic tank effluent. It was found that with as shallow as 0.5 to 1,0 depth of filters using crushed stones with size between 25-50 mm. as media, up to more than 85% and 75% BOD and COD removals respectively can be achieved, provided that the hydraulic loading and the detention time do not exceed 2 cum/ sqm-day or less than 6 hours respectively. (Annex 5). In fact, anaerobic filters have been used for treating septic tank effluent in this country for more than 30 years, but without known systematic study.

4.2 Anaerobic-Aerobic Ponds

Anaerobic-aerobic ponds system has been widely used for agro-industrial waste treatment in this country. The detention times for anaerobic ponds vary between 1-2 weeks whereas for aerobic ponds will be between 2-4 weeks. Anaerobic ponds were usually deeper than aerobic ponds and could be as deep as 3-4 meters. The effluent from this system of treatment usually had low BOD values, but there were problems associated with the production of algae in the aerobic and polishing ponds. Fish usually thrive in those ponds suggesting the possibility of pisciculture, although no systematic study had been carried out in this country. This method of treatment should also be suitable for wastewater treatment for the whole village in the rural areas. Incidentally, there are few housing estates in Malaysia using methods similar to this quite successfully.

4.3 Energy Production from Waste

The interest in waste treatment has recently assumed ne dimensions especially after the oil embargo and the energy crisis in 1975. The re-use concept of wastewater treatment gains wider attention than in the past. One of this re-use aspect is the energy production from waste.

The use of anaerobic digesters for the production of bio-gas has been practised for a number of years, notably in China and in India. The Department of Health, the Ministry of Health, Thailand, has conducted study and research in bio-gas production plants including the installation of a few plants in various villages for use with cattle manure. From the Advisory Leaflet on Bio-Gas Production from Manure published by the Division of Sanitation, the recommended digester can be constructed with masonry or concrete with diameter and depth varying according to the amount of manure available. The digested manure can be dried on a drying bed consisting of 0.2 meter gravel with 0.30 meter sand on the top. Other features are as constructed in the conventional practice.

Skulbhram(1978, Anexx 6), on the other hand, recommended two types of bio-gas digesters, one circular and the other a square one with smaller dimensions. Both plants were constructed and tested with the China Medical Board Research Fund in the Chitlada Palace Ground with H.M. the King's gracious permission. The tests conducted were of some interest since the manures used were those from milking cows and elephants, and the gas produced was used for cooking as well as for refrigeration. The results showed less gas from elephant manure compared with cow manure. Some interesting data are reproduced as follows:

Properties of mixtures of manure and water at the beginning

	Cows	Elephants
Specific gravity	1.0205	1.0545
pH	6.8	7.3
Total solids(gm/l)	71.2	78.2
Volatile solids(gm/l)	57.3	41.3
Fixed solids(gm/l)	13.9	36.9

Properties of the bio-gas

	Cows	Elephants
CH_4	28.2	48.1
H_2S	0.03	-
CO_2	24.8	41.0
O_2	10.8	1.8
H_2	0.2	0.4
N_2	35.97	8.7

Both plants are of continuous loading type. The costs of construction for the circular plant with cum capacity was B/ 3,700 and that for the square plant with 1.1 cum was B/4,200. The gas production were 2,200 litres and 1,100 litres for the former and the latter respectively. These were more than sufficient for cooking purposes which required only about 440 litres per day. The rest of the gas could therefore be used to operate a refrigerator or other food storage devices or food preservation devices.

4.4 Wastewater Treatment with Water Hyacinth

An experiment was carried out (Chujaval,1977) with pilot scale water hyacinth ponds. It was found that the ponds with water hyacinth can evaporate 5.8 as much water as the ones without. Ponds with water hyacinth also demonstrated consistently the ability to remove both BOD and COD slightly better than the ones without(the difference being about 5-6 per cent for BOD and COD loadings of about 14 and 10 lbs/1000cuf-day), but in terms of nitrogen and phosphorus, ponds with water hyacinth showed much higher percentage removals, indicating the possible use of water hyacinth for tertiary treatment.

The problems associated with water hyacinth ponds probably lie in the creation of possible breeding grounds for mosquitoes, and the tedious task of harvesting, since water hyacinth has been known to multiply at a tremendously fast rate and capable of doubling its own size in within one week. The use of water hyacinth as animal feed, especially feeding to pigs, has been practised in this country for a long time.

5 Research Organizations

The National Research Council recently conducted a survey of governmental organizations including governmental enterprises participating in scientific and technological research. The Report showed that there were 94 and 24 belonging to the former and the latter catagory respectively(The National Research Council, 1976).

The National Research Council itself has 10 committees on various branches of research, namely, physical sciences and mathematics, medical sciences, chemical sciences and pharmacy, agriculture and biology, engineering and industrial research, philosophy, laws, political science and public administration, economics, and social sciences. The main financial assistance for research projects and the normal operation of the Office comes from the annual government budget. The Thai Government also sponsors research projects in other ways, such as direct budget allocation to various organizations mentioned above and also to some special projects urgently needed by the communities. Funds for research are also available on occasion from international and bilateral agencies, and foundations

6 Recommendations

As far as organizational arrangement is concerned, there is at present no organization responsible directly for engineering and technical research for rural health. This results in the lack of integrated research aiming at solutioms to many health problems of the rural population. In this respect WHO can play a very important role in promoting the interest of its member countries in appropriate technology for rural health and to set up national coordinating centre vested with the responsibility of initiation, promotion coordination, and advice on research and development. On regional scale, a regional net work can be set up to coordinate research and development and to act as data bank within the region,.

Research into the social and technical aspects of provision of latrines to the rural population should have a high piority equal to the continued effort in water supply and wastewater treatment, but emphasis should be given to the re-use concept of waste treatment, in particular the feasibilty of food production and energy production from wastes.

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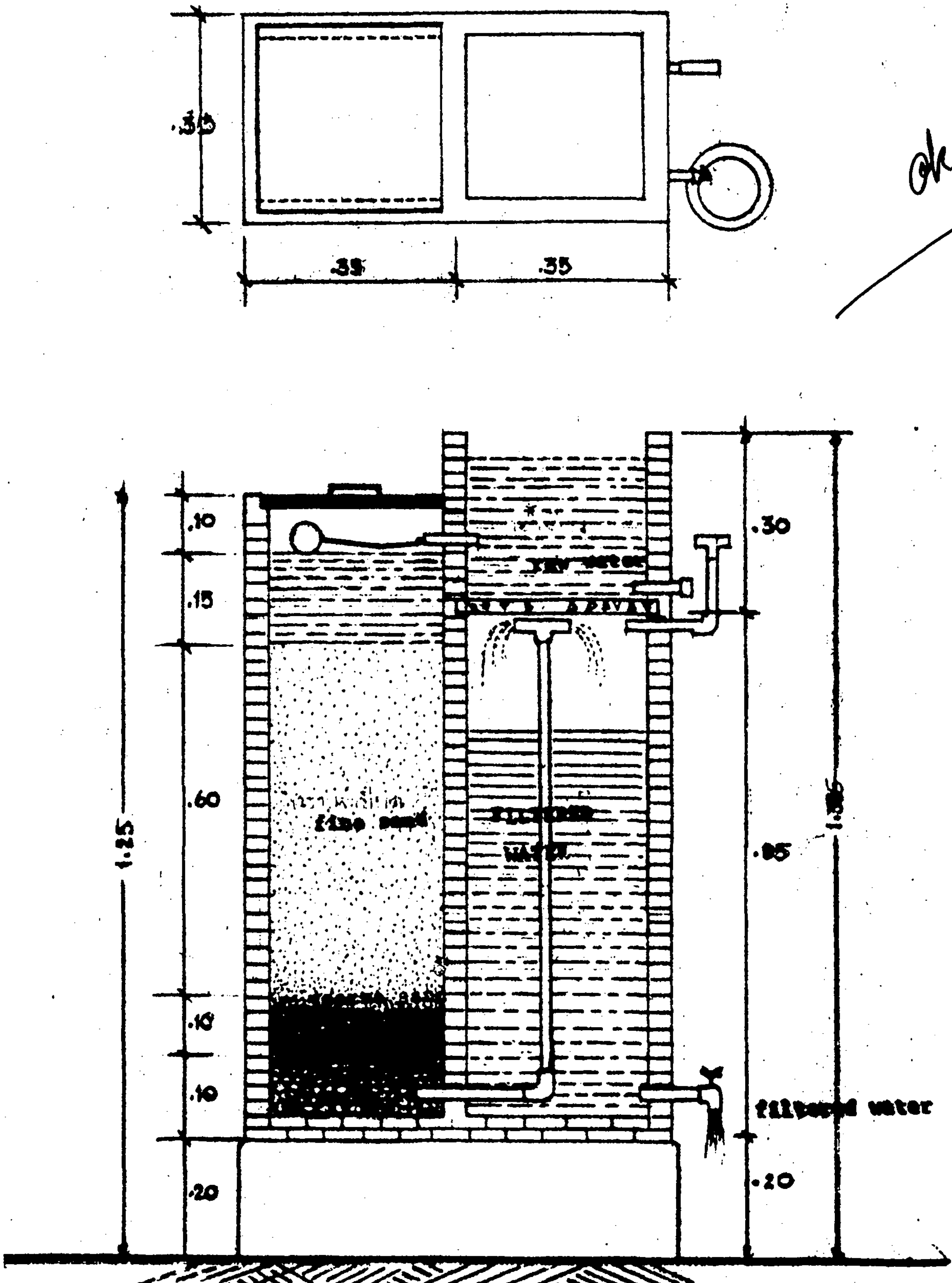
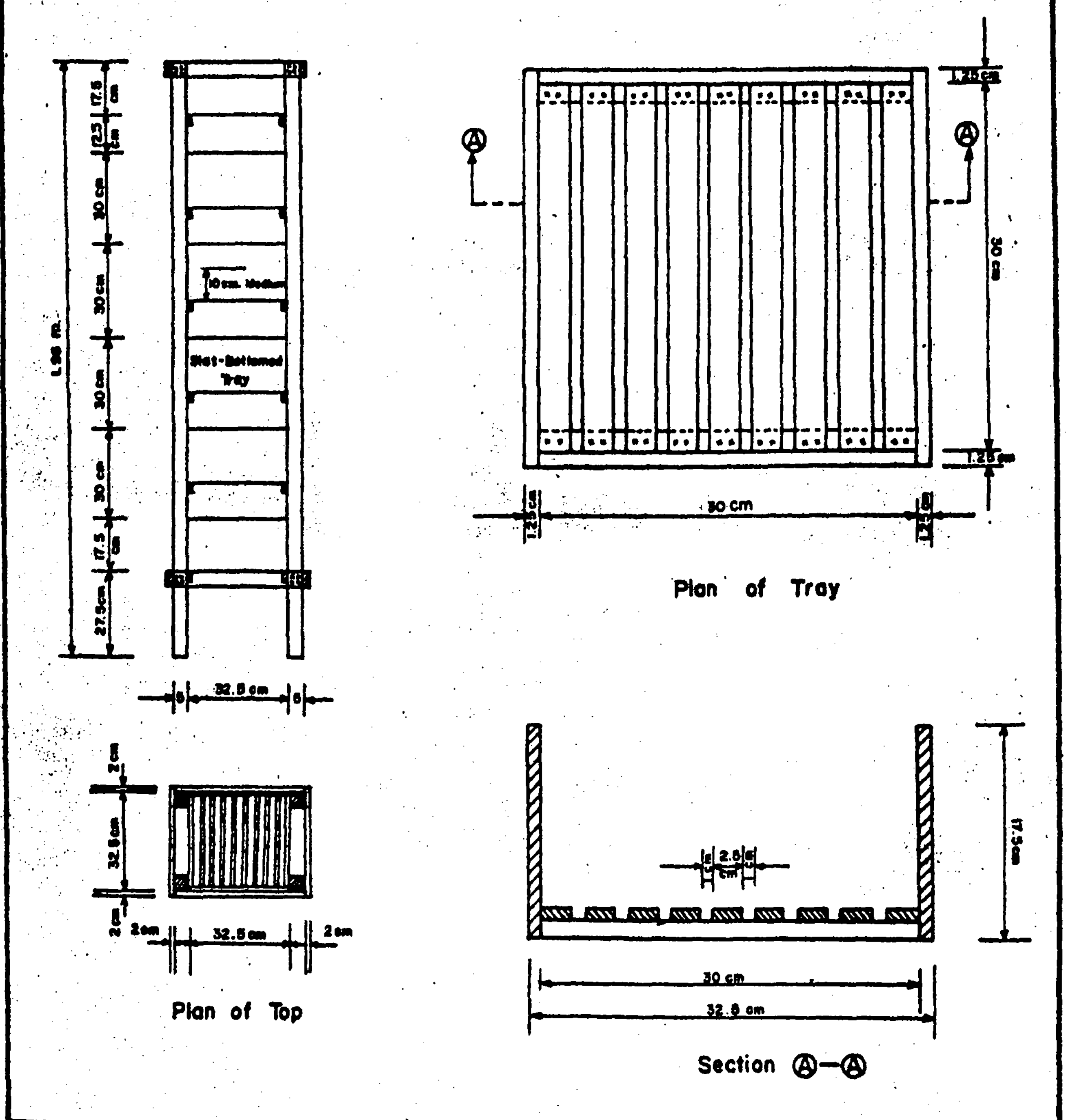
10 Supavong, B,(1978) The Use of Anaerobic Filter for the Treatment of Domes Domestic Wastewater, M.Eng. Thesis, SED, College of Engineering, Chulalongkorn University, Bangkok.

After P. Li[illegible]



