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6th WEDC Conference
24 28 March 1980

at AHMADU BELLO UNIVERSITY
Zaria, Nigeria

water and waste engineering in Africa

PROCEEDINGS

edited by John Pickford and Susan Ball

Water and waste engineering for developing countries

published by the WEDC Group

Department of Civil Engineering
University of Technology
LOUGHBOROUGH
Leicestershire LE11 3TU
England

January 1981

ISBN 0 906055 11 3 *softback*

Printed by the University Printing Unit

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His Highness The Emir of Zaria ALHAJI SHEHU IDRIS

OPENING ADDRESS

It is my great pleasure to welcome you to this important and timely International Conference on "Water and Waste Engineering in Africa". It is important because its theme covers the two aspects of the United Nations' Declarations - water supply and sanitation. And it is timely because it marks the beginning of the "Water Decade" (1981-1990) designated by the United Nations. This is the decade in which the general population of the world will have access to safe drinking water and appropriate sanitation.

I am sure you are aware that Nigeria is at the threshold of industrial and technological advancement. Its successful take-off cannot be achieved without an adequate water programme for human consumption, industrial and agricultural uses. Agriculture is the cornerstone of our economy and to achieve the "green revolution" which the Nigerian Government sets as a priority, water becomes an essential ingredient.

If there is an area where we have to learn from the experience of the industrialized nations, perhaps it is in the area of pollution. In our rush for technological advancement, we tend to overlook the potential dangers of pollution of our rivers, lakes and the environment in general. But we cannot enjoy the fruits of technological advancement if we fail to prevent environmental degradation which usually accompanies industrial activities.

The importance of water in our national development is underscored by the zeal with which both the Federal and State Ministries are tackling the problems of water supply. We are lucky to have with us today the Permanent Secretary to the Federal Ministry of Water Resources who will elaborate more on this in his keynote address. I am also happy to note that we have experts at this Conference from many parts of the world, who will highlight the various aspects of water resources and environmental problems. I therefore hope that your deliberations during the Conference will guide us into solutions that are feasible, economical and compatible with our present level of technology.

I sincerely welcome you to Zaria and I will enjoin you to visit as many places as possible within its environs before you leave.

Ladies and Gentlemen, it is my pleasure to declare this International Conference opened.

Dr ANWAR ABDULLAHI
Vice Chancellor, Ahmadu Bello University, Zaria

WELCOME ADDRESS

I have the pleasure to welcome all of you to Ahmadu Bello University, Zaria and to address you on this important International Conference titled "Water and Waste Engineering in Africa". This subject is of utmost importance to the overall development of this continent. Your choice to hold the Conference in Nigeria and more especially at Ahmadu Bello University, is indeed an honour to us.

The provision of safe drinking water and proper waste disposal facilities has become one of the most urgent issues in Africa in recent years. It is now clear that no real development can be achieved without the accomplishment of these two major environmental factors. The urgency of this vital issue has been very well documented in the recent survey of the World Health Organisation (WHO). The findings of the survey indicate that only three out of four Africans living in urban areas have access to safe drinking water and only two out of three are provided with proper waste disposal facilities. The situation in the rural areas is much worse. In these areas only one out of five Africans has access to both safe drinking water and sanitation facilities. It is quite clear from the survey that the rural area with an estimated population of about 85% of the total population is really underprivileged. The Third World in general and Africa in particular is badly affected by this disturbing situation.

The United Nations Organisation is aware of the urgency of this major environmental problem and has accordingly declared the present decade (1981-1990) as the "Water and Sanitation Decade". The target is "safe drinking water and proper sanitation for all by 1990". A combined global effort will be required to carry out this tremendous mission. It is my sincere hope that the deliberations of this Conference will contribute in no small way to the achievement of the excellent set goal of the Decade.

I would like to thank the Loughborough University of Technology in general and the Water and Waste Engineering for Developing Countries (WEDC) Unit in particular for organising this Conference jointly with Ahmadu Bello University Department of Civil Engineering.

The choice of Ahmadu Bello University as the venue for the Conference is thoughtful and wise because this University continues to encourage the development of Water Resources and Environmental Engineering Studies. A Division of Water Resources and Environmental Engineering has already been established in the Department of Civil Engineering. The Division provides a whole range of graduate and post-graduate courses to many relevant Departments within the University. Plans are in an advanced stage to establish a seperate Department of Water Resources and Environmental Engineering which will be capable of producing the urgently and badly needed manpower in this vital field.