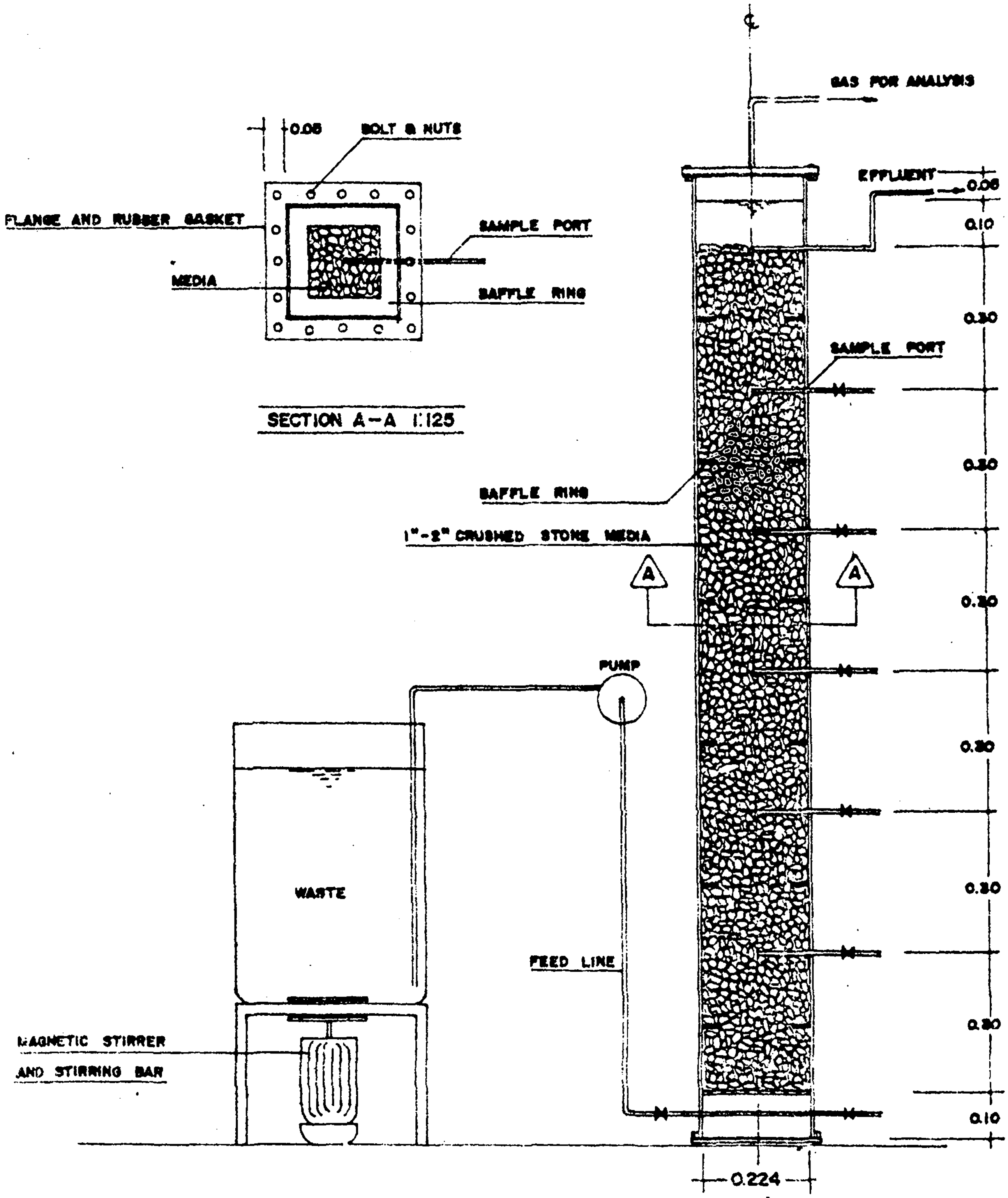
HOUSEHOLD SAND FILTER

รูป .... เครื่องกรองแบบที่ 2



—Details of Plant—Scale Aerator

After S. Limrat



SCHEMATIC DIAGRAM OF ANAEROBIC FILTER AND FEED SYSTEM

After S. Saipanit

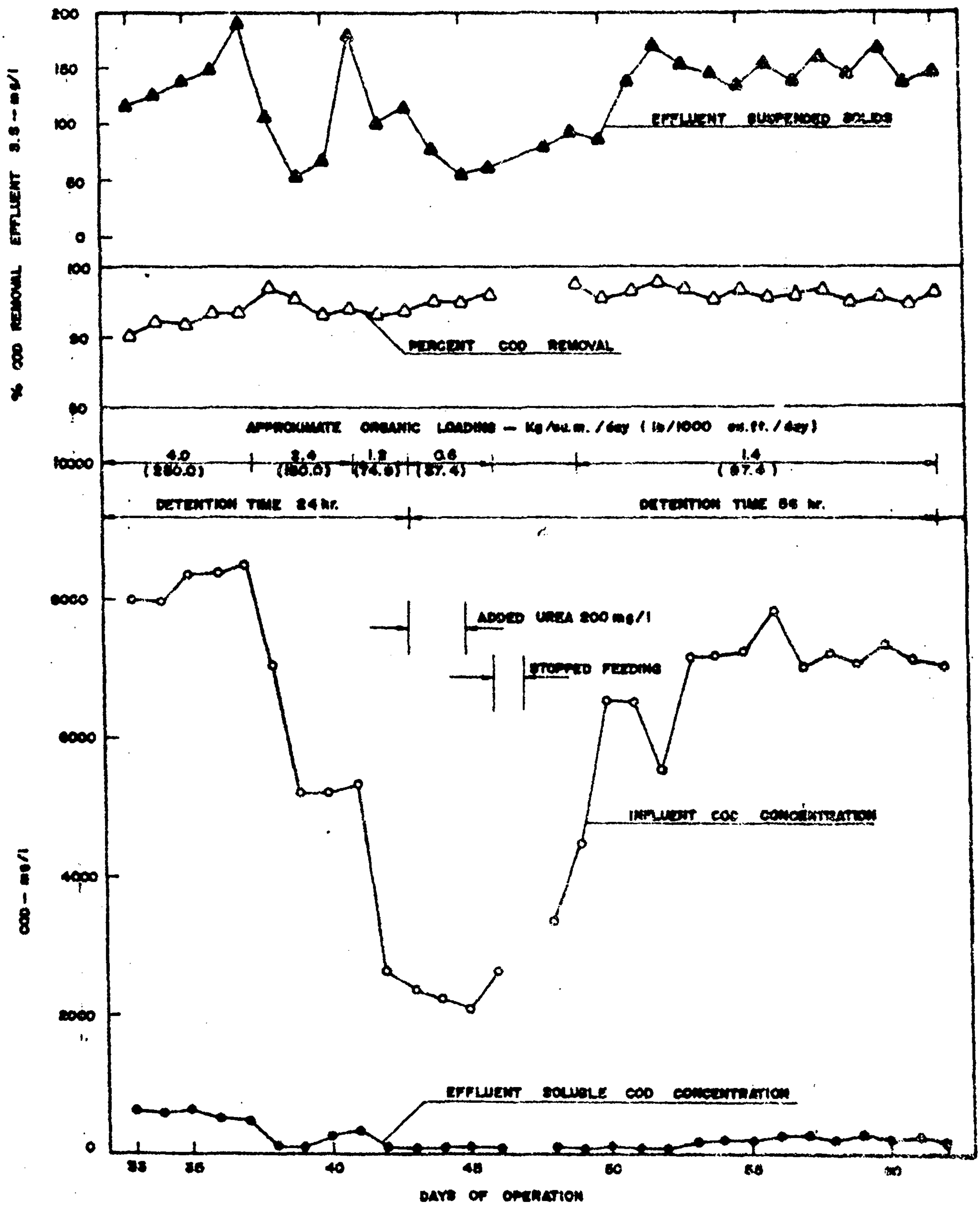
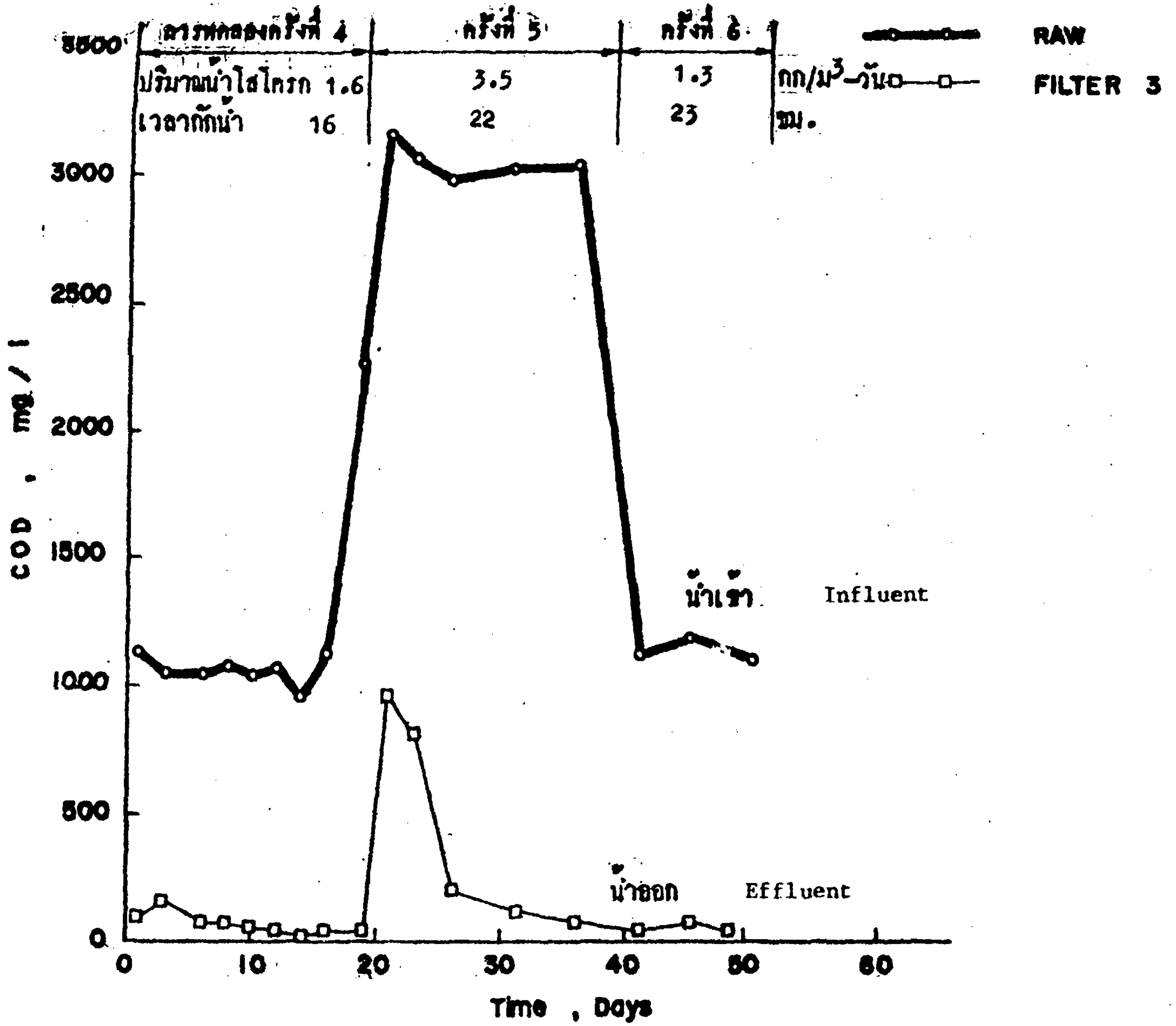


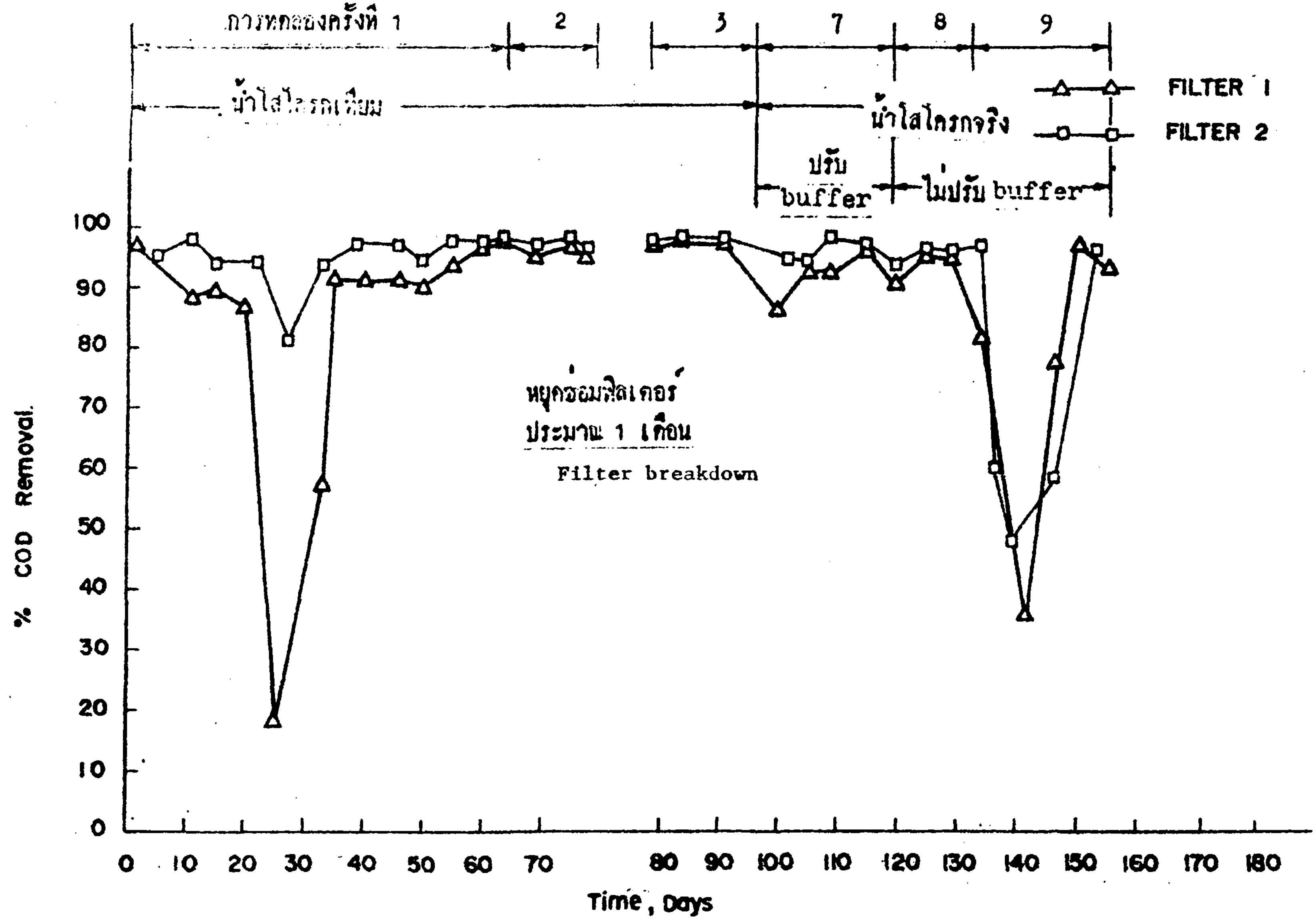
FIGURE 23. DAILY PERFORMANCE OF THE FILTER UNDER RAW WASTE CONDITIONS

After S. Saipanit



ภาพที่ IV-2 ซีโอดีของน้ำที่เข้าและออกจากฟิลเตอร์ 3 ภายใต้สภาวะต่าง ๆ

COD of Influent and Effluent After Pornprapa and Tuntoolves



ภาพที่ IV-25 เปอร์เซนต์การกำจัดซีโอดีโดยใช้แอนแอโรบิคฟิลเตอร์ 1 และ 2 ต่อกันอย่างอนุกรม

COD Removal with Filter 1 and 2 in Series After Pornprapa and Tuntoolves

ANNEX 5 5.1

After Supavong

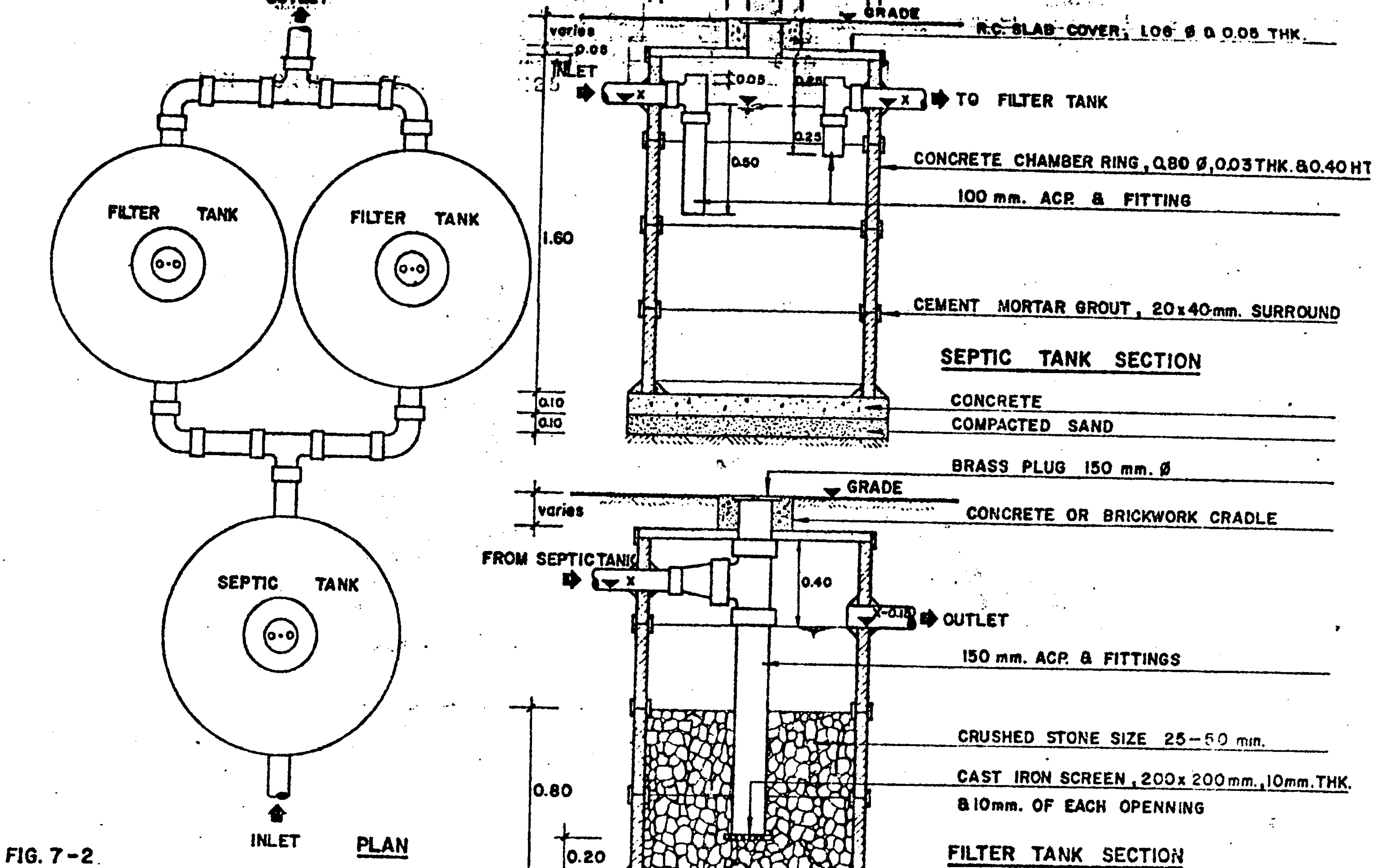


FIG. 7-2

SEPTIC & FILTER TANK FOR HOUSE SEWAGE | 1:25

ANNEX 6 6.1

BIO- GAS PLANT

After Skulbhram

ชุดเครื่องหมักแก๊สชีวภาพจากมูลสัตว์

ณ. โรงโคนม สวนจิตรลดา

สร้างทูลเกล้าถวาย ฯ

โดย

คณะสาธารณสุขศาสตร์ มหาวิทยาลัยมหิดล

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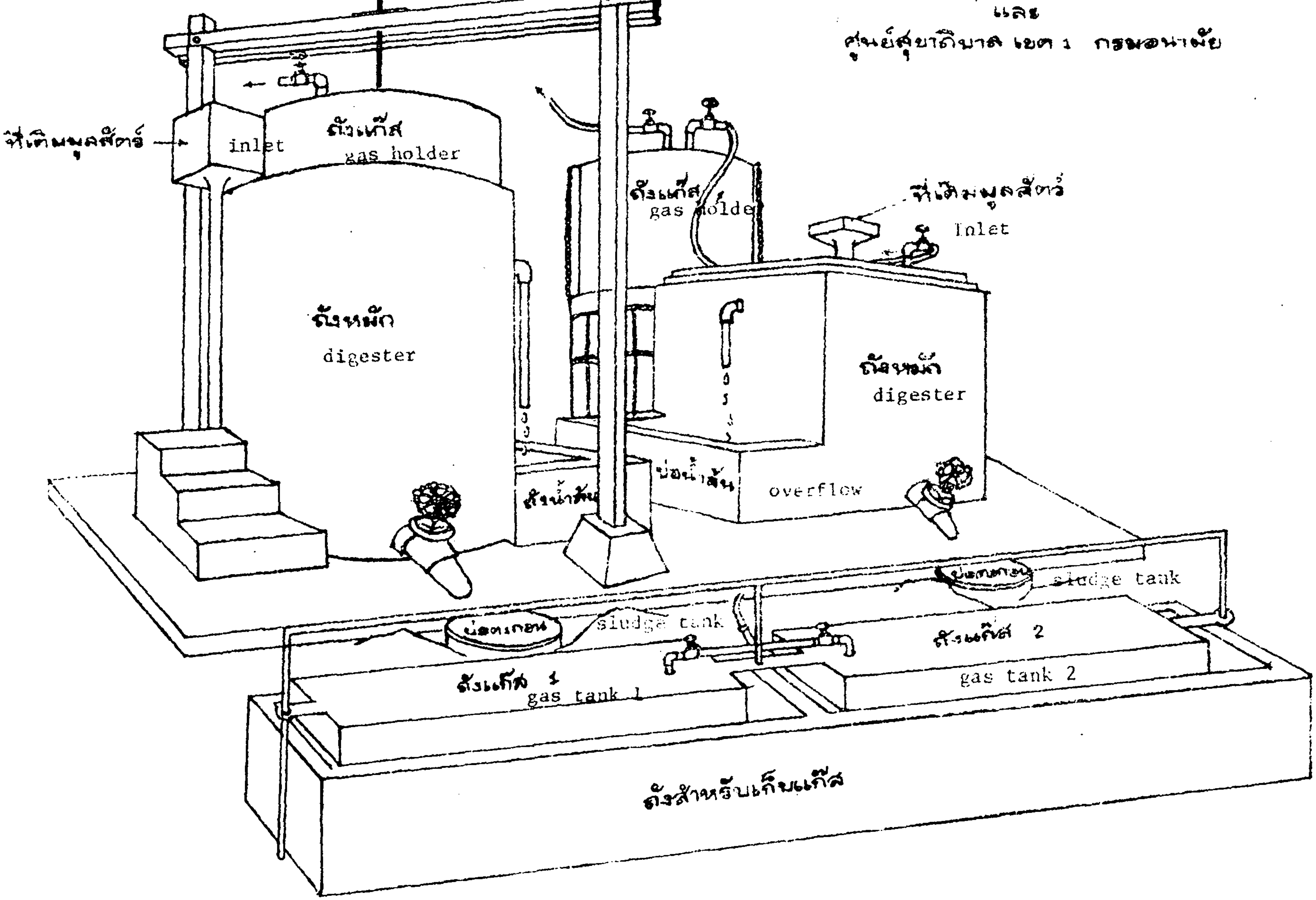
ศูนย์สุขาภิบาล เขต 1 กรมอนามัย



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WORLD HEALTH ORGANIZATION

REGIONAL OFFICE FOR SOUTH-EAST ASIA

Research Study Group Meeting on Appropriate Technology for Improvement of Environmental Health at the Village Level, New Delhi, 16-20 October 1978

Restricted

SEA/EH/RSG Meet.1/4.4a

10 October 1978

ENVIRONMENTALLY COMPATIBLE WATER SUPPLY AND WASTE UTILIZATION SYSTEMS FOR DEVELOPING COUNTRIES

By

Ok, deserves support!

B.B. Sundaresan

NWL!

questions:
- very sound idea, manageable on VL?; for cluster of villages or small towns!
- def. ~~option~~ comm.-popul. range to which applicable

5560

ENVIRONMENTALLY COMPATIBLE WATER SUPPLY AND WASTE UTILIZATION SYSTEMS FOR DEVELOPING COUNTRIES

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National Environmental
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...

INTRODUCTION

[redacted] in environmental health programmes should be [redacted] safe, [redacted] and scientifically sound, [redacted] compatible, economically viable, socially and culturally relevant and acceptable. Water supply and sanitation programmes in developing countries which are currently being undertaken meet these requirements only partly. Imbalances have become visible in several environmental health programmes in communities, even though heavy investments have been made in rural water supply and sanitation systems. The situation would get further aggravated if projects and programmes are implemented in isolation without suitable inter-linking and integration for optimum utilization of resources.

Wastewater treatment and the disposal systems are given a low priority in developing countries due to the high cost involved. The present method of providing water supply without adequate provision for collection, treatment and disposal of wastewater is harmful from public health considerations as well as maintaining a clean environment.

Cess pools of wastewater around community taps, streets and houses in small communities are a potential health hazard.

WASTE AS A RESOURCE

Wastes generated either in liquid or solid forms should be considered as a resource, as appreciable amounts of nutrients in the form of nitrogen, phosphorus and potash are present. An ecologically balanced system would put back the nutrients present in the wastes into the natural cycle. Recycling through aquaculture, agriculture, groundwater recharge and reuse should be considered as relevant for adoption in small communities. Sewage/sullage water contains about 60-70 mg/l nitrogen, 20-25 mg/l of phosphorus and 40-45 mg/l of potash. Total quantity of wastewater generated in rural India at the present rate of water supply (as per 1971 census) is about 40,000 million liters/day which, in turn, would be releasing about 2400, 800, 1600 tonnes/day of N, P & K respectively. This would further get increased under accelerated rural water supply programmes. Utilizing this resource will help the community considerably but inaction will result in environmental degradation, leading to public health problems.

Solid wastes generated in such communities are allowed to pile up without utilising this resource for recovery of either energy or nutrients. Garbage generated from households and farm-yard wastes have sufficient nutrients which could be put back into the ecological cycle with simultaneous recovery of energy and nutrients.

HEALTH HAZARD

An indication of the harmful effects of improper collection, treatment and utilization of the wastewater from such communities is revealed by the substantial increase in the population at risk of filariasis in India (Table 1)[1].

TABLE 1 - Comparative Figures of Population at Risk of Filariasis in India

Year	Population in millions
1953	25.45
1962	64.53
1967	121.81
1970	136.28
1975	136. 3

Harmful effects of unhygienic disposal of waste-water and excreta may not be noticeable in sparsely populated rural areas. Semi-urban growth centres with population in the range of 5000 to 20,000 are essentially rural in habitat formation but densely populated. In some countries communities with a population of 5000 and above, are grouped under urban centres. Growth centres with population in the range of 20,000 to 1,00,000 are marginally located around urban centres but the population is ill-prepared and under-equipped for urban living. Depending upon the growth potential, these centres grow in size with ill-equipped houses, badly formed roads, inadequate water supply and unsightly sanitary conditions.

Planners and administrators give water supply top priority and rightly so, due to the visible plight of the people and their clamour for drinking water. The waste-water collection, treatment and disposal systems are not contemplated initially and may not even be planned for the next three or four decades. The mid-decade progress report of WHO, SEARO (1977) indicates the situation in India and South East Asia region (Table 2). As against 19 % of rural population provided with reasonably safe water supply, only 6 % is provided with adequate excreta disposal as of 1975[2]. Under accelerated rural water supply programme, the disparity will become wider.

INTEGRATED SYSTEM

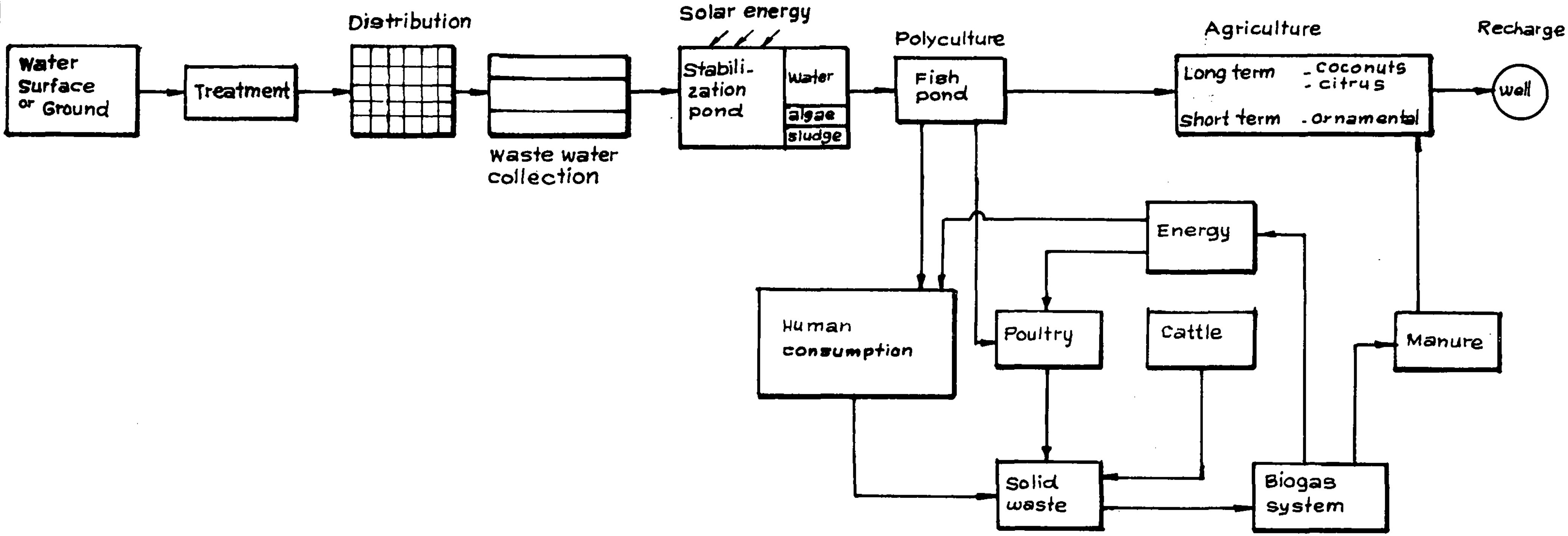
An integrated water supply - wastewater collection & utilization - energy recovery through biogas - composting - nutrient recovery and use through aquaculture and agriculture - has thus become an imperative need for such communities, whether rural or semi-urban growth centres. Planning for water supply in isolation is no longer relevant. An environmentally compatible and well integrated system thus becomes appropriate for urgent consideration.

A conceptual system has been outlined in Fig. 1. Sundaresan et al have demonstrated in a series of pilot plant studies at Madras and Nagpur, India, treating sewage in waste stabilisation ponds utilising solar energy, using the effluent for fish polyculture yielding a production of 11.5 tonnes/hectare/year and further use of effluent for coconut palm cultivation[3]. This becomes relevant where the environmental conditions are favourable for waste stabilisation and fish ponds as well as agriculture. In South East Asia region suitable modifications could be made for different species of fish or different types of crops to suit local needs. The additional income generated from such an integrated system would more than offset the operation and maintenance costs of the plant, in addition to combating environmental pollution. When such a system is adopted for small communities

TABLE 2 - Population Provided with Adequate Water Supply and Excreta Disposal in India and South East Asia Region

	INDIA				SOUTH EAST ASIA			
	1970 in million	%	1975 in million	%	1970 in million	%	1975 in million	%
URBAN								
Provided with water supply	66.30	60	107.00	80	75.75	50	127.50	69
Provided with sewer system	40.00	36	45.5	34	42.42	28	48.16	26
RURAL								
Provided with reasonably safe water supply	25.00	67	8.60	18	63.41	9	145.12	19
Provided with adequate excreta disposal	5.0	1	8.70	2	25.08	8	8.70	6

Source : Community water supply and wastewater disposal - Mid-decade Progress Report, WHO, SEARO Series, No. 4 (1977)



INTEGRATED ENVIRONMENTALLY COMPATIBLE WATER SUPPLY AND WASTE UTILIZATION SYSTEM the social benefit accruing out of the improved health status would further add to its value. The system is technologically and scientifically sound, economically viable and hygienically safe. The social and cultural acceptance of such a system should now be field-tested.

TECHNOLOGY TRANSFER

[illegible] effort along with technology transfer [illegible] in this area in select centres in South East Asia region where such systems could be introduced. The selected centres shall have protected water supply through surface or underground source, simple waste water collection system with open drains and ecologically balanced treatment and utilisation system for wastewater. In addition, individual or groups of biogas plants to adequately recover and use the energy source from dung, garbage and farm waste could be integrated in the system. An integrated project for field testing has now become necessary in order to make it socially and culturally acceptable and also dessiminate the technological innovations for wider application.

[illegible] education should form an integral part of the programme in order to prepare the population for accepting such systems as their own and for their benefit. Village demonstration programme on slow sand filtration has been undertaken by NEERI under the sponsorship of WHO/IRC, The Hague. Major part of the cost of slow sand filters, distribution system through public standposts is met by the local community and the State Government. Marginal inputs for construction of slow sand filters and scientific and technical back up is being provided by WHO/IRC through NEERI. Health education has been suitably incorporated even before the commencement of project construction in order to prepare the population on the beneficial effects of safe water supply and improvement in the health status. The operation and maintenance will be undertaken by the local community leaders. The response from four villages in four different States of India has been encouraging. This can now be extended to include the wastewater collection and utilisation systems.

The research component of such projects would involve studying this programme in greater detail for scientific harvesting and marketing of fish which will be hygienic, assessing the improvement in the health status of the communities, quantifying the nutrient and energy recovery, economic assessment of agricultural production, operation and maintenance techniques and acceptance by the population. The benefit cost analysis and optimizing the various system components would form part of the study.

METHODOLOGY

In South East Asia region, about 10 village centres could be identified, which have come under one or more of environmental health programmes. The sites should be representative of geographic character, agricultural and aquaculture practices, water resource potential, in addition to size of population and developmental stage. In each one of the demonstration centres, the present environmental health programme and its impact on the community should be assessed. The real need of the population in terms of water supply, excreta disposal, solid waste utilization and energy requirements should be categorised and an integrated system planned. It is likely that these ten centres are at different stages of development and requirements for an integrated system may vary. However, in each centre the integrated system should be representative of the requirements of the sub-region.

The cost for such an integrated system could be worked out and methods of funding outlined. The total cost of the programme for each centre should be suitably apportioned to the village, local and central governments as well as WHO and other UN funding agencies. Multi-disciplinary and multi-institutional approach should be emphasised. Elected or representative leaders of the local community should be effectively involved at the time of planning, construction and operation.

In order to select the sites and identify the organisations for involvement, an expert panel consisting of specialists in the area of environmental health, agriculture, aquaculture, sociology, economic analysis and environmental engineering should be constituted. This panel should visit possible sites, have dialogue with local governmental agencies as well as village officials and make an outline proposal detailing the work programme, cost and identify institutions and organisations to be involved for each centre. Cost benefit aspects should be indicated.

On the basis of the panel report, the first phase of the work programme could commence and agencies to be involved may be identified. An outline of time bound field demonstration programme could then be initiated as below :

Project Duration

Phase I

Constitution of expert panel	...	4 months
Visit and project preparation by expert panel	...	4 "
Negotiations with institutions and other UN agencies and programme finalisation	...	4 "

Phase II

Village Demonstration Programme

Site selection & preliminary work	...	6 "
Briefing participating organisations	...	6 "
Construction	...	1 year
Operation, maintenance & assessment	...	2 years
Total -		5 years

only here!

EXPECTED RESULTS

In each one of the sub-regions, the problems of technology transfer, social acceptance and economic viability would come under sharp focus. Total estimated costs for the sub-region for integrated systems could be assessed for wider application. Environmental health programmes planned in isolation for water supply, waste disposal and control of communicable diseases would be costly besides non-recovery of resources for beneficial purposes. Quantification of energy and nutrient recovery in each sub-region will prove to be attractive for wider acceptance by planners as well as local communities. Social benefits by improved health status would become visible to act as catalyst for further action in the sub-region. It is no longer valid or prudent to postpone waste disposal systems as they are costly and uneconomical for rural communities. Diseases could no longer be controlled or health status improved by mere provision of protected water supply. Control of a few water-borne diseases alone does not result in improved health status. The programme would ultimately lead to meaningful cost estimates for improving the health status of rural communities.

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Integrated Approach for Water Supply and Sanitation in Rural Areas with Multiple Water Sources (Spot Tubewells and Dug-Wells fitted with Handpumps)

By

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The opinions expressed in this paper do not necessarily reflect those of the World Health Organization

1. Introduction

More than eighty percent of the population in South East Asian Countries live in rural areas. India is the largest country in the region with 438 million people (64.7% of the total rural population in SEAR) in rural areas spread over 564,718 (1961) villages. The population in these villages vary widely from less than 500 to over 10,000 and the distribution of villages by population is shown in Table-1.

Table-1: Distribution of villages by population in India (1961)

	Village Number	Percentage	Population	
			Millions	Per cent
Less than 500	349 568	61.8	75.26	20.9
500 - 1000	119 197	21.1	83.84	23.3
1000 - 5000	92 784	16.4	165.90	46.1
5000 - 10000	3 396	0.6	22.18	6.2
Over 10,000	773	0.1	12.50	3.4
Total	565 718	100	359.68	100

About 19.4% of the rural population in the Member states have reasonable access to safe water supply[1] and only 5.5% have adequate disposal of human excreta. In India available information suggests that 64,000 villages covering 10% of rural population have been provided so far with drinking water supply systems and only about 1.8% have adequate excreta disposal systems[2]. These percentages are however further reduced due to improper and inadequate maintenance of water supply systems and complete lack of follow-up programmes for maintenance of excreta disposal systems.

Although during recent years, the development of water supply in the region has been accelerated by more than 2.3 times and that of excreta disposal by 1.7 times, still the coverage has been deplorably inadequate. In thickly populated countries like India and Bangladesh, the progress of excreta disposal is far lagging behind the progress of water supply. In Sri Lanka development of excreta disposal system is closely following development of water supply systems. In Thailand development of excreta disposal systems is ahead of development of water supply systems. In India although

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sanitation was an integral part of national water supply and sanitation programme during the past five plan periods, the emphasis was mainly on rural water supply and as such no concerted efforts were made to improve rural sanitation. Besides water supply and human excreta disposal, practically no measures are taken to improve other aspects of rural sanitation viz. waste water disposal, animal waste disposal etc. in order to achieve an overall improvement in rural environment. Many of the countries in the region are still focussing their attention mainly on water supply, understandbly due to limited resources. Hence, by and large, the status of environmental health in rural areas in South East Asian Region still remains at a low level and much is desired to be done to improve the environmental conditions.

2. Integrated Approach Needed

Experience in India and elsewhere, has shown that provision of safe drinking water supply alone will not reduce the incidence of gastro-intestinal diseases appreciably. Provision of safe drinking water and safe disposal of human excreta simultaneously, as well as an overall improvement of general sanitation and personal hygiene are essential to prevent incidence of gastro-intestinal and diarrhoeal diseases. Hence, an integrated approach for development of water supply as well as sanitation is a sine-qua-non for improvement in health status of rural population.

3. Water Supply Systems in Rural Areas

In vast countries like India, where geological, geographical and climatological conditions vary widely, different types of water supply systems will have to be developed. Where ground water is available at reasonable depths, in sufficient quantities and of satisfactory quality, it is the preferred choice as the source. Surface waters needing treatment facilities is used only when ground water is either absent or unsuitable. Piped water supply systems with a centralized source, and distribution by means of street hydrants and house taps will cost in India US $ 12 to 30 with a maintenance cost of not less than US $ 2.0 per head per year, which is rather expensive for the rural people, particularly

central org? State level

200*2=400 ₹.

for smaller villages with low agricultural income. Such schemes are also not feasible where yield from the source is meagre and villages are of a scattered development. In India about 44% of the rural population fall in the group of smaller villages ranging in population from less than 500 to less than 1000 covering 83% of the total number of villages. Piped water supply to these villages will be rather uneconomical both from the point of view of capital cost and maintenance cost particularly if electric power is also not available or expensive. Except in case of problem villages and villages in the cholera endemic areas, simple water supply systems with sanitary dug-wells, tube-wells or bored-wells fitted with hand-pumps is the preferred choice for these smaller villages for providing minimum drinking water needs. Such installations will cost about US $ 2 to 8 (Indian rupees 15 to 50) per capita and the maintenance cost of hand-pumps will vary from US $ 2 to 5 (Indian rupees 16 to 45) per tube-well per annum. This system is not only economical but also easier to maintain. The maintenance does not require much skill and the local people could be trained to develop the necessary skill to carry out minor repairs to hand pumps. Hence if set goals are to be reached with the limited resources, multiple-spot source system (tube-wells or wells) fitted with hand-pumps is the only answer, although usage may not be very satisfactory.

In Singur area under the All India Institute of Hygiene and Public Health, small diameter (40 mm), shallow tube-wells of depth up to 75 m, at a rate of one tube-well for every 100 people, located not farther than 50 metres from the farthest house served, is provided. An organization for proper maintenance of tube-wells is also developed.[4] Periodic survey conducted showed that the usage of tube-well is limited to drinking purpose only and only about 2.5 to 5.0 litres per capita per day of water is drawn from the tube-well. Recent health statistics[5] showed that there is no incidence of cholera although other gastro-intestinal and diarrhoeal diseases are still prevalent. Another observation made on the tube-well

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system, developed since three-decades, is that increasing number of tube-wells did not increase the usage of tube-wells proportionately. But the more the number of tube-wells, the lesser are the chances of people using unprotected sources for drinking water. This is because, when the nearest tube-well goes out of order or the pump breaks down, another tube-well in working order could be reached, with not much increase in walking distance. Hence, depending upon hydrogeological conditions and nature of village development, number of persons served by each tube-well could even be less than 100, so that at least there are two tube-wells within a radius of 25-50 metres. Sanitary protection of all wells and tube-wells is of prime importance.

4. Problems of Rural Water Supply

Provision of safe water supply adequate in quantity and acceptable in quality poses a variety of problems which differ between regions and most often within the region of the country depending on the hydrogeological conditions. These problems may be broadly classified into three catagories, viz: (a) Managerial & Maintenance, (b) Financial, (c) Techological. To this may be added problems relating to sociological and cultural factors:

(a) Managerial & Maintenance Problems:

Multiplicity of agencies employed on the rural water supply programmes as in India, operates as a handicap in the effective implementation of the rural water supply as well as Sanitation Programmes. It diffuses the efforts and reduces cost-effectiveness. A unitary agency, State Health Ministry with a separate department with trained environmental specialists should have the control over the entire field of activity. Planning should be carried out at the district level with the Zilla Parishad (district elected body) being involved. The community must be involved in sharing the cost either in kind or coin and the local panchayat (village level elected body) should take the initiative in mobilising community participation both in providing a water supply system as well as in its maintenance systems involving choices by the users themselves and an analysis of the risks they are willing to take, weighed against the benefits they feel they will receive, are more likely to bring them, lasting results. The State Public Health Engineering departments should design and execute all rural water supply projects. Investigation and monitoring cells should be set up to survey the existing status and to evaluate the progress from time to time. National policy and strategy for future development should be clearly defined, giving high priority for environmental health in rural areas. A perceptive planning to develop time-bound programmes to reach the set targets should be adopted.

Lack of preventive maintanence is the major cause for break-down of hand-pumps and tube-wells. At the village level, Panchayats with a few trained volunteers should be able to carry out routine checks, lubrication and minor repairs such as replacement of bolts, nuts and leathers-cup etc. At the Block-level (alternately Primary Health Centre), a trained mechanic, should be placed in-charge of 200-250 tubewells (number should be decided on the type of pump and the scatter of villages & communication), who should carry out major repairs to hand-pumps (replacement of tie rods, cylinder valve etc) and also resink derelict tube-wells in the area, with people's participation. At the Distric Level, under the Public Health Engineering Division, mobile squads should be set-up to attend to emergencies and to carry out more difficult type of repairs and renewals which the block mechanic is unable to attend. Adequate spare parts should be stored at all levels. The cost of maintenance could be met out of people's contribution on a pro-rate basis. There should be one supervisory staff for every 1000-2500 tube-wells with hand-pump in each sub-division.

3 tier-system

(b) Financial Problems:

Financial constraint is a major bottleneck in rural water supply and sanitation. However with the integrated development of rural areas leading to economic progress, the situation will slowly and steadily ease-out. But the time-lag may be so long and unpredictable that one cannot sit idle without further attempts to solve the financial stringency. In India a number of schemes for financing water supply and sanitation projects are already envisaged and implemented. First and foremost action needed is the pooling of all resources and proper collection of funds. Secondly involving public financing institutions like Life Insurance Corporation and Nationalised Banks. Thirdly, setting up of state or regional Rural Water Supply and Sanitation Boards to mobilise resources and implement schemes. Fourthly, assistance from international agencies such as I.D.A., UNICEF, W.H.O., World Bank etc. could be sought for an accelerated programme. Lastly, maximising community participation, so that the same money spent out of public funds, more people could be served.

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(c) Technological Problems:

There is no dearth for methodology for solving many of the rural water supply problems. But known technology is either inapplicable to a local situation or uneconomical or does not meet the aspirations of the local people. Hence what is needed is, development of more appropriate forms of technology, that would be low cost, labour intensive, use local materials, be easy to operate and maintain, and fit harmoniously with local values and preferences. This is required not only in rural water supply but also in rural sanitation. Many examples could be cited where appropriate technology is already developed. Manually operated techniques for sinking shallow tube-wells in deltaic areas where soil is sandy and clayey to great depths, is more appropriate than power operated rigs. Hence both sludger method and water-jetting method are not only economical but also labour intensive as practiced in India and Bangladesh. In Singur area shallow tube-wells are now fitted with hand-made (coir-wound) strainers, which are cheaper than machine made metallic strainers. Resinking of such tube-wells does not also need any workshop facility and reconditioning of strainer costs only US$ 0.50 to replace damaged coir-wire as against US$ 5.00 for replacing metallic wire-mesh.

There is scope to develop appropriate technologies for solving many of the problems still existing in rural water supply. Some important problems for which Research and Development in appropriate technology are necessary is suggested below for consideration by the expert group.

(d) Research & Development Needs:

(i) Simple and economic treatment methods for treatment of surface waters available in open tanks, ponds and canals for rural water supply. Suggested methods of roughing-fitters, built-in slow sand filters, and infiltration galleries in tanks and canals require study and evaluation.