Distinguished guests, on behalf of Ahmadu Bello University, Zaria, I say "welcome" and wish you a successful and fruitful deliberation in your important assignments. I wish you safe journey back to your respective stations at the end of this important International Conference.

Dr S Y AKU
Dean of the Faculty of Engineering, Ahmadu Bello University, Zaria

WELCOME ADDRESS

It gives me great pleasure to be present at this very important Conference which is being declared open this morning by His Royal Highness, the Emir of Zaria, Alhaji Shehu Idris. The Vice Chancellor has already welcomed you to Ahmadu Bello University and I think it is only proper that I should welcome you in particular to the Faculty of Engineering. Our Faculty, which is one of the oldest in Black Africa,was started in the middle fifties as the Faculty of Engineering of the University College Ibadan. The first degrees of London University were awarded in June 1960. With the creation of Ahmadu Bello University in 1962, the special relations with London University ended in June 1965 when the first graduates of Ahmadu Bello University were produced. Up to the end of the first decade of the existence of the University, the Faculty consisted of three Departments - Civil Engineering, Electrical Engineering and Mechanical Engineering.

Specialisations in Land Surveying and Quantity Surveying in the Civil Engineering Department formed the nucleus of the Department of Surveying which was created in 1975. The Agricultural Engineering section of the Institute for Agricultural Research developed into a separate department in 1974 in the Faculty of Agriculture and was transferred to this Faculty in October 1977. The Industrial Chemistry course in the Department of Chemistry developed into the Chemical Engineering Department which became part of this Faculty in 1977.

The Mechanical Engineering Department has continued to grow and a division of Metallurgical Engineering was created in 1977 and will become a separate Department in October 1980. The various State Governments and the Federal Government requested for specialised courses in Water Resources in the middle sixties and post graduate courses in Water Resources were introduced in 1967. These courses have earned wide recognition with the result that various Governments in the country, UNESCO and WHO have requested that we mount undergraduate courses in Water Resources and Environmental Engineering. In response to the needs of society, the Department of Civil Engineering worked very hard to develop a very reputable team of Water Resources and Environmental Engineering experts and a division of Water Engineering was created in October 1977. This division is becoming a full fledged Department in October 1980. Your Conference is being hosted by this new Department and I am sure that your Conference on Water and Waste Engineering in Africa is going to enhance further the reputation of the Department.

Having given you this brief history of the Faculty and the development of the Water Resources and Environmental Engineering Department, I once again extend our very warm welcome to you in the Faculty and wish you a pleasant stay in Zaria, and very successful and fruitful discussions.

6th WEDC Conference: March 1980: Water and Waste Engineering in Africa

N O POPOOLA
Permanent Secretary, Federal Ministry of Water Resources, Lagos

Keynote Address: WATER CRISIS IN AFRICA

Presented by: Dr O C IGWE

The importance of the topic of this Conference needs no further explanation in so far as it affects the world in general and Africa in particular. There can be no other proof of the concern of the world community in respect of the world water resources and environmental situation, than the historic Conference held in Mar Del Plata, Argentina a few years back. This Conference, sponsored by the United Nations, met to discuss what is considered a near crisis situation in world water resources. That Conference, it will be recalled, also discussed strategies for the solutions of problems associated with the development of water resources world-wide.

The situation in Africa is a rather unique one because the elements that go to create a crisis in water resources can be identified. Indeed these are being identified from time to time. A brief discussion of these elements will be made in this address.

It should be realised that discussing and talking about problems from time to time has not necessarily led to the solutions of those problems. And this indeed is what Africa has been doing. Africa must change this approval. We must learn to solve or attempt to solve problems rather than for ever discussing them. Discussions are necessary, especially in a forum such as this, where experiences are to be pooled. The only thing is that discussions should be meaningful and directed towards known problem areas with a view to finding acceptable but practicable solutions.

We could look at one example. We can ask what is the most modern method of waste disposal available and prevalent in Africa or more specifically in Nigeria today. If you consider the case of human waste, the answer will be varied and will depend very much on the locality. This situation is confirmed by the recently concluded Rapid Assessment Programme by the Department of Water Resources for the World Health Organisation in respect of water resources utilisation in Nigeria.