(ii) Sanitary dug-wells form the major spot-sources of drinking water in rural areas. The conventional method and materials of construction are still costly and not within the reach of many small rural communities. Use of non-conventional materials and semi-mechanised methods for sinking and lining the well to reduce cost is needed to cover a wider area. The construction method used in Indonesia with precast concrete lining/casing pipe is worth a trial in other areas, if it proves more economical.

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(iii) Rain-water collection systems are used in hilly areas for individual home supply. A socio-economic study or a cost-benefit study as carried out in Ghana[7] is needed to determine efficiency of the system.

(iv) Rural piped water supply systems are prohibitively costly because of high cost of distribution pipelines. Use of cheaper but not short-lived materials, preferably locally available, should be tried. Bamboo pipes if locally available hold promise. Indonesia has developed technology in the use of bamboo pipes. Other countries like India, where there is wider scope may well adopt the known technology and develop it further. Treatment of bamboo against the attack by termites by such chemicals that will not contaminate the water carried is to be developed. The methods known so far are not suitable.

(v) Hand-pumps both deep-well type and shallow-well type are widely used in rural water supply. A good deal of research and development is taking place all over the world. A summary of the latest technology development on hand-pumps is presented in the brochure on 'Hand-Pumps' prepared by I.R.C., which is a very useful document for transfer of technology to take place. Although the improved designs like India-Mark II and Bangladesh new No.6 hand pumps are excellent in performance, their costs are still not within the reach of many a poor village community. Still simpler devices like what has been designed by organizations like VITA*, ITG** (plastic pumps, wood pumps, chain pumps) are worth developing in this region. Similarly foot-operated hydro-pump 'Vergnet' developed by African Committee on Hydraulic Studies[8] is worth adopting with suitable modification to reduce cost, with a view to increase usage as less energy is spent by an individual, provided people accept its mode of operation.

(vi) A vital part of a tube-well is the strainer which corrodes and chokes due to various causes, needing thereby replacement which the villagers neither can afford nor take timely action. Research carried out by All India Institute of Hygiene and Public Health (A.I.I.H.& P.H.) and elsewhere on several indigenous materials like coconut-coir, nylon thread wound on non-metallic base pipe has proved their high suitability and low cost while a coir wound on perforated bamboo base pipe is the cheapest; coir wound on plastic base pipe, or hand-made slotted plastic pipe strainer gave best performance. All these hand-made strainers need extensive field testing.

(vii) A continuous chlorinating device, to chlorinate tube-well water as it is delivered through pump-spout is yet to be developed.

(viii) PVC pipes are used as casing pipes for tube-wells both in India and Bangladesh. Problem of extracting pipe and strainer is yet to be solved because of low strength of PVC pipes.

(ix) A number of plastic strainers of different designs are developed commercially. These have to be standardised by scientific performance studies.

(x) A number of simple hypo-chlorinators are developed in laboratory studies. Examples: drip-chlorinators, syphon feed chlorinators, floating bowl chlorinators, carbouy chlorinators, single pot and double pot chlorinators, floating platform chlorinator, inverted bottle-chlorinators. Some are already field tested and found useful. But most of them need extensive field trials and checking suitability for small diameter tube-wells.

(xi) Simple units for removal of iron from water lifted from tubewells by aeration and filtration have been developed. But experience in field testing with such units connected directly to hand-pumps presented problems i.e. not effective for higher concentration of iron above 4 P.P.M., frequent fouling of sandbed, difficulty in washing choked bed etc. besides low rate of filtration (lower than normal rate of hand pumping). Villagers have neither the time nor patience to operate and maintain them. Further studies on various design aspects are necessary

(xii) Plastic pumps, bamboo pumps, wood pumps have scope for private tube-wells in individual homes, as they are delicate and are to be operated with care. Designs should be developed using indigenous materials and tested extensively. Pumps made in Korat (Thailand) is an example of appropriate technology for such a pump.

The pump body and cylinder is made of 50 mm seamless pipe, steel-balls taken from anti-friction bearings are used as check-valves, local leather is used for piston-cups and local hard-wood for the handle. An all bamboo-pump (including poppet valve, check valve etc.) fabricated at Singur (Health Centre) worked satisfactorily as a barrel pump, hence useful in pumping water stored in containers to prevent secondary contamination.

(xiii) Studies to define extent of pollution of existing rural water supplies, especially hand-pump systems, should be carried out in several areas to determine the significance of hydrogeological, engineering, socio-economic and health factors. Reports on such studies are scanty in the literature.

(xiv) A systematic approach to improve methodology of impact evaluation in rural water supplies and to readjust allocation of scarce resources i.e. men, material and money has rarely been applied. Evaluation research in developing countries has been mainly concerned with economic and technical aspects neglecting socio-political, psychological, institutional and administrative issues which in reality seems to determine project impact and effectiveness.

(xv) Domestic portable and package water purification units are yet to be perfected to the level that they are reliable and need simple operation and maintenance. In all these equipments, gravitational flow with automatic hydraulic operation is necessary to simplify operational attendance.

(xvi) Further development of solar pumps, heat-pasteurization of water, ultra-violet disinfection using sun-rays, will widen scope for application in rural water supply.

(xvii) Simple techniques for enumeration of bacteria in rural water supply is an urgent need for effective quality control during emergency situations like cholera outbreaks etc.

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5. Rural Sanitation

Waste disposal is an important aspect of rural sanitation. The four components of wastes produced in rural homes are: a) human excreta b) cattle dung and urine, c) household refuse and cattle shed refuse, d) spillage and waste water from tube-wells and wells and sullage water from the kitchen.

A conceptual diagram of an ecologically balanced waste disposal system in rural area, which results in effective recovery of nutrients to increase food production in the form of organic manure is shown in Figure 1. It also results in conservation of energy by producing bio-gas which can be used for cooking and lighting in rural homes. The system could be tried both on an individual household basis as well as on community basis. In the latter case, community latrines and community participation is the key for the success of such scheme. In the former case, well-to-do families with adequate number of cattle heads can adopt the system. It is obvious that cost of the system will be more economical when installed as a community co-operative venture rather than on a family unit basis. However, return on investment will defray the capital investment in a reasonable period of 4-6 years. The capital cost per cubic metre varies from US $ 140 (Rs.1100) for the minimum size of $2m^3$ capacity bio-gas plant to US $ 52 (Rs.420) for a maximum capacity of $140m^3$.

In India, community latrines are practically unknown in rural areas. Experimental studies conducted in the long-past also proved a failure. Perhaps this may not be the case in other countries in the region. Since life styles and social structure in rural areas are also changing in recent years, it is worthwhile trying once again community latrines in rural areas. Recent experiences in towns has shown that community latrines are acceptable to urban poor.

Bio-gas plants are in usage in almost all the SEAR countries. India has built the largest number (over 50,000 by the end of 1977). The scheme is popularised by Khadi Gramodyog Commission in India. Villagers have come to realise the added advantage of digesting cow-dung instead of either burning directly as dried cakes or by preparing manure in a manure pit, which are the two age-old practices for disposal of cattle-dung and urine in rural India. If a change in attitude and habit of defecation in open fields could be brought about by general and health education measures, community latrines disposing off both human excreta and animal dung in a common bio-gas plant might be the most economical and environmentally compatible system. Such a system may not be readily acceptable in many areas. Where not acceptable, household latrines should be installed. At present, in India, digested pit contents is not recovered as organic manure as in many places. Here again social scientists and health educators should play a significant role to bring about a change in attitude. There is no danger of health hazards if pit contents are allowed to digest for 6-8 months before they are dug up for recovery of manure. Addition of carbonaceous materials (leaves, straw etc.) during digestion of night-soil will hasten digestion and reduce digestion period to 3 months. Temperature reaches above 50°C and all the viable helminthic ova and cysts are destroyed.

From a critical review of the research and extension work carried out both in India and other SEAR countries, a fairly simple and appropriate technology which can be applied with the available local materials and skill for manufacturing and constructing sanitary latrines, suited to a particular local conditions of soil, climate, physiography, culture and customs, is available. What is need is a change in attitude, habit, beliefs and taboos.

(a) Health Education

Both general and health education of the people is essential for the success of a rural latrine programme. Education concerning the negative health effect of the present defecation practices would result in change of habit, in favour of using latrines for defecation. Individual contacts and group meetings with educational aids will prove effective in motivating people to take to latrines.

(b) Organization Needed:

An adequate organizational set up with trained and dedicated personnel is essential for the success of any latrine promotion programme.

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The community development blocks as set up in India, provide the most promising administrative frame-work for this purpose. The State health and public health engineering departments should provide necessary administrative and technical backing and advise and collaborate in the activities. At present neither the Block Oversear (subordinate engineering staff) nor the sanitary inspector in the primary health centre attached to the block have any free time to attend to sanitation work. Hence, additional sanitarians should be provided in each block with full-time masons and helpers to cast latrine plates and pans centrally to area served. Village masons if available could also be utilized for this purpose. In the present system of peripherial health care, one multi-purpose health worker incharge of 5000-10000 people and one community health worker for every 1000 villagers are available under the primary health care scheme. These two auxiliary health workers working at grassroots level should be made responsible for community participation in the programme and to coordinate the activities of community block, primary health centre and public health engineering department. Community health workers should also be made primarily responsible for follow up of completed latrines to ensure usage and maintenance.

(c) Financial Assistance:

Experience in working out latrine programmes in India has shown that at present stage of development when there is hardly any urge from the villagers to provide latrines in their homes, some sort of a subsidy should be provided as an incentive. The subsidy however should be restricted to meeting the cost of essential parts of a latrine such as pan and trap and pit-cover only. Studies elsewhere has shown that offering subsidies to latrine programme acted as a deterrent factor. For the programme under the balanced ecological scheme for disposal of wastes as discussed earlier, capital assistance in the form of grant-in-aid from Government and loan facility from nationalised banks should be provided. Under the bio-gas scheme of the Ministry of Agriculture, Government of India, 20-25% of the cost of plant is subsidised. Besides, a loan of US $ 37 (Rs.300) per compost-pit and US $ 50 (Rs.400) per sanitary

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latrine is arranged through the banks. The scheme can be modified and channeled through community development blocks for wider coverage.

Hence the time is now opportune to tackle the problem on a national scale by launching a crusade like the Smallpox Eradication Programme. In this effort, developed countries should come forward to offer any form of assistance needed to developing countries. Factors that lead to the success of sanitation programme in China, Sri Lanka, Thailand and Burma should be taken into account in other countries of the region. Above all, there should be a definite national policy giving high priority in the country to health services and in particular for water supply and sanitation in rural areas.

As already discussed in an earlier paragraph, both rural water supply and waste disposal systems should be a combined programme for effective control of gastro-intestinal diseases. The experience gained in the pilot environmental sanitation project in Gorakhpur in U.P. (India) should justify this integrated approach. The Community Health Programming (CHP) carried out in some countries in the region has been reported to be a success in bringing out planning and management for environmental health as an integral part of health programmes. Hence it is proposed that 'pilot' project on integrated and ecologically balanced systems of water supply and waste disposal as envisaged in this paper be set up in each of the member countries and closely studied to evaluate its success and impact on community health. Research and development studies are also needed on each of the components of the system. Some studies needed are noted below for consideration by the Research Study Group.

(d) Research Needs:

(i) Most suitable geometry for the pit latrines from the stability and performance point of view.

(ii) Digestion characteristics of pit-contents in different soil composition and varying water table conditions. Objective is to gather information on life of pit.

(iii) Critical evaluation of pollution travel in the different soil composition and water table conditions - objective is to determine safe location of water wells in relation to latrine pits.

(iv) Soil-cement bricks for lining the pit and for latrine super structure, other non-conventional materials like flyash cement, light weight aggregates should also be tried.

(v) Cheaper lining for latrine pits and septic tanks to reduce cost.

(vi) Manurial value of digested night-soil, digested slurry from bio-gas plant and finished compost from compost pit - A comparative study.

(vii) Trial on 'Compost-Toilet' as per Swedish design

(viii) Costing studies to evaluate cost benefit

(ix) Impact evaluation of integrated system.

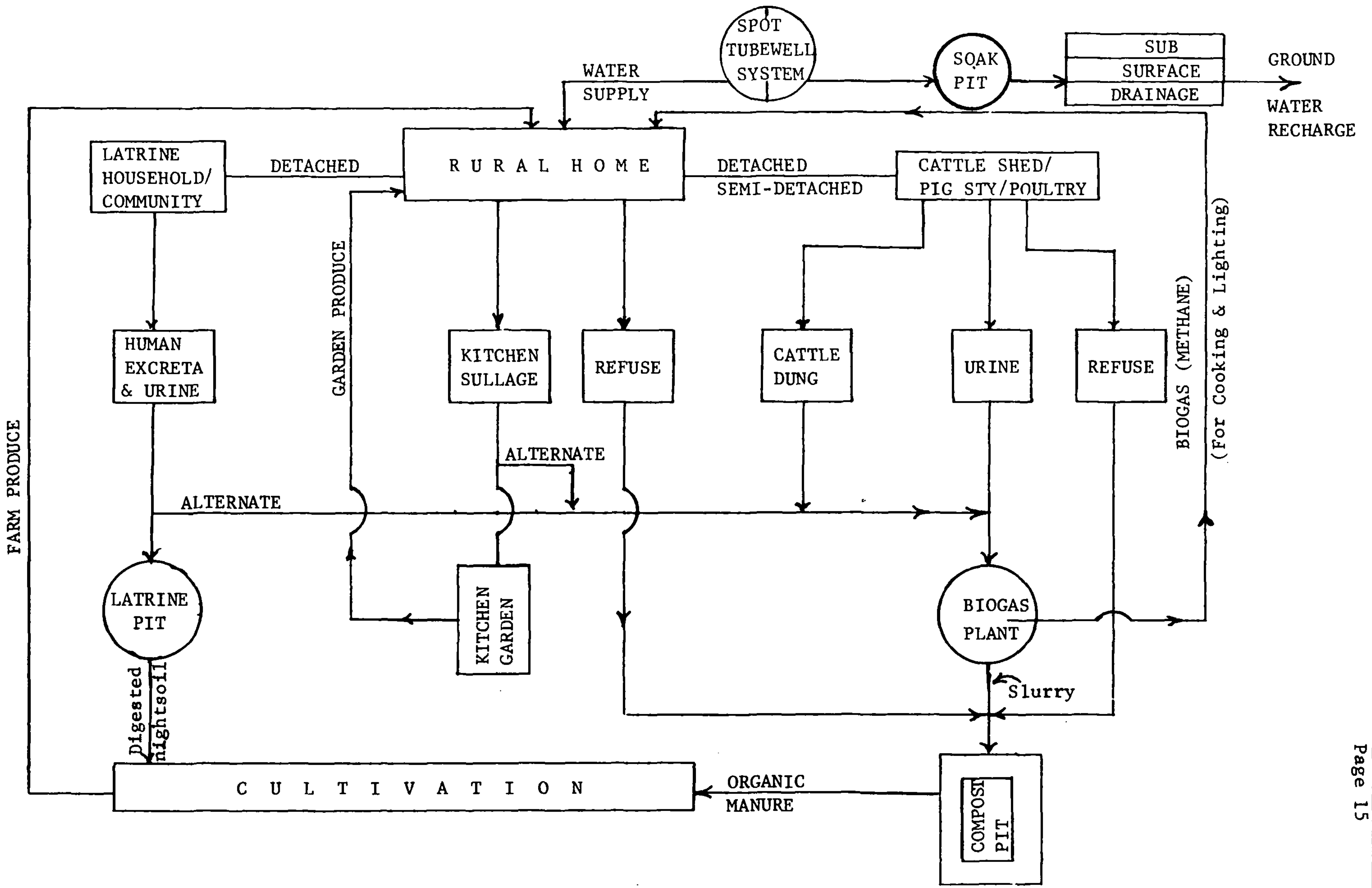

FIG 1. CONCEPTUAL FRAMEWORK FOR ECOLOGICALLY BALANCED WASTE DISPOSAL SYSTEM IN RURAL HOMES

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Notes:

*VITA - Volunteers for International Techbical Assistance

**ITG - Intermediate Technology Group

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IMPACT OF WATER SUPPLY AND SANITATION ON HEALTH

(A Brief Review)

By

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Contents

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The opinions expressed in this paper do not necessarily reflect those of the World Health Organization.

1. INTRODUCTION

There is not doubt that water supply and sanitation have positive effect on health and that investments in improvement of water supplies and sanitation are beneficial. However, as the health and other aspirations of developing nations rise while resources continue to be very limited the problem of most appropriate utilization of these limited resources to cover many needs including those for health, water supplies and sanitation becomes crucial one. Therefore, there is an increasing need to bring up the evidence of impact of various types of water supply and sanitation on health; to quantitate health benefits of incremental investments in these activities in order that on the ground of a sound cost-effectiveness and cost-benefit analysis of these and other public activities a decision can be made on allocation of available resources for health, social and economic development. However precise measurement of health benefits and costs of water supplies and sanitation might become, no formula will ever be developed that will automatically indicate where and how much resources must be invested. The priorities and preferences will always have to be decided on political grounds in first instance. Nevertheless in decision making processes (which are primarily determined by political factors) evidence based on sound data on impacts, effects and cost of water supplies and sanitation would facilitate decision on investment in this sector of public activities. Thus there is a need for studies and for monitoring of the health effect of specific water supply and sanitation programmes.

Available evidence on the effect of water supplies and sanitation has been interpreted in different ways according to the concepts of the reviewers and definition of health they used. There is a need to examine first these definitions and concepts and then accordingly analyse the evidence on health impact of water supplies and sanitation and determine the requirements for further research in this field.

There is an extensive literature on the subject but most complete and comprehensive reviews have been recently prepared[1,2] or are under way[3] by World Bank and it seems most appropriate that this brief review be mainly based on these publications and a few of those resulting from studies carried out in South East Asian Region[4,5].

2. DEFINITIONS AND CONCEPTS

Impact on health of water supplies and sanitation was in the past always expressed in terms of disease incidence. In fact most of the studies on the health impacts of sanitary measures were actualy on their effects on illness and not on positive health. While none of the earlier studies have measured the health effects of sanitation the studies on the effects of water supplies on water associated diseases were useful since they provided certain quantitative evidence of relevance to health. It seems logical that the definition of health contained in WHO Constitution stipulating that health is not merely absence of disease but the state of mental and physical wellbeing should be taken as yardstick for measurement of impacts of water supplies and sanitation on health. The reasons why measurement of positive health as defined by WHO Constitution has not yet been applied is simply the absence of reliable methods and criteria for the measurement of positive health. These have not yet been developed perhaps because health workers are professionally too much disease oriented.

Should clean dress and body be taken as an expression of positive health? How positive health can be graded in a quantitative way otherwise than listing the absence or presence of diseases and/or their symptoms? There is the need to define positive health and to develop the methods to measure it, in order to express the impact of water supplies and other sanitary measures on health in exact terms.

3. STUDIES ON HEALTH IMPACTS OF WATER SUPPLIES AND SANITATION

World Bank has recently published [1,2] and is preparing further publication[3] on the subject with extensive review of studies that have been undertaken to demonstrate the effect of these measures. It would be beyond scope of this paper to review this material.

However, it might be useful to point out to some studies that indicate the complexity of the problem of the measurement of the effects of water supplies and sanitation.

It has been proved that water supplies and sanitation has been effective in the control of enteric fevers and dysentery although it was difficult to determine exactly the degree of effectiveness in view of differences in epidemiological conditions and interference of many other factors[1-11]. Some studies[6,7,8,9] indicate that feasible sanitation programmes do decrease the risks of transmission for about 50% for indefinite period of time. Similar water supply and sanitation programmes have shown that provision of modest water supply/or privies decrease incidence of cholera for about 50% annually and such sanitation programmes have cumulative effect leading to the eradication of disease when both water supplies and excreta disposal are improved[11]. Results of these and other studies fully analysed in above mentioned reviews commissioned by World Bank[1,2,3] refer to specific diseases and to well defined epidemiological conditions. Results of the above studies may not be applicable in other areas and in different epidemiological set ups. There are numerous epidemiological and socio-economic factors which have an affect on the results of sanitation programmes; malnutrition and infection is one not, to mention the others. It is, therefore essential that results of such studies be critically interpreted by the team of epidemiologists, sanitary engineers and other experts. They should develop wholistic, team approach and consider all relevant factors and their interference or synergism in disease prevention and promotion of positive health.