The method of waste disposal must of necessity affect the quality and reliability of water supplies, especially in situations of burst pipes and leaks. Such effects may also have engineering and health implications.

We shall now try to examine some of the elements we referred to earlier on , and which to our mind contribute to some crisis situation in water resources in Africa as we know it today. In this context, the following are easily identified:

1. Geography
2. Absence of technology
3. Absence of priority
4. Lack of water resources planning data
5. Lack of proper personnel
6. Lack of sincere involvement in regional and sub-regional co-operative effort.

These elements will now be treated one by one in the order indicated above, in order of priority.

<u>Geography</u>

This is the element which, by its nature, very little can be done about. Indeed the little that can be done will, through the intervention of science and technology, enable man to have a measure of control over what nature provides. The history of desert formation is very well known to most of us and we must accept the desert or near-desert situations as they are. The Kalahari and Sahara Deserts are typical desert situations in Africa, where nature ensures that in so far as water resources are concerned, crisis situation abounds. Even in areas where the desert situation does not exist, the effect of the vagaries of meteorological phenomena could create crisis situation. The desert is not known to support much vegetation and yet it could. Even in areas where the rainfall pattern is fairly predictable, crises do occur when such predictability becomes unreliable. Therefore some human technological intervention becomes necessary. This could be by way of long term forecasting or by storage or even by mining where underground water resources exist. The desert situation is not peculiar to Africa, but because of Africa's situation the effect becomes more intense. We are now talking about the philosophy of skills to intervene for the purpose of remedying the situation.

Absence of Technology

As mentioned earlier, technological interventions do help to save situations in crisis. We have heard so much about transfer of technology or techniques and yet not much has been achieved. In effect, one could say that nothing has been achieved. Certainly this is a challenge to African Engineers and Technicians who must make deliberate attempts to rededicate themselves to the solution of local problems through the application and adaptation of scientific know-how. Practical knowledge and competence can only be acquired through practice. It is a matter for regret to notice that today many of our young engineers and other professional colleagues close their minds totally to the fact that the acquisition of theoretical competence is only the first step towards becoming skillful professionals. There is the ugly tendency for our young engineers and other professionals, after their second and third degrees, to abandon field work, and opt for the office. It appears to me that the professional bodies in this continent must re-examine this whole situation and suggest a solution. There is no doubt that, with time, it should be possible to evolve an atmosphere where preliminary training and practical experience would be the desire of any engineer or other professional individual. But there are known militating factors. The scarcity of Water Engineers in this continent is probably dictated by the lack of incentive and other professional job satisfaction. What can we do about this? This is because, apart from the very top management in most of our Water Resources Establishments, very few experienced hands are available to generate interest among the newly recruited young Engineers. It is feared that, in time, the experienced hands may leave, and they have to leave someday; in which case the entire set-up may virtually collapse. To acquire technology, there has to be the receiving medium, in this case the man, the right man with the right attitude.

Absence of priority

It is not unusual in the very recent past to see a project conceived and implemented with no regard for some essential elements such as water supply, which could make such projects effective. This type of approach is even extended to Regional and National planning where not enough priority is placed on water supply or Water Resources Development as a necessary development input. Here the crisis is that of the mind and of the mentality which relegates this important element to the background.

Lack of Water Resources planning data

In all the discussions in Africa since the 1960s, related to Water Resources Development, one major crisis item is the lack of Water Resources data. We are not discussing here the availability of long-term data because that in itself is very difficult to come by. Not only this, much consideration goes into the decision as to whether a set of long term data is reliable or not. In the case of water resources, land use practice certainly affects and influences most of the deciding parameters. We do not see why it should not be possible to give the acquisition of data in water resources the same priority as is given to activities such as the development of roads, airports, new towns etc. The acquisition of accurate water resources planning data is a most important determining factor in the development of our land resources, energy, navigation etc. In Africa, except in a very few cases, even the basic network for data acquisition does not exist. This, to our minds, is one of the elements which causes the so-called crisis in Africa.