In the recent studies in Bangladesh[4], it was concluded that the evidence shows that "Bangladesh hand-pump tubewell programme is not meeting its stated objective in reducing the incidence of cholera." From this disease oriented study an erroneous conclusion could be made namely that hand-pump tubewells have no positive effect on health. If cholera is both food-and-water-borne as it is there is no reason why water supply improvement alone should prevent its spread, while other factors which favour the spread of cholera are left unchecked. The improvement of water supply certainly had some effect on water uses, cleanliness, way of living etc. which are closely related to health but these were not measured and re[illegible]tive health in the above study. The author[4] is disappointed that "children who ingest, almost exclusively, water of good bacteriological quality apparently have the same cholera attack rate as those children who drink highly polluted water" and asks "why?". Obviously because they are infected as well by other means (food, contacts etc.). Unless these other factors are eliminated improvement of water supply may appear as having no effect on transmission of cholera. Results of such studies which are designed to demonstrate the effect on single disease control can be wrongly interpreted as indicating uselessness of water in improvement of many other facets of health.

[illegible] of water supplies in India, namely in [illegible] B[illegible] provision of [illegible] has made [illegible] fo[illegible] impact on the community, its health and well being and actually have triggered irreversible transformation of a community and became cornerstone of their social, economic and health [illegible]. It is obvious that these changes were not produced mechanically by simple installation of wells and water-pipes. Human factor certainly played an essential role in this project. Before World War II in Mraclin, a village near Zagreb, the School of Public Health launched a programme similar to one in Banki Block with similar results. Then the war came and water supplies were destroyed. Yet in spite of devastating war the infant mortality and other indices have shown that the village continue to be far ahead of their neighbours. Water supplies supported by health education and other elements of Community Development programme have had such a deep impact on the population that they inspite of all hardships were able to cope and protect their health.

The importance of psychosocial aspects of appropriate technology (such as water supplies) for health was rightly stressed by SEAR's consultation on ATH held in Delhi last year.* Participation and initiative of the part of the population will make modest water supply scheme very effective and absence of interest and motivation render the same wells and pipes ineffective in promotion of health. While it is relatively easy to measure and quantitate investments in water supplies the contribution of people's participation is difficult to assess in precise quantitative terms, but an effort in this direction is needed.

Appropriate technology, should comprise besides purely technical aspects concerning wells and pipes also social and educational aspects in order to mobilize all resources in the community and to make sanitation programme part of genuine popular drive for progress and health.

4. NEEDS FOR FURTHER RESEARCH

It is evident that there is need for further research on appropriate technology for improvement of environmental health at village level. Rural water supplies and sanitation were relatively neglected as engineering talents and financial resources were directed towards urban problems and large scale water supply projects. Orthodox engineering approaches seem to be too expensive and too much demanding to be applicable at large scale at present in the majority of underpriviledged rural communities. Thus the need for search for new solutions and new approaches. In this search, the creativity and practical experience of the common man may be helpful. It is difficult to envisage all varieties of problems related to water supplies in different rural areas and even more difficult to find appropriate solutions for them without close cooperation with population. Most ingenious are the simplest solutions which could be found by a talented peasant or village black-smith as well as by fully trained expert. Moreover when it comes to enlisting public cooperation, people from the community are better placed to find solutions.

Accordingly, it seems that study teams could be set up in rural areas composed of villagers and some experts to work together in search of new solutions, suitable for specific rural conditions. The teams could include village blacksmith and a teacher. The subject of study could comprise:

1. Simple protection of wells and water sources
2. Simple methods of water disinfection
3. Design of pumps and pipes which could be made from locally available materials and could stand the tear and wear
4. Design of suitable distribution of water points which would be inexpensive and yet to acceptable to community.
5. Effectiveness of various methods and techniques in the involvement of the community and the assessment of their impact on their peoples knowledge, attitudes and practices (K.A.P.).

Such studies should be carried out by above mentioned teams; experts of appropriate disciplines must be present in order to cover all technical aspects. The studies directed towards development and evaluation of appropriate methods for motivation and cooperation of the people in water supply and sanitation programmes should be undertaken by the teams of social-scientists, anthropologists and others.

Last but not least an effort should be made to design suitable methods of measurement and assessment of health that would enable meaningful evaluation of the impact of water supplies and sanitation on health status of the population. More appropriate methodology should be made available for assessing the impact of specific ATH in sanitation and to determine their cost-effectiveness. As new water and/or sanitation technology might be developed, its effectiveness should be evaluated and be compared with the effectiveness and the cost of other technologies. Since water supplies and sanitation are not only methods that can be used in promotion of health and in disease control the effectiveness, health benefits and cost of the alternative techniques and methods should be compared and evaluated in order to provide meaningful data for decision making[13].

5. CONCLUSIONS

Water supply and sanitation have beyond doubt as shown in many studies positive effect on disease control and on health in general. However most of past studies have been rather of descriptive than strictly analytical nature and thus lack of quantitative data on the degree of the effectiveness of various control measures. Most of the studies were designed for measurement of the effect of sanitation on specific diseases rather than on health status of population. Lack of the definition of positive health and of the methods of measurement of health status hamper evaluation of the health effects of sanitation. Thus such methods of measurement of health should be developed. There is need also to develop methods which will enable evaluation of other important factors. [illegible] is of utmost importance, as sanitary water supplies if not supported by proper uses of water by population may have little or no effect on health improvement. In search of new better techniques, human factor should not be neglected. Water supply and sanitation could give much better results and greater health benefits if such a programme is supported by the active interests of properly motivated and educated population.

In search of new and more appropriate technology for rural areas, the common man can greatly assist experts in particular in enlisting peoples cooperation and finding solutions suitable to the community and acceptable to it. It seems, therefore, that in the search of new technology there is need for close cooperation between experts and the members of the community.

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AN ECONOMIC APPRAISAL OF SANITATION ALTERNATIVES

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Abstract
The theory of economic costing is briefly reviewed and applied to the analysis of alternative sanitation technologies. Using this method the costs from 44 systems in 12 countries are computed and compared. A value engineering approach is taken to analyze cost sensitivities and productive areas for future technical research.

INTRODUCTION

Comparative costing lies at the heart of the analysis of alternative sanitation technologies. A common denominator is needed to objectively compare diverse systems. That common denominator should reflect the positive and negative consequences of a given technology and indicate its overall "score" either on an objective scale or relative to other alternatives.

The scoring measure most commonly used in project evaluation is the cost-benefit ratio. (See note b.) It has the advantage of providing a single summary figure representing the net economic effect of a given project which can be readily compared with those of alternative projects. The disadvantages of cost-benefit calculations are that they do not easily accommodate non-economic costs and benefits (particularly if they are unquantifiable), they may give misleading results when applied to mutually exclusive projects and they may not reflect macroeconomic goals such as employment creation or increased savings. Fortunately, the latter two problems can be remedied by variations of the basic calculation. However, the difficulties of benefit measurement for sanitation projects cannot be overcome readily. Indeed, in the case of water supply projects, it has been concluded that the theoretical and empirical problems involved in quantifying incremental health benefits are so great as to make serious attempts at benefit measurement inappropriate as part of project appraisals (Ref. 2).

In general, there is no completely satisfactory scoring system for comparing alternatives with unquantifiable benefits. Only in the case of mutually exclusive alternatives with identical benefits can one apply a cost minimization rule. In such cases one should select the alternative with the lowest present value of cost when discounted at the appropriate rate of interest. For given levels and qualities of service the least-cost alternative should be preferred. But where there are differences in the output or service, the least-cost alternative often will not be the economically optimal one.

Alternative sanitation systems provide a wide range of benefit levels. While most properly selected systems can be designed to assure pathogen destruction (Ref. 3), the user convenience offered by an indoor toilet with sewer connection is hard to match with a pit privy. Many benefits exist in the mind of the user, and varying qualities of service result in varying benefit levels. For this reason a least-cost comparison will not provide sufficient information to select among sanitation alternatives. Nonetheless, if properly applied, it will provide an objective common denominator which reflects the cost trade-offs corresponding to different service standards. Once comparable cost data have been developed, the consumer can make his own determination of how much he is willing to pay to obtain various service standards.

Note a: The data used in this paper were collected as part of the World Bank's research project on Appropriate Technology for Water Supply and Waste Disposal. However, the views presented are those of the author and should not be attributed to the World Bank or any of its affiliates.

Note b: Variations of this calculation include the internal rate of return and the net present value. For a discussion of the set of conditions under which each is appropriate, see Squire and van der Tak (1).

Thus the economic evaluation of alternative sanitation technologies comprises three components: comparable economic costing, maximizing the health benefit from each alternative through proper technical design, and allowing the user to make the final cost-benefit determination. This paper deals with the first of these.

ECONOMIC COSTING IN THEORY

The basic purpose behind economic costing is to develop a price tag for a given good or service which represents the opportunity cost of producing that good or service to the national economy. Translated into practice, this purpose can be summarized in three principles to be followed in preparing cost estimates.

The first principle is that all costs to the economy, regardless of who incurs them, should be included. In comparing costs of public goods such as water or sanitation, too often only costs attributed to the public utility are considered in a cost comparison. The costs borne by the household are ignored or subsumed as being identical across alternatives. In analyzing the financial implications of alternative technologies such a comparison would be appropriate. However, for an economic comparison (i.e., for the determination of the least-cost solution) it is necessary to include all costs attributable to a given alternative whether borne by the household, the municipal utility, the national government, or whomever.

The determination of which costs to include should rest on a comparison of the situation over time with and without the project. This is not the same as a "before and after" comparison. Rather than using the status quo as the "without" scenario, one must estimate how the current situation would improve or deteriorate over the project period were the project not to be undertaken. In the case of sanitation systems for urban fringe areas, for example, the costs of groundwater pollution and the difficulty in siting new latrines are likely to increase over time as population pressure mounts. There is likely to be an optimum time to undertake a sanitation project. By acting too soon one may incur costs that could have been postponed. By waiting too long the per capita cost of the project could rise (in real terms) because of increases in population density, for example, which aggravate construction difficulties.

Once the relevant costs to include have been identified, the second costing principle concerns the prices which should be used to value those costs. Since the objective of economic costing is to develop figures which reflect the cost to a given economy of producing a good or service, the economist is concerned that unit prices represent the actual resource endowment of the country. Thus a country with abundant labor will have relatively inexpensive labor costs in terms of labor's alternative production possibilities. Similarly, a country with scarce water resources will have expensive water costs, in the economic sense, regardless of the regulated price charged to the consumer. Only by using prices which reflect actual resource scarcities can one ensure that the least-cost solution will make the best use of a country's physical resources.

Because governments often have diverse goals which may be only indirectly related to economic objectives, some market prices may bear little relation to real economic costs. For this reason it is often necessary to "shadow price" observed, or market, prices to arrive at meaningful component costs of a sanitation technology. Calculating these shadow rates, or conversion factors, is a difficult task and requires intimate knowledge of an economy's workings. The shadow rates used in this paper were developed according to the method described by Squire (1).

The third principle of economic costing is that incremental rather than average historical costs should be used. This principle rests upon the idea that sunk costs should be disregarded in making decisions about future investments. In analyzing the real resource cost of a given technology, it is necessary to value the components of that technology at their actual replacement cost rather than at their historical price. In the case of sanitation systems this is particularly important in the treatment of water costs. Because a city develops its least expensive sources of water first, it generally becomes more and more costly (even excluding the effect of inflation) to produce and deliver an additional gallon of water as the city's demand grows. By using the average cost of producing today's water one is often seriously underestimating the cost of obtaining additional water in the future. The decision to install a water carried sewerage system will increase a given population's water consumption by around 50 to 70 percent. (See note a.) Thus in calculating the costs of such an alternative, it is extremely important to properly value the cost of the additional water required for its proper functioning.

Note a: Based on developed country data, the water used to flush toilets is around 40 percent of total domestic water use excluding garden watering.

SPECIAL PROBLEMS OF SANITATION PROJECTS

The application of these costing principles to sanitation projects is difficult for several reasons. The main one is the problem of finding a scaling variable that allows comparison among diverse technologies regardless of their design populations. On-site systems such as pit latrines are generally designed for a single family or household. The latrine's lifetime will depend on how many people use it. However, the life of some components, such as a vent pipe, may be independent of usage, so that the annuitized per capita construction cost of a latrine used by 6 people will probably not be the same as that of one used by 10 people. For this reason all costs presented in this paper are given in household rather than per capita units.

A further problem is that the construction cost of a sewerage system will vary considerably as the design population varies. In addition, it would be misleading to use the design population in deriving per capita costs to compare with those of a pit latrine since in the former case the benefits only reach a portion of the users during the early years, while the latrine's "design population" is served immediately upon construction. Any technology which exhibits economies of scale in production will result in a diversion of cost and benefit streams. With a facility such as a treatment plant or large interceptor all of the investment costs are incurred at the beginning of its lifetime while the benefits (leading to its full utilization) are realized gradually over time. Figure 1 provides a skematic representation of this diversion between cost and benefit streams.

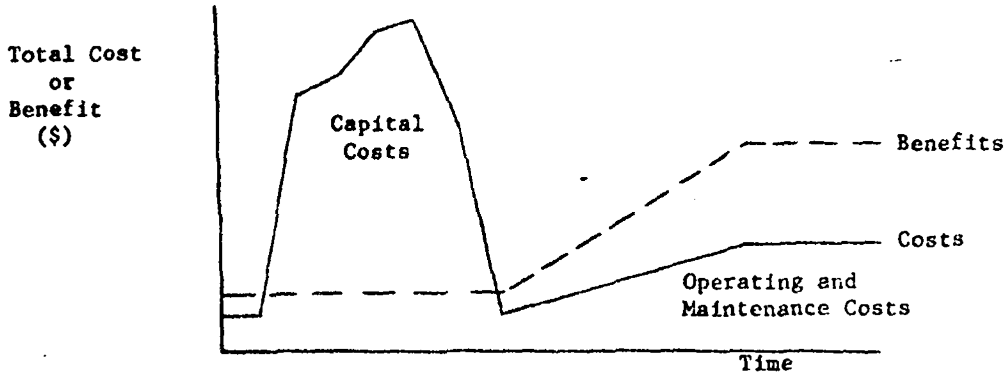

Fig. 1. Cost and benefit streams of an investment with economies of scale

Just as costs incurred in the future have a lower present value than those incurred today, benefits received in the future are less valuable than those received immediately. In the case of deriving per capita (or per household) costs this means that serving a person five years hence is not worth as much as serving the same person now. To divide the cost of a sewerage system by its design population would understate its real per capita cost when compared with that of a system that is fully utilized upon completion.

To overcome this problem of differing capacity utilization rates across systems the average incremental cost (AIC) calculation has been used. The per household AIC of a system is calculated by dividing the sum of the present value of construction (C) and incremental operating and maintenance (O) costs by the sum of the present value of incremental households served (H):

$$AIC_t = \sum_{t=1}^{T} \frac{\left[C_t + (O_t - O_{t_o})\right] \div (1+r)^t}{(H_t - H_{t_o}) \div (1+r)^t}$$

where r is the opportunity cost of capital and all costs have been appropriately shadow priced. Note that for a system which is fully utilized immediately this calculation reduces into the familiar annuitized capital and incremental operating and maintenance costs divided by the design (household) population.

In practice it is often easier to calculate the AIC on a volume (e.g., cubic meter) basis rather than per household served. For the sewerage costs in five of the case studies the AIC per cubic meter was calculated first for residential consumers since year-by-year projections of treated wastewater were available. Then these volumetric costs were transformed into per household costs using average household size and per capita demand figures.

An additional problem in deriving comparable sanitation system costs is the differing treatment of sullage wastes. With sewerage, most septic tanks, and some aquaprivy systems, sullage is disposed of along with excreta. With most of the on-site technologies sullage disposal must be accomplished separately through stormwater drains or ground seepage. If stormwater drains are present (or would be constructed anyway) then the incremental cost of disposing of sullage is very small since storm drains are usually designed to handle flood peaks. If sullage is left to soak into the ground, health and environmental risks may or may not be created depending on soil conditions and ground water tables. Alternatively, separate disposal of sullage may be considered a positive benefit by populations who recycle kitchen and bath water to irrigate gardens or dampen dust. In such a case, the removal of sullage through the introduction of a sewerage system would involve a negative benefit. In a particular case it is not difficult to decide how to treat sullage removal costs when comparing different sanitation systems. However, for the purposes of this paper where a more general comparison is required, a consistent assumption needs to be applied. Therefore, the costs in Tables 1 and 2 include sullage disposal only where the sanitation system itself is designed to accommodate it. This is true of all of the sewerage systems, all of the septic tanks and two of the sewered aquaprivies.

A final problem in designing comparable cost figures for sanitation systems concerns the approach to be used in gathering data. The study from which this data were abstracted was statistically based in contrast to a synthetic framework which develops an ideal model and tests the effect of varying assumptions. Both approaches have their advantages and disadvantages. Because so little is known about the technology or costs of non-conventional sanitation systems, it was decided that a broad-based study involving many systems in many different settings would provide the best overall framework for designing particular studies or, indeed, selecting "typical" technologies and settings to proceed with a synthetic model. The major disadvantage of a statistical approach, however, is that it is very difficult to identify the factors which result in increased or decreased costs since it is impossible to vary one factor at a time while holding all others constant. Cross-country comparisons can be misleading unless one is familiar with the background of each case. For this reason caution should be employed in generalizing the field results beyond their base or in using them for predictive purposes.

It is also important to note that the economic costs shown below do not represent average annual financial outlays. In general they will be higher than financial costs since sanitation projects usually have access to long-term finance (debt or equity), and financial interest rates are usually below the opportunity cost of capital. The focus of this paper is on a least-cost, economic comparison of alternatives rather than a financial appraisal.

FIELD RESULTS

The costs discussed below have been disaggregated in two ways: by function and by investment versus recurring costs. In disaggregating by function, the categories used are on-site facilities, collection, treatment and reuse. This distinction is made primarily because disaggregating by function allows one to broadly examine the cost effects of repackaging components (for example, many treatment alternatives can be linked with a variety of collection systems and/or on-site facilities). In addition this disaggregation is amenable to a "value engineering" approach by identifying the areas where the greatest potential for cost savings exists. It also provides a rough guide for the financial analyst to determine the proportion of system costs which must be borne by the utility as compared to that incurred directly by the household. The latter is a useful figure in estimating consumer willingness to pay utility rates since that willingness will be based in part on the costs to the household of obtaining the private facilities to enable it to make use of the utility's service.

The second type of disaggregation is the separation of capital and recurrent costs. The difference between high capital cost and high recurrent cost technologies generally parallels that of capital intensive versus labor intensive technologies. This is because investment costs of most systems are mainly capital while recurrent costs are mainly labor. The distinction is made in this paper between investment and recurrent rather than between capital and labor partly to focus on the main cause of the difference and partly because of the important institutional implications of managing a high recurrent cost system.

Cross-technology cost comparison

The single most useful figure for cross-technology comparisons is the total annual cost per household (TACH). It includes both investment and recurrent costs, properly adjusted to reflect real opportunity costs and averaged over time by the AIC method. The use of per household rather than per capita costs is appropriate for those systems whose on-site facilities are designed for use by a single household. However, TACH is misleading when applied to communal facilities or cases where several households share one toilet. In those instances an adjusted TACH has been calculated by scaling up per capita costs by the average number of persons per household.

Table 1 summarizes the TACH obtained for the ten technologies studied. Several summary statistics are shown due to a wide variation in the number of cases studied and the range of costs.

TABLE 1. Summary of total annual costs per household (1978 $)

	Mean TACH	Number of Observations	Range	Mean Investment Cost	Mean Recurrent Cost
Waterseal Pit Latrine	18.7	3	13.2	13.2	5.5
Pit Latrine	26.4	7	48.6	26.3	0.1
Communal Waterseal Latrine	34.0	3	34.2	24.2	9.8
Bucket Cartage	49.5	3	57.0	28.0	21.2
Composting Latrine	55.0	3	40.3	50.4	4.8
Aquaprivy	87.7	1	-	79.8	7.9
Vacuum Truck Cartage	104.2	9	184.7	67.0	37.4
Japanese	187.7	4	38.6	127.7	60.0
Others	37.5	5	28.1	18.1	19.3
Sewered Aquaprivy	180.0	3	120.6	141.2	38.7
Septic Tanks	204.0	4	345.3	130.8	73.1
Japanese and Taiwanese	348.2	2	84.3	216.7	131.5
Others	59.7	2	29.5	45.0	15.0
Sewerage	395.8	8	499.1	272.0	122.7

Contrary to expectation, when ranked according to cost the technologies do not divide cleanly into community and individual systems. The most expensive group (those with TACH greater than $300) includes sewerage and Japanese and Taiwanese septic tanks. The middle range technologies (those with TACH between $150 and $200) are Japanese cartage systems and sewered aquaprivies. The low cost technologies (those with TACH less than $100) include both community systems such as buckets and non-Japanese cartage and most of the individual systems. The division between high, middle and low cost-technologies is fairly sharp with large buffer areas available for system upgrading. The fact that variations of septic tanks and vacuum truck cartage appear in two categories indicates the potential for installing a low-cost technology at an early stage of development and improving its standard as development proceeds.