Lack of proper personnel

It will therefore appear that some of the crises as we know them are not crises in the real sense. The so-called crisis simply arose because man in Africa has not realised that he must intervene positively with nature, first of all by understanding the normal phenomena, then using technology to turn this phenomenon to his advantage, and finally to continue to monitor what effect his intervention is having on his environment.

Lack of sincere involvement in regional and sub-regional co-operative effort

This address shall not be complete without mentioning the role and importance of regional co-operation in the solution of what we now call water crisis in Africa. Examples of such co-operation are already available between the Sudan and Egypt. There are areas of Africa where billions of cubic meters of water run to waste into the sea. This same amount of water could be used to generate power, which could be used then to transport water from that same source to areas of need, either for the purpose of domestic supply or for the betterment of the environment. Equatorial Africa, for instance, has this feasibility and potentiality, while Tropical and Sub-tropical Africa have the need. Therefore it would appear that the crisis we have must be in most parts, a crisis of ignorance of the size of our resources and our inability to effectively utilise those resources either locally, sub-regionally or regionally.

The elements which, to our minds tend to frustrate us in our attempt to develop water resources are not so insurmountable. All that is necessary is the determination to find solutions. The solution shall not be possible until a change occurs in our attitudes. We must be willing to accept the challenges of our environment and understand at the same time that it is us, and largely no-one else, who must resolve the crisis. We shall however welcome assistance - especially positive

assistance which will not continue to
emphasise the hopelessness of our situation.

I do wish all of us a very useful and
fruitful Conference.

ROBERT R BANNERMAN

HAND PUMP MAINTENANCE PROGRAMME: GHANA

MAINTENANCE OF REGIONAL RURAL WATER SUPPLIES - THE GHANIAN APPROACH

1. INTRODUCTION

A Regional Well Maintenance Programme was implemented between 1974 and 1978 in the Upper Region of Ghana in support of the installation of 2 400 wells equipped with hand-pumps (see figure 1). This was part of Ghana's Upper Region Water Supply Project, jointly financed by the Government of Ghana, through the Ghana Water and Sewerage Corporation (GWSC), and the Government of Canada, through the Canadian International Development Agency (CIDA) and Consultants.

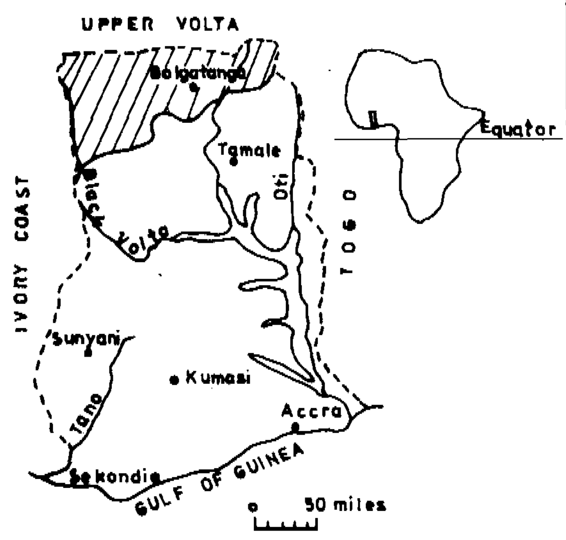


FIG. 1 LOCATION MAP OF GHANA

▨ — PROJECT AREA

The main objective of the Programme was to have a network of well water supplies throughout the Upper Region effectively maintained and kept in continuous operation in order to optimize the serviceability and life span of the units (see Plate 1).

2. SCOPE OF WELL AND PUMP MAINTENANCE

The well design and construction were carried out in a manner which would minimize the need for maintenance. Similarly, great care was exercised to ensure the selection of hand-pumps, which would require a minimum of maintenance within economic reason. Despite these precautions, it was evident that the ultimate success of the entire project would depend upon the effectiveness of the maintenance programme.

Generally, a pump malfunctions when the screen is clogged, the leather-cups have become worn, or the water table has dropped. In most cases, hand-pump mechanical failure develops where the pivot points become worn or the handle is broken due to rough usage.

It is desirable, therefore, that each well be checked and serviced periodically. This entails an inspection of the exterior working mechanism, lubrication of the bearings and replacing the worn out parts. At the same time, an examination of the pumping capacity would indicate if a major below grade problem existed.

3. COMPONENTS OF THE MAINTENANCE PROGRAMME

3.1 Organization Pattern

The amount of servicing which the wells and hand-pumps would actually require was the most important factor that determined the organizational structure, capital outlay, manpower, transportation and equipment requirements of such a Maintenance Programme. This, even though was difficult, must be predetermined.

The strategy was adopted was to:

(i) establish the well maintenance activity within the existing GWSC organization, with control at the regional headquarters;

(ii) operate the well maintenance function from five district centres, with defined boundaries;

(iii) construct and equip workshop facilities at the headquarters and at the district centres;

(iv) conduct maintenance of hand-pumps as two separate activities:

(a) inspection and minor repairs on a 2 to 3 month frequency;

(b) complete pump service on "as required" basis.

In order that rural wells and hand-pumps service would not have to compete with other services in the region, such as urban distribution systems, it was set up as a separate function.

3.2 Personnel

The GWSC Regional Manager was responsible for the Programme and provided general direction. He was assisted by the Maintenance Engineer and Field Supervisor who were responsible for the continuous functioning of the programme.

A total of 250 field and workshop staff consisting of a core of trained technicians and mechanics were assigned. At the district levels these personnel had only well maintenance responsibility.

Most of the staff were newly-hired. However it was found desirable to use some of the existing staff to fulfill some of the new functions and this facilitated training.

Training for the experienced staff was aimed at upgrading their organizational and technical skills through on-the-job experience. Newly-hired staff received training in the maintenance, servicing and repair of vehicles and hand-pumps; and in record keeping, related to work performed and materials used. The experienced staff were used to train the newly-hired through on-the-job and formal sessions.

3.3 Transportation and Equipment

A complement of vehicles, mechanical and electrical equipment for the districts and workshops were carefully selected, after consideration of the levels of service to be provided at each district.

Vehicle access to a large portion of the hand-pump sites necessitated following trails, footpaths and crossing cultivated fields. Thus transportation throughout the rural areas, especially during the rains and the growing season, was of particular concern.

Due to the poor access to the pumps, occasioned by the limited road network, and due to the ever increasing cost of fuel, it was decided to utilize lightweight trail motorcycles for routine inspection of the hand-pumps (see Plate 2).

Whereas inspection required a very limited service capability, complete field servicing of a hand-pump necessitated the availability of at least two men having a service vehicle, equipped to remove and replace hand-pumps, drop-pipes, cylinders, leather-cups etc., that is, all below grade components.

The type and number of service trucks located in the districts were dependent upon the number of wells to be serviced and the distances to be traversed. These trucks were equipped with front-mounted winches; rear-mounted derrick facilities; compartments on both sides of the truck for storing spare parts; tool boxes full of accessory tools and equipment (see Plate 3).

3.4 Workshops and Stores Depots

In establishing the workshops, consideration was given to the level of services to be provided at the regional headquarters and in the districts.

Maintenance workshop operations consisted of:

(i) repair, service and maintenance of vehicles (trucks and motorcycles);

(ii) repair of hand-pumps;

(iii) repair, service and maintenance of mechanized pumps;

(iv) storage and control of supplies and equipment.

Generally the workshop buildings incorporated the following facilities:

(i) offices for supervisor/foreman;

(ii) stockroom for pump and vehicle parts;

(iii) sanitary facilities;

(iv) maintenance and repairs sections.

At the Regional Stores Dept, a complete stock of pump, vehicle and equipment spares and consumable supplies was maintained. At the district depots only stocks of fast moving parts and consumables for pumps and vehicles were kept.

The Regional Stores had responsibility for the procurement of local supplies including: petrol, gas-oil, lubricants, cement and disinfectants required for well maintenance. Also, they were in charge of the identification and scaling of a large quantity of off-shore running spares, consumables and equipment.

Supplies were distributed to the districts and field under a controlled stores ledger system.

3.5 Field Operations

The centre of the Programme was set up at Bolgatanga, the regional capital, where the main stores supply depot and the major repair workshop for pumps, vehicles and equipment were located. Here too a complete set of records of all the wells in the region was kept on file and up-dated as data were submitted from the District Maintenance Offices. Communication between the Headquarters and the Districts was facilitated by radio communication.