Within the low-cost technology group, there is a fairly large variety of systems, ranging from aquaprivies and simple septic tanks to pit privies and waterseal latrines. Vacuum truck cartage (non-Japanese) and bucket cartage, with TACHs in the $30 to $50 range, fall in the middle of this group. However, the cartage figures are derived mostly from Taiwanese and Korean case studies which exhibit a degree of labor efficiency that might be difficult to replicate in other parts of the world. Bucket cartage figures are mostly from Africa and represent poorly functioning systems that probably should not be replicated without upgrading. Thus the TACHs of community systems in the low cost group are likely to understate their cost of construction and operation in other countries. Of course, since all of the costs in Table 1 are derived from particular case studies, none can be considered an accurate representation of what it would cost to build a particular system in a different country. However, there is no reason to suspect that the individual system costs are biased either upward or downward because of country selection.

Cross-country cost comparison

Before examining the cost data for each technology it is useful to consider the overall variation of costs across countries. The magnitude of the total variation is quite large, as is indicated in the third column of Table 1. In nearly all cases the range is at least as large as the mean TACH. In the case of the pit privy the range is nearly double the mean. In a statistical study of this type such a wide variation is to be expected and does not present a major problem since the figures are meant to be informative rather than predictive. Further, the relatively wide margins between the grouping of technologies into high, medium and low cost systems indicates that the groupings are probably accurate even though the means may be 50% too low or too high.

The total variation is due in part to differences in the costs of basic inputs such as labor and in part to differences in the input combination used (e.g., different types of treatment processes among the sewerage systems). To some extent these two factors are off-setting since a country with high capital costs would be expected to choose a less capital-intensive treatment process, for example. For two of the systems, vacuum truck cartage and septic tanks, the difference in input combinations seems to be very important since the case studies' costs exhibited a bimodal distribution which could be directly traced to differences in the technologies employed in different countries. In no two case studies is the exact design of a system replicated; i.e., no two pit privies are exactly alike. However, for most of the technologies the variation in cost across countries parallels the general price levels of the countries.

Investment and recurrent costs

The distinction between investment and recurrent costs is an important one for both financial and technical reasons. A city or community with very limited fiscal resources at present but with a good growth potential might find it impossible to raise the investment finance to build a system with large initial capital requirements, whereas it could build and maintain another system (with the same TACH) whose recurrent expenses were relatively high. Conversely, a major city in a developing country which has access to external sources of funds might prefer to build an expensive system initially with the help of grant or low-interest loan capital and thereby reduce its need for recurrent funds. (See note a.)

From the technical viewpoint high recurrent costs generally stem from large or sophisticated operating and maintenance requirements. In those developing countries where skilled labor is scarce or where the management necessary to coordinate large numbers of unskilled workers does not exist, it may be unwise to opt for a system with high recurrent costs. However, an offsetting argument is that the employment benefits arising from a high recurrent cost system such as vacuum cart collection may be large enough to justify importing the management skills necessary.

The final two columns of Table 1 present the investment and recurrent cost breakdown for the 10 technologies studied. One interesting conclusion that could be derived from these columns is that as one moves from the most expensive to the least expensive system, recurrent costs as a percent of the total first increase and then decrease. The two high cost and the two medium cost technologies exhibit recurrent costs amounting to between 20 and 36 percent of TACH. The highest recurrent cost systems (as a percent of the total) are in the middle of the low-cost technology group, non-Japanese cartage and buckets, with 52% and 43% recurrent cost, respectively. As one moves to technologies such as composting latrines and pit privies the porportion of recurrent cost drops to less than 10%.

This somewhat surprising pattern is due in part to the make-up of the recurrent cost figure. Because economic rather than strictly financial costs are used in this study, a major item is included in recurrent cost which typically does not appear in engineering cost estimates: the water used to flush some systems. In order to see how the inclusion of flushing water cost affects the investment versus recurrent cost breakdown, separate calculations excluding water costs were made for those six systems which require water.

If one excludes flushing water from recurrent costs, only vacuum truck cartage and bucket systems show recurrent costs of more than 30%. The overall conclusion is that nearly all of the sanitation systems studied are relatively high in investment as opposed to recurrent cost. Only in the case of non-Japanese cartage do recurrent costs represent more than half of TACH. In ten of the twelve systems (treating the two varieties of septic tanks and cartage as separate systems) investment costs account for more than 60% of TACH.

There are several implications of this concentration on investment costs. One is that it will probably be necessary to set up financing arrangement for the utility regardless of which technology is chosen by a particular city or community. High initial costs almost invariably require some sort of financial mechanism to smooth payments so that they are more in line with benefits delivered to (and paid for by) the consumers. A second implication is that where funding constraints are binding, the size of the initial investment requirement may be the most important determinant of technology choice. There is relatively little scope for substituting a higher recurrent cost system. In that sense, the distinction between the relative importance of investment and recurrent costs of different systems becomes moot. While sewerage and waterseal latrines both entail recurrent costs of about 30% of their respective TACH, the important point is that the investment cost (per household, per year) of the former is more than 20 times larger than that of the latter.

On-site collection, and treatment costs

The separation of TACH into its functional components is useful in determining where to

Note a: This would not be an economically efficient solution since the opportunity cost of capital does not depend on the source of the funds or the terms of a particular loan package.

focus the design effort in attempting to reduce costs. For most of the individual systems, of course, all (or greater than 90%) of the cost is on-site. Thus an investigation of the cost reduction potential for them must center on the materials and methods used to produce and install them. In one African case between 40 and 60 percent of the TACH for pit latrines, composting latrines, and aquaprivies went for the superstructures which were made of concrete blocks. If these units were built using local materials such as clay brick or straw matting their costs could be reduced significantly.

Table 2 presents the functional breakdown of costs for the ten systems. Even among the six community systems, on-site costs account for at least 45% of the total. Japanese and Taiwanese septic tanks have the highest on-site costs of over $320 per household per year. The large role that the costs incurred by the household play in total system costs shows the importance of finding ways for funding on-site facilities. The very low connection rates of many sewer systems in developing countries (often in the face of legal requirements to connect) probably is at least partly due to the large household expenditure involved.

With the exception of the bucket systems, collection costs and treatment costs make up about equal proportions of the TACH of the various community systems. In the bucket systems covered in this study the only "treatment" practiced was trenching so that it is not surprising that treatment costs represented only 8% of the total.

Table 2. Average annual on-site, collection, and treatment costs per household (percent)

	On-site	Collection	Treatment
Waterseal Latrine	100	-	-
Pit Privy	100	-	-
Communal Waterseal Latrine	100	-	-
Bucket Cartage	48	44	8
Composting Latrine	85	-	15
Aquaprivy	100	-	-
Vacuum Truck Cartage	64	22	14
Japanese	68	18	14
Others	45	37	18
Sewered Aquaprivy	54	23	23
Septic Tanks	94	4	2
Japanese and Taiwanese	93	5	2
Others	100	-	-
Sewerage	49	21	30

An additional functional category was included in the original study to represent any economic benefits accruing from reuse of treated nightsoil or sewage effluent. Unfortunately, it was very difficult to locate working examples of human waste disposal systems with a sizable reuse component. A few of the sewerage systems produced small amounts of methane from their digestors which was used to heat the plants. There was some demand from orchard farmers in the Far East for the nightsoil collected by vacuum truck but the municipalities made no effort to set up a delivery system or to charge a market-clearing price. The composting latrines built in Africa were too new to yield useful data on reuse. All except one of the biogas units observed ran on animal rather than human waste. In short, while there is much experimental and theoretical data on the economic potential of reuse technologies, there is a dearth of actual experience. (See note a.)

COST SENSITIVITIES

It may be useful to summarize the broad conclusions from this review of cost data from a total of 44 sanitation systems studied in 12 countries. Precise calculations of the sensitivity of system costs to changes in particular parameters are impossible to undertake within the framework of an empirically based study such as this one. However, it is possible to discern areas of relatively greater and lesser importance.

The two most outstanding influences upon total household costs are factors which have often been ignored in engineering analyses: on-site household costs and the cost of flushing water for water-carried systems. The former is important in all systems and never accounted for less than 45% of TACH. The latter is most important for sewerage and septic tank systems. Where the economic cost of water is high, the payoff from designing systems with low requirements for flushing water is large.

Note a: The obvious exception to this statement is the experience of mainland China, but scientifically documented information on it is rare, and it was not possible to include first-hand observation in this study.

A second conclusion relates to those aspects of sanitation systems which do not significantly influence costs but can make a big difference in benefits. Two components of individual systems, ventilation pipes and water seals, aid greatly in reducing odors and fly breeding without adding noticeably to system costs. In one of the case studies it was found that people were very concerned about the color of the floor of their latrines. While this is an aesthetic concern without technical importance, it may make the difference between a facility that is kept clean and regularly used and one that isn't. In another case, in an effort to cut costs the latrine designers had used pre-cut sheets of zinc for the superstructure siding. However, this meant that the siding did not reach all the way to the floor which provided easy access for rodents and scorpions during the night and embarrassment for the people (whose feet could be seen while using the latrine). Such unimportant details from the cost viewpoint are often very significant in enhancing health and aesthetic benefits (both of which generate a willingness to pay on the part of the user).

A final caution is appropriate in the interpretation of these case study costs. In very few cases were the systems optimally designed. This was true of the overdesigned superstructures of the experimental African latrines, the reuse components found in the Far East, some sewered aquaprivies in Zambia (which fed into conventionally sized collectors designed for a full sewerage system), and many of the other cases. Nonetheless the broad ranking of technologies, the cost sensitivity patterns, and the method used to arrive at appropriate figures for a least-cost comparison are believed to have general applicability.

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ALTERNATIVE APPROACHES TO SANITATION TECHNOLOGY*

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Introduction

This paper reports progress to date of the World Bank's two-year research project on Appropriate Technology for Water Supply and Waste Disposal initiated late in 1976. Although results and conclusions presented herin are necessarily provisional, we feel sufficiently secure in their general validity to make this presentation.

Background

Traditionally, development aid has emphasized productive sectors, i.e., projects which have a significant impact on productivity in the near term. Thus, in its early years, the World Bank and most other lending agencies concentrated on transportation, agriculture, power production and other sectors for which benefits could be easily quantified and economic productivity demonstrated. Other areas such as water supply and sanitation, health, etc. where the impact could not be as easily quantified and translated into measured values, were less emphasized in lending programs. As late as 1960 a strong case was made that the World Bank should finance water supply projects only if "circumstances clearly indicate that there are no other suitable projects available, and that the economic benefits to the borrowing country will be substantial." (1) The primary reason for emphasizing so-called productive projects was the then commonly accepted theory that benefits from increased production would accrue to all population classes, rich and poor, through the "trickle down effect."

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More recently, it has become clear that to reach the low income population, the rural as well as the urban poor, projects would have to be specifically designed to achieve this objective. In other words, the trickle down effect often does not exist or is too slow and small to

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have a significant impact in the foreseeable future. Consequently, the Bank has changed its strategy and emphasizes in its projects and direct impact on the poorer population groups. This emphasis on helping the poor of the developing countries was first clearly communicated by Mr. Robert McNamara in his address to the Governors at the Annual Meeting in Nairobi in 1974 where he outlined a Bank strategy to assist the rural poor. A year later, at the Annual Meeting in Washington, in 1975, Mr. McNamara again discussed the Bank's strategy in terms of its impact on the poor, this time establishing a strategy to attack urban poverty.

With the emphasis on projects designed to improve the productivity and living conditions of the urban and rural poor, so-called social projects or project components (water, health, nutrition, family planning, etc.) play an increasingly important role, even though benefits cannot always be quantified. To further the understanding of the impact of such projects and evolve a comprehensive approach for improvement in the living conditions of the poor -- and thus their productivity — the Bank is now developing a basic needs strategy.

Water supply and sanitation will undoubtedly be a major consideration in any basic needs strategy because, together with housing, it is the sector with the greatest immediate impact on the living conditions and well-being of the poor in developing countries. Two recent conferences — HABITAT in Vancouver in 1976 and the U.N. Water Conference in Mar del Plata in 1977 -- have focussed attention on water supply and sanitation, leading to the adoption of the 1980s as the "Drinking Water Decade" by the U.N. General Assembly. It is hoped that these actions will lead to an increased commitment by governments and development finance institutions towards the provision of increased funds for water and sanitation projects.

For the Drinking Water Decade to succeed major efforts in planning, organization and funding are required. One of the greatest needs is to reexamine water supply and sanitation methods to discover and/or develop technologies which are both less costly and appropriate to conditions in developing countries. Conventional solutions based on capital intensive practices in North America and Europe result in spending at least three times as much to properly dispose of water as it costs to provide it.

The emphasis has consequently been on supplying greatly increased quantities of water without providing for adequate waste disposal. This has not only led to serious water pollution and public health hazards in many countries, but has often resulted in the provision of expensive, high standard water supply and sewage disposal services to the well-to-do few in preference to supplying a large number of the poor with less costly services at lower standards.

In 1973, E.F. Schumacher proclaimed "Small is Beautiful" (2). That the book met a need is shown by the several score of recognized organizations that have sprung up to deal with appropriate technology and by the 9000 references to it recently identified (3) by a computer search. Our operational definition of appropriate technology is that process or technique which provides a socially and environmentally acceptable level of service or quality of product at the least social cost.1/ The rigorous application of such a definition in the field of water supply and sanitation is difficult since alternative technologies generally provide varying levels of services (and possibly of health benefits). However, this lack of quantifiable benefit information only reinforces the need for careful and complete cost calculations. Such calculations should be based on incremental costs to the economy rather than simply those to the ministry or utility. Thus shadow pricing of foreign exchange, unskilled labour, power and other inputs frequently is necessary. In addition, all costs to the householder (e.g., indoor plumbing, labour contributed for latrine construction, etc.) must be taken into account. Calculations summarized later in this report have shown that including the economic cost of flushing water for a sewerage system raises total system costs by 20 to 30 percent. Finally, adjustments must be made for the unutilized capacity (which produces no benefits) during the early years of a large water or sewerage project when its costs are compared with those of small, decentralized alternatives. The traditional methods of costing used by engineers often ignore these factors and thus bias technology choice toward large, capital-and import-intensive designs.

1/ For a complete derivation and definition of social cost see Squire and van der Tak (4).

Examples of both appropriate and inappropriate technologies abound. The appropriate ones important in water, waste disposal and reclamation come from a variety of sources, including peasant artisans whose ancestors are identified by McGarry (5) as the progenitors of the industrial revolution. Many of the ancient technologies are still appropriate. A number of them are still in use today, and are described by, among others, Forbes (6). Modern materials, design criteria and techniques also support appropriate technologies ranging from butyl sheets for rainfall catchments (7) to the better use of ferro-cement materials for construction (8). Since appropriate technologies for developing countries tend to be small, dispersed, labor-intensive and resource conservative; their impact on the natural environment tends to be minimal. These characteristics promote innovation, improvement, and, for physical infrastructures, staged construction in which capacity and demand are closely linked.

Research Objectives

The long-range objectives of the World Bank research project are to improve the efficiency of the Bank's lending operations and to enhance its ability to direct the benefits of its loans to the urban and rural poor. The immediate objectives are to determine:

- the technical and economic feasibility of various options which are available for water supply and waste disposal in developing countries;
- the economic and environmental systems effects of technologies which provide for conservation of water and other resources and for reclamation of wastes; and
- the scope for designing technical improvements of existing intermediate technologies to improve their efficiency or enhance their transferability and acceptance.

Considerable urgency attaches to the project because of decisions now being made by officials of developing countries, lending institutions, development agencies, and by their engineering and economic advisors.

These decisions are characteristically made on the basis of short-term financial considerations, but they result in long term commitments with significant social and economic impacts. Even when long-range planning is attempted, the lack of information on low cost alternatives to conventional systems of waste disposal frustrates effective decision making. Project designs are needed which permit officials to provide service to many at low service levels and low cost without, however, precluding a gradual increase in service levels to keep pace with increasing demand and ability to pay of the consumer.

Project Scope and Research Approach

A total of 20 countries were chosen for study. Of these, 12 were selected for detailed field investigation. The balance is included to provide specialized information or locations for pilot projects. Collectively, the countries include a variety of stages of development, technologies, cultural and institutional forms, and environmental features.

Geographic coverage currently includes (1) Japan, Taiwan, and Korea; (2) Indonesia, Malaysia, Vietnam, India, and China; (3) Afghanistan, Egypt, and Sudan; (4) Botswana, Ghana, Nigeria, Tanzania, and Zambia; and (5) Colombia, Guatemala, El Salvador, and Nicaragua. Principal investigators and supporting consultants oridinarily are selected from host country specialists.

Technological options being considered include the following either singly or in combinations:

- water service levels of 10 to 500 liters per capita per day obtained from streams, wells, vendors, community standpipes and/or sanitation services, yard spigots, or high-volume plumbing;

- low-cost options for waste disposal by privies, vaults, composting toilets, aquaprivies or cesspools, septic tanks, removal by cart, vacuum truck, or low-flow sewers;

- traditional, advanced, or exotic waste treatment based on composting, digestion, fermentation, oxidation, or spreading of nightsoil, sewage, agricultural manures, or food wastes; and

- reclamation schemes including biogas, fertilizer, aquaculture, pig-raising, stock and garden watering, and irrigation.

For each technology studied at the community level by the field consultant, a technical evaluation of the system's construction and operation first is carried out with special reference to any problems associated with the performance or community acceptance of the existing system. Using standard cost-benefit techniques (including shadow pricing 1/ where appropriate) each technology's economic feasibility then is analyzed, and average household costs are computed. Special emphasis is given to the ability or willingness of consumers to pay for the system, their real or perceived improvement in health and living conditions, and any obstacles to adaptation of the technology for other communities.

In both the technical and economic evaluations, an attempt is made to broaden the scope of analysis to include system linkages between the waste disposal technology and its effect on labor and product markets. In addition, more complex relationships with other economic sectors such as agriculture and energy (where reclamation through fertilizer or biogas production is practiced) are explored.

1/ Failure to consider shadow pricing in engineering works often results in favoring alternatives which are too capital and import intensive. By removing from the analysis distortions due to political decisions, minimum wage laws, overvalued local currencies, and development capital available at low rates, and by providing a framework for consideration of such social goals as income redistribution or savings generation, shadow pricing can help identify the appropriate technology (3).

One example of this focus on system comparisons is the inclusion of water costs in the total economic cost of sewerage, septic tanks and other water-using sanitation technologies. However, the judgement on how much of a household's total water use is related to its sanitation system is a difficult one. It has been argued that since a conventional sewerage system requires household water connections, the entire cost of the water connection should be included in the incremental cost of sewerage.1/ Under certain conditions this would be a valid approach. For example, a city planner faced with designing site and service plots in a new area should compare the combined costs of piped water plus sewerage with the combined costs of standposts plus pit latrines plus drainage for sullage (for example) if those are the two options being considered. In such a case, of course, the relative benefits of the two combiantions would also have to be compared.

Since benefit comparison is so difficult, and also since the real world rarely presents one with such a clear-cut choice between two distinct and mutually exclusive alternatives, we have chosen to employ a "marginalist" approach to system definition (and therefore costing). The entails holding as many variables constant as possible (including the water service level) in order to focus specifically on incremental sanitation costs and benefits. The decision on sanitation is then one which compares the costs of various alternatives with the incremental health and other benefits to be gained, given the water service level and other technical parameters.2/ Therefore, the appropriate water supply cost to include in the sanitation system is only that which is necessary for the proper operation of the facility.

1/ Indeed, this was the official British position first set forth by Chadwick in 1842 in which the provision of an adequate and constant supply of water under pressure to every dwelling for flushing wastes was seen as an essential precursor to the elimination of insanitary conditions and epidemics in manufacturing towns (9).

2/ Ideally, of course, the water supply decision should take into account the costs of properly disposing of whatever water is provided. However, the current impossibility of incorporating that cost due to the lack of basic cost information on alternative sanitation systems was one of the factors which led to the formulation of this World Bank research project. Thus our objective at this stage is more limited. We are now aiming to arrive at comparable incremental economic costs for various sanitation components, and the relationship between water supply and sanitation is taken as a technical parameter in the sense that each sanitation technology will be defined as applicable only over a specified range of water service levels.

Once the amount of water has been determined it must be costed not at its price to the consumer, but as its opportunity cost to the economy. While there are theoretical problems involved in applying this principle to commodities such as water which require "lumpy" investments to produce, 1/ the measure we have chosed to approximate the opportunity cost of water is its average incremental cost (AIC), as defined by Saunders, et.al. (10). The AIC is a measure which represents the long run marginal cost of production given input costs and factor scarcities of the country.

Early Technological Results

The first phase of the research involved a detailed bibliographic search for literature relevant to low-cost waste disposal technologies. This was followed by field evaluations of existing sanitation technologies in selected countries in the Far East, Southeast Asia and Africa. Findings include the following:

- A title, abstract, and detailed review of over 18,000 potentially relevant publications selected by key word indexing revealed that less than 2 percent are of practical value in developing countries; that conventional engineering wisdom indicating that there are no viable technological alternatives lying between pit privies and sewerage systems is invalid; that much information is available on septic tanks but little on pit privies; and that much information exists on treatment of dilute wastes by oxidation ponds but little on treatment of concentrated wastes (nightsoil sludge, etc.) by composting or aquaculture.

1/ See Saunders, et. al. (10) for a description of these problems and how to deal with them.

TABLE 1. BASIC COMMUNITY DATA (1976)

	JAPAN				TAIWAN			KOREA		
	Hannoh	Higashi Kurume	Kyoto	Tateyama	Keelung	Pingtung	Tainan (Southern District)	Chuncheon	Yipyung	Yusan
Population	56,000	103,000	1,462,000	57,000	342,000	175,000	85,000	141,000	310	285
Population density (persons/km^2)	420	7,900	2,400	520	2,580	2,690	3,780	420	low	low
Average household size (persons)	3.8	3.1	3.1	3.3	5.1	5.3	5.1	4.9	5.3	5.3
Average household income ($/yr.)	6,300	6,600	11,790	5,080	2,930 1/	2,210 1/	2,990 1/	1,800	1,500	1,600
Population with piped water (%)	87	99	97	72	83	20	90	77	-	88
Average water consumption (lcd)	271	268	340	208	125	108	136	143	40	100
Population serviced by sewerage (%)	15	46	41	-	-	-	-	-	-	-
Population serviced by septic tank (%)	6	7	15	10	70	57	66	1	-	-
Population serviced by nightsoil collection (%)	59	46	41	81	29	29	9	74	-	-
Population serviced by pit privies or other private system (%)	20	1	3	9	1	14	25	25	100	100

1/ 1975 figures.

- Field studies of nightsoil collection and/or disposal confirm the findings of the literature review. As summarized in Table 1, studies were conducted in 10 communities with populations varying from 285 to 1,500,000 in Korea, Taiwan and Japan. The communities exhibited a wide diversity in average income levels, per capita water consumption, and climate. Their systems for waste disposal also varied widely. Annex 1 presents a descriptive summary of the technologies found in each community. Table 2 presents the technology cost comparison. The annuitized capital and annual operating costs of complete nightsoil cartage systems ranged from around $25 per household in Taiwan to around $170 per household in Japan in 1976. Reported costs for a sewerage system ranged from about $330 to $480 per household per year.

- Sewerage costs were found to be highly sensitive to the cost of incremental water usaage. Our cost estimates assume a difference of 80 lcd in the water consumption of a Japanese household with flush toilets and that of a similar household with vault latrines. 1/ The economic cost of incremental consumption was estimated by calculating the average incremental cost of water for each city. Thus in Kyoto, for example, where water is very expensive to produce, nearly one-fifth of the total sewerage cost represents the cost of incremental water usage.

- Consideration of environmental impacts of sullage disposal to surface drains reveals no significant degradation of water quality in streams receiving the dispersed discharges. In contrast, the discharge of sullage and sewage after treatment by conventional activated sludge results in point-source pollution.

1/ In Taiwan the water usage difference is 40 lcd due to low rate water use toilets.

TABLE 2. ANNUAL WASTE DISPOSAL COSTS PER HOUSEHOLD

(1976 US$)

	Household Cost		Collection Cost			Treatment Cost			Reuse Benefits			
	Capital	O&M	Capital	O&M	Incremental Water	Capital	O&M	Total Waste Disposal Cost	Fertilizer	Biogas	Fish	Net Waste Disposal Cost
Sewerage												
Hannoh	122.3	38.0	48.9	11.1	94.3	81.0	74.7	470.3	-	-	-	470.3
Higashe Kurume	126.6	31.0	29.9	3.2	58.8	45.7	35.1	330.3	-	-	-	330.3
Kyoto	124.8	31.0	66.8	9.1	95.0	110.5	44.6	481.8	-	negl. 1/	-	481.8
Septic Tank												
Japan (average)	181.6	60.8 2/	-	-	76.9	4.7	9.0	333.0	-	-	-	333.0
Taiwan (average)	187.9	76.5	-	-	29.8	-	-	294.2	-	-	-	294.2
Cartage System												
Hannoh	106.2	19.0	6.2	36.1	-	15.7	4.2	187.4	-	-	-	187.4
Higashe Kurume	99.5	15.5	3.0	13.6	-	14.0	14.9	160.5	-	-	-	160.5
Kyoto	97.5	15.5	5.4	53.9	-	7.3	5.6	185.2	negl.	-	-	185.2
Tatayama	87.7	16.5	2.8	17.5	-	7.3	13.9	145.7	negl.	negl.	-	145.7
Keelung	8.9	2.0	1.8	11.3	-	3.6	2.2	29.8	-	-	-	29.8
Pingtung	8.9	2.0	0.7	7.5	-	2.2	2.4	23.7	1.7	-	-	22.0
Tainan	8.9	2.0	2.0	14.1	-	-	-	27.0	-	-	1.2	25.8
Chuncheon	19.0	6.0	0.1	5.2	-	4.5	7.4	42.2	1.1	-	-	41.1
Vault Privies												
Yusan, Yipyung	9.4	12.5 3/	-	-	-	9.3	-	31.2	28.0	-	-	3.2

1/ Biogas produced in sludge digestion is used for heating the treatment plant.

2/ $130.8 with oxidation tank.

3/ Includes repair and emptying.

Note: Opportunity cost of capital: 10% for Japan, 12% for Taiwan, 14% for Korea
Conversion factors for foreign exchange: 1 for Japan, 1 for Taiwan, 0.89 for Korea
Conversion factors for unskilled labor: 1 for Japan, 0.90 for Taiwan, 0.81 for Korea
negl. = negligible.

December 23, 1977

- In African countries, where even urban population densities are significantly below Asian levels, on-site disposal systems provide comparable environmental and health benefits at much lower cost than community systems. IDRC sponsored research in Botswana, for example, has demonstrated the technical efficiency of improved pit latrines, Reed Odorless Earth Closets (ROECs), double vault composting latrines and aquaprivies in overcoming health and nuisance hazards. An economic cost comparison carried out by the Bank shows all such systems to be significantly cheaper on a per household basis than sewerage.

- A preliminary evaluation of the sewered aquaprivy, studied in Nigeria and Zambia, indicates that it may be a promising intermediate technology, making use of existing on-site investments as population density or water usage increases to a point requiring off-site treatment and disposal of wastes.

- Reuse on a community scale, as observed in some Korean and Taiwanese cities, does not significantly reduce net waste disposal costs. However, caution should be exercised in generalizing this result. In the communities studied waste reclamation was more of an afterthought than an integrated part of the system. Where farmers made their demand for treated nightsoil known the utility generally was willing to provide it. However, no attempt was made to set prices at a profit maximizing level or even to discover what sort of product the farmers would prefer so that more could be sold. The scope for capturing reclamation benefits on a community scale has not yet been explored.

In addition, they are able to sell two oxcarts of sludge for a total of $10.50 each year. Thus the net cost of waste disposal for this family is about $4 per year. If bottled gas prices continue to rise they will realize a net benefit.

Table 3. Annual Costs of Pingtung Biogas Unit

(1976 US$)

Construction cost	$ 227
Land (15 m^2)	355
Total Capital Cost	582
Annuitized Cost (20 years, 12%)	78
Desludging cost	16
Total Annual Cost	$ 94

0 A final technological implication which emerged from cross-country comparison is the importance of selecting a technology which is amenable to staged construction and upgrading. In many respects the Japanese systems are simply more sophisticated (and more expensive) versions of the Taiwanese systems, which in turn are more elaborate than the Korean. The level of environmental improvements reflects and parallels the capacity of the consumers to afford it. If priorities are to be determined by the users, a range of possible alternatives (rather than the "all or nothing" master plan) permits a closer matching of preference and technical solutions, as well as a more orderly progression over time in line with income growth and economic development.

Equally important are the demographic and economic constraints which may result in a first-stage project surviving for a long time which still must be capable of improvement to a higher service level at any time. If, for example, elimination of losses from a water system constitutes the first stage,

- Reuse demand was reported to be more sensitive to convenience and economic factors such as changes in relative prices of chemical fertilizer or labor costs than to concern over public health or aesthetics. As the opportunities for non-farm rural employment grow, farm households increasingly substitute chemical fertilizer for organic. This may be a short-term phenomenon. There are recent reports of Japanese farmers making private arrangements for obtaining nightsoil from areas served by municipal collection. Presumably, this nightsoil is used to restore humus, tilth, and water retention characteristics lost from the soil during three decades of intensive chemical fertilization. This indicates a developing agricultural need for appropriately handled nightsoil and a corresponding need for reexamining the long-term implications of technological and economic criteria used in construction, extension, and operation of sewerage systems.

- At the household level waste reclamation can provide significant economic benefits, at least for rural or semi-rural families who raise animals. The large size of household latrines in the two Korean villages studied (and hence their large initial cost compared to those of urban Chuncheon) is puzzling until one discovers that animal waste is being added to increase the volume of composted output. Indeed, the "net benefit" shown in Table 2 would nearly double if the compost from animal manure were included. Thus the entire operation yields the farmer a net benefit of about $20 per year on a $31 annual investment.

The household biogas plants in Taiwan present a similar picture. Table 3 shows the annual cost of a typical unit belonging to a family of 5 which also owns 5 hogs. The methane produced is more than sufficient to provide for their daily cooking requirements and thereby replaces the 20 kg cylinder of LPG that they formerly purchased each month for $6.27.

other conservation and maintenance measures will have to provide for basic needs until a delayed second stage is implemented. In any event, with rising interest rates and the shifting balance between capital and labor intensive schemes due to economic development, it is generally true that the smaller the stages, the lower the present-value cost of the total project. In other words, the more closely that demand and production capacity are matched, the more efficient the investment.

Public Health Implications of Technological Findings

The costs of alternative sanitation technologies are relatively easy to quantify. Environmental benefits, including tourism and reclamation, also can be defined and determined. Public health effects are more elusive. A major effort is being made in the World Bank's research project to develop better guidelines for assessing health benefits. At the macro level the Ross Institute of Tropical Hygiene, London, has been engaged to evaluate the relationship of different technologies for disposal of excreta and of sullage to specific categories of water and waste related diseases. At the micro level health data are being collected in all of the communities studied and, where possible, analyzed in connection with different levels of household sanitation. For example, in Egypt the results of 15,000 parasitological examinations of stool samples from residents of 40 villages with different cultural, environmental and sanitation features are being analyzed.

Preliminary results from our community studies show that no simple ranking of waste disposal technologies according to their effects on community health is possible. While good sanitation is certainly an important factor in promoting good hygiene, a sophisticated waste disposal system appears to be neither a necessary nor a sufficient condition for high levels of general health. Some African cities with waterborne sewerage have very high incidences of water related diseases. An opposite extreme is Kyoto where 40 percent of the population is served by nightsoil collection with sullage discharged to surface drains. Our consultants were unable to find any difference in the health profiles of those sections of the community served by collection from vaults as compared to those served by waterborne sewerage or septic tanks. Health authorities from the WHO and elsewhere have long stressed the importance of health education and other complementary programs to the simple provision of better water or waste disposal services. Our findings reinforce these views.

The pivotal importance of social and educational inputs to the improvement of community health leads to another conclusion relevant to the choice of waste technology. The most cost effective method for achieving a given improvement in environmental sanitation may be a package involving relatively low-cost technical designs (e.g., vaults, composting pits) coupled with an educational program on the effective use of the new systems.

Thresholds and Constraints

Research findings include preliminary identification of a number of public health, technological, environmental, economic, and institutional thresholds and constraints which affect the choice of sanitation technologies.

Recent technological advances include low-cost, low-technology composting systems (See Annex 2) which provide safe fertilizers. Other options for reclamation of nightsoil, garbage, and manures, include on-site and off-site systems for treatment or methane production. Methane (biogas) holds particular promise as an alternative energy source as costs of energy increase.

Environmental constraints are particularly important in areas subject to desertification such as northern and southern Africa, much of Asia, and parts of western South America. Here, the search for fuel is resulting in loss of trees, shrubs, and animal dung. Reclamation of biogas for direct use, of water for gardens, crops, and reforestation, and of organic fertilizer is expected to become increasingly important.

Institutional thresholds are still being defined. It is expected that data on sizes and economic development of urban centers and their support of water supply and sanitation services for surrounding rural areas will permit generalizations on optimum sizes of service areas. Studies of successful and unsuccessful institutional arrangements for financing these services will provide guidelines for further development.

The major economic threshold relates to household income levels. In non OPEC developing countries, where public sources of finance are invariably scarce, the community and individual willingness to pay for sanitation improvements sets a binding limit on what will be accepted and used. Where this has been ignored, for example, in building sewerage systems which require large household plumbing and water supply investments, a massive unwillingness to connect has led to the failure of the entire system. Household questionnaires reveal that sanitation, unlike water, is seldom top priority of poor families. Thus to propose facilities which cost more than about five percent of household income is to court community rejection and eventual system disintegration.

By the same token, as income levels increase it is important to respond to demands for improved service levels in an appropriate way. If, as in some African countries, a white porcelain seat is viewed as an important improvement, this can often be provided through an aquaprivy rather than sewerage at far lower cost for the same degree of customer satisfaction.

In any event, costs of providing a minimum level of service can properly be shared by both the beneficiaries and the larger community or national agency. In contrast, the costs of convenience or aesthetic satisfaction should be paid by the beneficiaries themselves.

Products and Implementation of the Research

Early products of the research are the annotated bibliographic and state-of-the-art reports on appropriate waste disposal technology and health effects prepared by the World Bank, IDRC, and the Ross Institute. Selected interim reports on individual country findings, pilot projects, and improved mechanical designs for sanitation systems are now available. An example is a recently completed review of composting operations and related research. (11) One of the interesting designs discussed in that report is a simple forced-draft aeration system that is being used in the U.S. to compost nightsoil and sewage sludge. Temperatures in excess of 70°C are sustained in windrows for several days, assuring complete kill of pathogenic organisms. The costs are low enough that in metropolitan areas where the alternatives for sludge disposal include incineration, distant burial, wet oxidation and other high technology processes, as much as $2 million per hectare could be spent for land without affecting the economic superiority of composting. Appendix 2, prepared by Dr. Hillel I. Shuval, consultant to the World Bank, presents a more detailed summary of these results.

Final publications will include books, field manuals, and instructional materials prepared for decision makers in development agencies, developing countries, consulting engineering organizations, and universities. These will aid in both the technical and economic evaluation of alternative water supply and waste disposal projects or urban projects with a water supply component.

Conceptual and final designs will be developed for improved mechanical devices; for prototype studies of alternative storage, collection, and transportation systems; for treatment and land application systems; and for final disposal systems. A provisional listing of technological options to be considered includes mechanical emptying and rejuvenation of pit latrines, mechanical seals for odor and fly control, replacement of bucket latrines with vault and hand-operated vacuum cart systems, condominium latrines, aerated-pile composting systems, and limited flow water supply and sanitation systems. Cooperative institutional support and participation in prototype studies is being developed within the various sectors of IBRD activities and with other international, bilateral, and private agencies.

Seminars, workshops, and specialty conferences are being planned for developing country officials and for their engineering, economics, and public health consultants.

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Waste Disposal and Reuse Technologies

Technologies vary widely among the ten communities studied. They are summarized as follows:

Kyoto, Japan. The population is 1 ½ million, 41 percent of which is served by separate or combined sewers leading to a conventional activated sludge plant with effluent chlorination. Water use is 340 lcd. Average per capita sewage flow is 852 lcd of which one third is industrial. Primary and waste activated sludge are treated by thickening, 2-stage digestion, elutriation, vacuum filtration, and incineration. Methane is desulfurized and used for boiler, incinerator, and electric generator fuel.

A system of vaults and vacuum trucks is used by another 41 percent of the population. 1.85 lcd is collected twice a month from household vaults using a municipal fleet of 213 trucks of from 0.5 to 7 tons capacity. Nightsoil is taken to a transfer station where it is comminuted, screened, stored, and discharged to a trunk sewer during off-peak hours. The system is sanitary, highly mechanized, and well controlled.

Nightsoil from 2 percent of the population (8000 vaults) is collected by private arrangements with farmers for use as fertilizer.

Higashi-Kurume, Japan. This is a satellite city, population 103,000, located 24 km northwest of Tokyo. Water use is 268 lcd. Separate sewers handle 408 lcd from 46 percent of the city. Only 2 percent of the flow is industrial. Another 46 percent of the city has municipal nightsoil collection of 1.43 lcd using nine 2 or 4-ton trucks which discharge to sewers for activated sludge treatment. Most of the remaining 8 percent of the population is served by septic tanks.

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Hannoh, Japan. Hannoh is a 56,000 inhabitant rural city, 48 km from Tokyo at the foot of the Chichibu range. 87 percent of the city consumes 271 lcd of tap water. The balance use shallow wells. 15 percent are served by sewers leading to an activated sludge plant, 6 percent have septic tanks, 59 percent have municipal nightsoil collection, and the remaining 20 percent are farmers who use their own nightsoil as fertilizer.

Tateyama, Japan. This is a resort city of 57,000 population, 72 percent of whom consume 208 lcd of municipal water. 10 percent have septic tanks, 81 percent are served by municipal nightsoil collection with vacuum trucks, and the rest are farmers who use thie own nightsoil. The municipal nightsoil is diluted with an approximately equal amount of water for trickling filter treatment.

Keelung, Taiwan. Keelung is a coastal city 23 km east of Taipei with 344,000 inhabitants. 70 percent of the people use septic tanks. 29 percent have municipal nightsoil collection by dipper and bucket, and the rest use their own nightsoil for fertilizer. The municipally collected nightsoil is diluted, pre-aerated for ten days, then treated by activated sludge and ocean discharges. Excess sludge is centrifuged and given to farmers.

Pingtung, Taiwan. This city of 175,000 population is located inland in southern Taiwan. 57 percent of the people have septic tanks, 29 percent receive nightsoil collection, and the rest of the nightsoil is collected at 3 or 4 day intervals by farmers. 40 tons of nightsoil (0.8 lcd) are collected by dipper and bucket at 2-week intervals. In 1976, 8,400 tons were sold to farmers.

Thirty famillites have biogas units for their nightsoil and the manure from an average of 5 pigs.

Tainan, Taiwan. This coastal city lies 300 km southwest of Taipei. 56,500 of the 85,000 people in the southern district of the city use septic tanks. Nightsoil (1.4 lcd) from 8,000 people is collected for sale to farmers and used for agriculture or aquaculture. The remainder is collected privately and sold by entrepreneurs.

Chuncheon, Korea. Chuncheon with 141,000 population is located 80 km northeast of Seoul. 74 percent of the population consume 143 lcd of piped water. 104,000 people have privately-operated nightsoil collection service by dipper and bucket, 60 percent of which is carried by four 3-ton tank or vacuum trucks to a new 100 kl/day capacity nightsoil treatment plant for 2-stage digestion. The nightsoil from the rest goes directly to farms. 36,000 people have shallow pit latrines and 1,000 have flush toilets discharging to surface streams.

Yipyung and Yusan, Korea. These villages have populations of 310 and 285, respectively. Nightsoil is stored in pits until full; then removed and composed with animal manures and crop wastes for use as fertilizers in orchards and on vegetable crops.

Hygienic Composting of Nightsoil by an Aerobic-Thermophilic Process

Prof. Hillel I. Shuval*

Current research by the World Bank includes evaluation of methods for hygienic and economical means of treating nightsoil by modern composting. These methods shows promise for initiation, continuation, or expansion of separate nightsoil collection, disposal, and safe reuse systems.

Nightsoil use as a fertilizer in agriculture has been practiced in China and other Asian countries for centuries and has been considered by most public health authorities as a serious contributing cause to the high levels of enteric disease and parasitic infestations which debilitate the population. Nevertheless, nightsoil use as a fertilizer has apparently play a critical role in maintaining vital soil fertility in areas of Asia so intensively farmed for thousands of years. For example, recent reports from China indicate that as a result of a national campaign for nightsoil treatment and reuse, one-third of the fertilizer requirements of agriculture in China has been provided by recycled nightsoil.

The public health problems to be overcome in nightsoil treatment and reuse are severe since research has amply demonstrated that nightsoil and sewage sludge carry high concentrations of the full spectrum of pathogenic bacteria, viruses, protozoans and helminths endemic in the community. Many of the pathogenic micro-organisms, helminths in particular, are highly resistant to the environmental conditions prevalent in conventional nightsoil and sewage sludge digestion and storage and can survive for weeks and even months in the soil and on fertilized crops.

From a survey of the literature on nightsoil treatment, it can be clearly concluded that the only fail-safe nightsoil treatment method which will assure effective and essentially total pathogen inactivation including the most resistant helminths such as Ascaris eggs and all other bacterial and viral pathogens is heat treatment to a temperature of $60^{\circ}C$ for several hours.

*Director, Environmental Health Laboratory, Hebrew University - Haddasah Medical School, Jerusalem, Israel

Pathogen inactivation caused by other environmental factors can be effective under certain conditions and for certain pathogens but cannot be considered as reliable as heat inactivation. To accomplish this by direct heating by conventional energy sources is out of the question because of high fuel costs.

The modern day search for economical and effective methods for nightsoil treatment by composting which will both assure protection of the public health and provide a continued supply of low-cost soil conditioner was started by Sir Albert Howard in India in 1931.

Extensive modern research in composting has demonstrated that the very high temperatures required for heat inactivation of pathogens can be obtained during the active decomposition of organic matter by aerobic thermophilic microorganisms that operate effectively in a temperature range of $45^{\circ} - 85^{\circ}$ C and generate the considerable amounts of excess heat energy required for destrying the more resistant pathogens.

Numerous experimental and full-scale composting plants have been developed during the last 30 years in an effort to achieve effective aerobic thermophilic composting of municipal refuse and sewage sludge under controlled conditions, many of which could be applied to composting nightsoil together with other organic wastes. However, most of these plants are based on very expensive high-level technology whose cost has usually been greater than could be afforded even in highly developed economies. In addition, serious operation and maintenance problems have plagued most of the systems.

For the present review, technological assessment of composting has concentrated on two locations where sewage sludge is composted prior to agricultural or harticultural utilization. One is the windrow composting plant of the County Sanitation Districts of Los Angeles (1975).

Here digested vacuum filtered sewage sludge with 23% solids is mixed with old well-composted sludge in open windrows turned at least once a day by huge mobile mechanical composter-shredder machines. The previously composted sludge provides for workability and moisture control. Maximum temperatures in the piles above 60°C have been reported for most piles while the temperatures in the external portion of the pile are close to ambient. All sludge is presumed to be exposed to 60°C or more for a period of time during the 35-day composting cycle since the piles are turned daily. Laboratory tests show that this process is reasonably effective in inactivating pathogens in the final compost, but some pathogens remain. This process is not considered appropriate for most developing countries because of its dependence on expensive and complex equipment presenting serious maintenance problems.

The second process is the Beltsville Aerated Rapid Composting (BARC) system developed at the U.S. Department of Agriculture's Agricultural Research Service Laboratories at Beltsville, Maryland (Epstein, et al, 1976). This process is based on mixing either raw or digested sewage sludge with wood chips as a bulking material. This reduces moisture content, provides a carbon source needed for more effective composting, and assures the open structure required for the free flow of air in the static compost pile aerated by a 4" (10 cm) perforated pipe under the pile. Other materials such as straw, rice hulls, or waste paper could be used. Air is drawn through the aeration piping system by a simple 1/3 hp blower. The only other equipment required is a front-end loader and a mechanical screening system for wood chip recycling which might not be required for all cases.

Research on the BARC system indicates that extremely high temperatures are achieved consistently in all portions of the fresh sludge mix, which is covered by 30 cm of old compost to provide insulation against heat loss, absorption of odors and water penetration. Maximum temperatures exceed

80°C while in no case has the minimum temperature at any point in the pile been lower than 60°C at least for a 2 - 5 day period. Under these conditions thermal inactivation of most pathogens can be assured. Laboratory assays for pathogens indicate that it is highly effective in destroying pathogenic bacteria, viruses and helminths. The BARC system has also been used effectively to compost nightsoil from the National Capital Park Service latrines. Sawdust is added as an additional bulking material to absorb the greater amounts of liquid in raw nightsoil. The estimated cost of sludge composting with the BARC system is $38.50/dry ton in a 50 ton/day plant, or about $8.50 per ton of wet sludge of 22% solids.

The BARC composting system appears to be ideally suited as a nightsoil composting system for developing countries because of its simple operation of limited inexpensive mechanical equipment and even more so because of its highly effective and uniform heat inactivation of pathogens which should assure that the final compost is safe from a public health point of view. The system further appears to be one which can contribute to solving the public health problems associated with continuing or expanding use of direct nightsoil disposal systems which are technologically between pit privies and expensive central sewerage systems.

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THIRTIETH WORLD HEALTH ASSEMBLY

WHA30.33

18 May 1977

COORDINATION WITHIN THE UNITED NATIONS SYSTEM - GENERAL MATTERS

United Nations Water Conference

The Thirtieth World Health Assembly,

Having considered the report of the Director-General on the United Nations Water Conference;[1]

Noting the recommendations made by that Conference, particularly with respect to community water supply and the priority given to the provision of safe water supply and sanitation for all by the year 1990; the priority areas for action within the framework of the Plan of Action formulated by the United Nations Water Conference; the actions to be undertaken at national level as well as through international cooperation; and the proposal that 1980-1990 be designated as the International Drinking Water Supply and Sanitation Decade;

Recalling resolutions WHA29.45, WHA29.46 and WHA29.47 concerning directly and indirectly the interests of WHO with respect to the provision of adequate and potable water and sanitary disposal of wastes;

Considering that previous mandates of the Organization, as stated most recently by the Twenty-ninth World Health Assembly in the resolutions referred to above, and the ongoing and planned programmes of WHO in the field of community water supply and sanitation enable the Organization, making maximum possible use of its national collaborating institutions, to play a leading role in implementing the relevant recommendations of the United Nations Water Conference, including the request to WHO to monitor the progress of Member States towards the attainment of safe water supply and sanitation for all by the year 1990, through technical cooperation with individual Member States and in cooperation with other concerned organizations, institutions and programmes of the United Nations system,

1. URGES Member States:

(a) to appraise as a matter of urgency the status of their community water supply, sanitation facilities and services and their control;

(b) to formulate within the context of national development policies and plans by 1980 programmes with the objectives of improving and extending those facilities and services to all people by 1990 with particular attention to specific elements such as:

(i) the elaboration of sector development policies and plans through comprehensive studies of the national water supply sector;

(ii) the development of alternative approaches and materials so as to suit best the particular conditions of the country;

(iii) the identification and preparation of investment projects;

[1] Document A30/28 Add.2 and Corr.1.

(iv) the improvement of the operation and maintenance of facilities, including the surveillance of drinking water quality;

(v) the assessment of water resources, and their conservation;

(vi) the prevention of pollution of water resources and spread of disease resulting from water resources exploitation;

(vii) the improvement of manpower and management capabilities;

(c) to implement the programmes formulated in the preparatory period 1977-1980 during the decade 1980-1990 recommended by the United Nations Water Conference to be designated as the International Drinking Water Supply and Sanitation Decade;

(d) to ensure that people consume water of good quality by periodic inspections of water sources and treatment and distribution facilities, by improving public education programmes in the hygiene of water and wastes, and by strengthening the role of health agencies in this respect;

2. REQUESTS the Director-General:

(a) to collaborate with Member States in the above-mentioned activities, including the provision of specialized staff upon the request of Member States, with immediate efforts to be made for a rapid assessment of ongoing programmes and the extent to which they could usefully be expanded to meet the objectives recommended by the United Nations Water Conference;

(b) to revise as appropriate the review being undertaken in accordance with resolution WHA29.47 operative paragraph 5 (4), with a view to meeting the terms of the recommendation of the United Nations Water Conference concerning country plans for water supply and sanitation, and as a major contribution to the preparations for the proposed International Drinking Water Supply and Sanitation Decade;

(c) to ensure WHO's fullest participation in implementing the Plan of Action formulated by the United Nations Water Conference and in the actions to be undertaken during the proposed International Drinking Water Supply and Sanitation Decade, in close collaboration with the concerned organizations of the United Nations system, other intergovernmental bodies, and nongovernmental organizations;

(d) to reinforce if necessary WHO's longstanding ability, making maximum possible use of its national collaborating institutions, to play a leading role in the field of community water supply and sanitation in cooperation with the other concerned organizations of the United Nations system;

(e) to strengthen collaboration with multilateral and bilateral agencies and other donors regarding the provision of resources to Member States in the development of their water supply and sanitation programmes;

(f) to study the future organizational, staffing, and budgetary implications for the Organization, and the role it should assume in the light of the recommendations of the United Nations Water Conference; and

(g) to report on developments occurring in the light of the present resolution to a future Health Assembly under a separate agenda item.

Thirteenth plenary meeting, 18 May 1977
A30/VR/13

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THIRTIETH WORLD HEALTH ASSEMBLY

WHA30.40
18 May 1977

DEVELOPMENT AND COORDINATION OF BIOMEDICAL AND HEALTH SERVICES RESEARCH

The Thirtieth World Health Assembly,

Having considered the Director-General's report[1] on Development and Coordination of Biomedical and Health Services Research;

1. THANKS the Director-General for his report;

2. NOTES with satisfaction the orientation of WHO's research promoting and coordinating activities in conformity with the Sixth General Programme of Work;[2]

3. ENDORSES the research policy guidelines outlined by the Director-General, with particular attention to:

(a) the role of WHO in strengthening national research capabilities, promoting international cooperation, and ensuring the appropriate transfer of existing and new scientific knowledge to those who need it;

(b) the emphasis on greater regional involvement in research, with the active participation of regional Advisory Committees on Medical Research;

(c) the setting of research goals and priorities in the regions in response to the expressed needs of Member States;

(d) the concept of Special Programmes for Research and Training in major mission-oriented programmes of the Organization;

(e) the keeping of an appropriate balance between biomedical and health services research;

4. REAFFIRMS that effective biomedical and health services research activities aimed at the solution of major health problems of Member States, especially of developing countries, play an important role in technical cooperation between the World Health Organization and Member States;

5. CONFIRMS the need to strengthen further the research development and coordination mechanisms outlined by the Director-General with emphasis on:

(a) close coordination between the regional and the global Advisory Committees on Medical Research in the long-term planning and development of the WHO research programme;

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[1] Document A30/9.

[2] Sixth General Programme of Work Covering a Specific Period (1978-1983) - WHO Official Records No. 233, 1976, Annex 7.

(b) collaboration with Medical Research Councils or analogous national research bodies to ensure effective coordination of national, regional and global research programmes;

(c) utilization of research promotion mechanisms, such as scientific working groups, to ensure broadly based participation of the scientific community in the planning, implementation and evaluation of WHO's research programmes;

(d) increased technical cooperation with, and between, research institutions of Member countries to carry out collaborative research and training and improve communication between scientists;

(e) developing and strengthening research into the more efficient deployment of resources within health care delivery systems, especially on a national and regional basis;

(f) broadening the basis of advice and support for Health Services Research by extending the membership of the Advisory Committee on Medical Research and related Committees and the WHO Collaborating Centres to include social, management and other sciences;

(g) increasing the number of Collaborating Centres in the field of health services research, and ensuring the strengthening of this research;

(h) achieving a balanced geographical distribution for Collaborating Centres for biomedical and health services research;

6. REQUESTS the Director-General to further elaborate the WHO long-term programme in the field of development and coordination of biomedical and health services research, taking into account the suggestions of the Advisory Committee on Medical Research, of Regional Committees and Regional Advisory Committees on Medical Research, as well as the forecasts of developments in medical science and health practice in Member States, and to report his further proposals to the Executive Board and to the World Health Assembly.

Thirteenth plenary meeting, 18 May 1977
A30/VR/13

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THIRTY-FIRST WORLD HEALTH ASSEMBLY

WHA31.34

23 May 1978

ACTION PROGRAMME OF APPROPRIATE TECHNOLOGY FOR HEALTH

The Thirty-first World Health Assembly,

Having considered the report of the Director-General[1] and resolution EB61.R31 on the activities of the programme of Appropriate Technology for Health,

1. THANKS the Director-General for his report;

2. NOTES with satisfaction the development of the programme of Appropriate Technology for Health in pursuance of resolution WHA29.74 and expresses its desire to see it implemented throughout all levels of the Organization;

3. INVITES Member States to promote the use of available appropriate technology and develop new technology needed for the better implementation of health care, particularly of primary health care;

4. REQUESTS the Director-General

(1) to intensify involvement of Member States in the further development of a global plan of action for the programme of Appropriate Technology for Health and to foster cooperation with and between Member States as well as with other appropriate international agencies both inside and outside the United Nations system in this very important field of public health;

(2) to report to a future session of the Executive Board and a subsequent World Health Assembly on the progress of this action programme.

Twelfth plenary meeting, 23 May 1978
A31/VR/12

[1] Document A31/14.

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23 May 1978

DEVELOPMENT AND COORDINATION OF BIOMEDICAL AND HEALTH SERVICES RESEARCH

The Thirty-first World Health Assembly,

Having considered the Director-General's report on Development and Coordination of Biomedical and Health Services Research;[1]

Recalling resolutions WHA25.60, WHA27.61, WHA28.70, WHA29.64 and WHA30.40;

Reaffirming that effective biomedical and health services research aimed at the solution of major health problems of Member States, especially of developing countries, plays an increasingly important role in effective technical cooperation between the World Health Organization and Member States;

1. THANKS the Director-General for his report;

2. ENDORSES steps already taken to implement the relevant resolutions of the World Health Assembly;

3. NOTES with satisfaction the reorientation of the Organization's research activities, particularly through the greater involvement of regional Advisory Committees on Medical Research in defining programmes of action consonant with national and regional health priorities;

4. URGES Member States to:

(1) review their research needs and institutions with a view towards strengthening their research capabilities;

(2) collaborate among themselves and with WHO in accelerating relevant programmes for biomedical and health services research;

5. REQUESTS the Director-General:

(1) to continue to pursue the Organization's long-term efforts to coordinate and promote research, emphasizing:

(a) strengthening the research capability of Member States;

(b) fostering technical cooperation with and between research establishments of Member States;

(c) involving more closely the Executive Board, Regional Committees as appropriate, and the Advisory Committees on Medical Research in the formulation of policy, the definition of priorities and evaluation of the Organization's research activities;

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[1] Document A31/15.

(2) to present to the Executive Board and the World Health Assembly a comprehensive programme of research in which WHO is involved, as requested by the previous resolutions of the World Health Assembly, covering priorities of Member States outlined in the Sixth General Programme of Work, as well as the special research programmes, including the programme of health services research; and

(3) to report periodically on progress, as appropriate, to the Executive Board and the World Health Assembly.

Twelfth plenary meeting, 23 May 1978
A31/VR/12

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THIRTY-FIRST WORLD HEALTH ASSEMBLY

WHA31.40

23 May 1978

COORDINATION WITHIN THE UNITED NATIONS SYSTEM: UNITED NATIONS WATER CONFERENCE

The Thirty-first World Health Assembly,

Having considered the reports of the Director-General on follow-up to the Mar del Plata Action Plan of the United Nations Water Conference,[1] and on WHO's Human Health and Environment Programme;[2]

Recalling resolution WHA30.33 on the United Nations Water Conference;

Emphasizing the need to make a determined effort to attain the targets of the International Drinking Water Supply and Sanitation Decade and particularly to meet the needs of those populations now deprived of these services;

Emphasizing further the need for participation by all sectors of national and international institutions that can contribute to attain the Decade target;

Considering that the participation of the community is indispensable and that special efforts are required to provide full information to the population to encourage community participation;

1. URGES governments:

(1) to mobilize all possible resources for an accelerated effort to provide safe water and sanitation to all people within the framework of the Decade;

(2) to prepare plans with realistic standards for water supply and sanitation;

(3) to develop necessary organizational arrangements that will facilitate pooling of all available resources and focusing them on meeting priority health needs;

2. REQUESTS the Director-General:

(1) to strengthen technical cooperation with Member States in preparing for the International Drinking Water Supply and Sanitation Decade;

(2) to promote cooperation and coordination at the international level with the aim of increasing awareness, priority and the flow of external resources for water supply and sanitation;

(3) to identify clearly the contribution of the Organization for the Decade as part of the medium-term programme for the promotion of environmental health.

Twelfth plenary meeting, 23 May 1978
A31/VR/12

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[1] Document A31/45.

[2] Document A31/27.

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THIRTY-FIRST WORLD HEALTH ASSEMBLY

WHA31.44

24 May 1978

PROGRAMME ON DIARRHOEAL DISEASES CONTROL

The Thirty-first World Health Assembly,

Concerned by the high rates of morbidity and mortality from acute diarrhoeal diseases, particularly in children;

Recognizing that diarrhoeal diseases constitute a serious socioeconomic and public health problem;

Aware of the recent advances in knowledge on different aspects of acute diarrhoeal diseases, particularly the progress made towards the application of simplified and effective methods of diagnosis, treatment, including rehydration, and control;

Recalling the commitments made by Member States in various forums towards the control of these diseases;

Endorsing the priority accorded to this problem in the WHO Sixth General Programme of Work;

Noting with satisfaction the actions already taken by the Organization at the country, regional and global levels, with a view to launching a major attack on diarrhoeal diseases;[1]

Conscious that the application of simple and effective measures for prevention and control of diarrhoeal diseases would constitute an important element in increasing the effectiveness and acceptability of primary health care services;

Bearing in mind the importance of proper nutrition for the prevention of diarrhoea and its complications, especially in infants and young children, as stressed in resolution WHA31.47;

1. URGES Member States to identify diarrhoeal diseases as a major priority area for action, and to apply known effective measures for the management and control of diarrhoeal diseases in the primary health care context;

2. REQUESTS the Director-General:

(i) to intensify involvement of Member States in the development of a plan of action for an expanded programme on diarrhoeal diseases control and to collaborate with Member States in the development of the Programme at country level, with particular reference to its integration into present or future development activities in health and other fields;

(ii) to promote technical cooperation with and among Member States in programme formulation, implementation and evaluation, and in training health workers at different levels;

(iii) to accord high priority to research activities for the further development of simple, effective and inexpensive methods of treatment, prevention and control of diarrhoeal diseases in areas having varying kinds of health service facilities;

3. EXPRESSES appreciation to UNICEF for the support already given to action against diarrhoeal diseases and for its continued cooperation;

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[1] Document A31/A/Conf.Paper No.14.

4. CALLS UPON UNDP, IBRD, UNFPA and other international organizations and funds actively to support this Programme;

5. THANKS the Government of the United Kingdom of Great Britain and Northern Ireland which, through its generous contribution, has given an initial impetus to the Programme, and urges other governments to provide further support to allow the Programme to expand;

6. REQUESTS the Director-General to keep the Executive Board and the World Health Assembly informed of the progress made in the implementation of the Programme on Diarrhoeal Diseases Control.

Thirteenth plenary meeting, 24 May 1978
A31/VR/13

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RESOLUTIONS

THIRTY-FIRST WORLD HEALTH ASSEMBLY

WHA31.44

24 May 1978

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Thirteenth plenary meeting, 24 May 1978
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