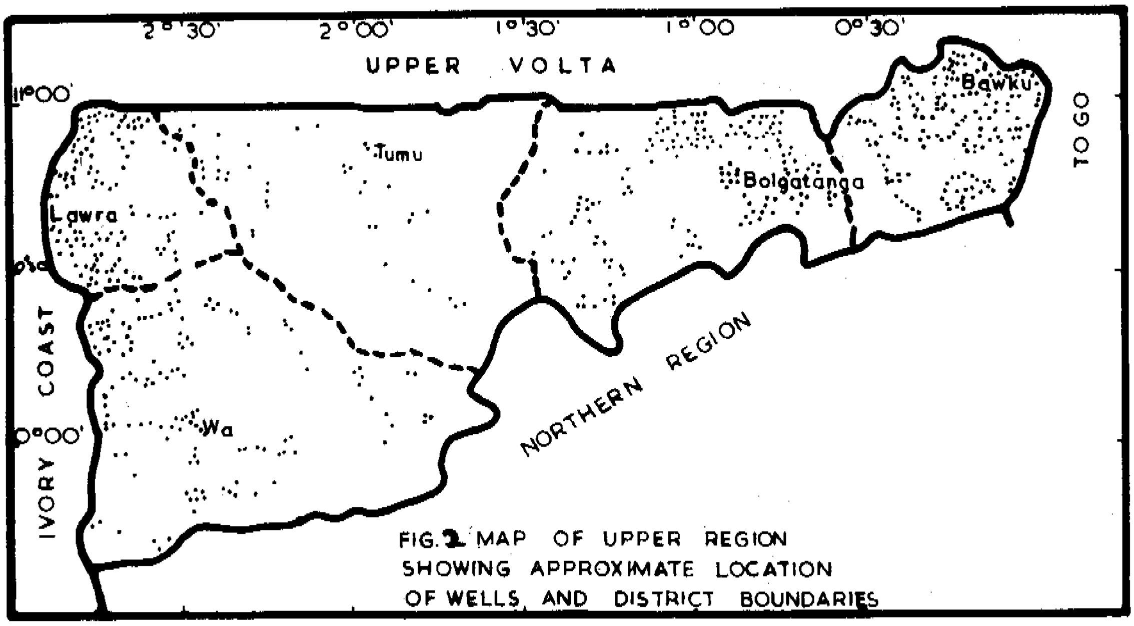


FIG.2 MAP OF UPPER REGION SHOWING APPROXIMATE LOCATION OF WELLS AND DISTRICT BOUNDARIES

Field operations were carried out within five maintenance districts at Bawku, Bolgatanga, Tumu, Lawra and Wa (Fig.2). In each district, a system of motorcycle inspectors, service truck crews and workshop facilities was provided.

The operation was first established on a pilot stage in one district - Bawku - and on a successive district by district basis, until the entire region was fully serviced.

Each of the district organizations operated independently under the general direction of the Regional Headquarters, represented by the Maintenance Engineer and Field Supervisor. The District Officer was responsible for the repair, servicing and maintenance of hand-pumps and wells in his district.

Mechanics utilized eight lightweight trail motorcycles for routine inspections of the hand-pumps, along designated routes within the districts (Fig 3), providing a site visit every 2 to 3 months. They also carried out lubrication of pumps, provided preventive maintenance as well as made minor repairs and reported on pump failures. On the average 80% of the total hand-pumps in the region were inspected each month.

Eight specially equipped service vehicles also based in the districts carried out repairs on hand-pumps which could not be completed by the inspectors. These units did not make routine inspections, but responded only to reports from the inspectors or the villagers of pump failures.

A reported breakdown of pumps was scheduled into the work programme of the service vehicles. Normally a response time of pump repair was at least 3 to 4 days after a failure was reported. Since there was usually more than one well in each community adjacent wells were used in the interim.

The service vehicle crews also undertook maintenance and repair of mechanized well pumps and periodic chlorination of the wells and pumps.

3.6 Reporting and Maintenance Records System

Proper communication among the Maintenance Staff themselves on one hand and between them and the rural water consumers on the other was particularly important at the very early stages of the programme implementation.

In fact, part of the reason for such frequent inspections of hand-pumps was because of the lack of adequate communication facilities. Therefore the routine inspections served as a reporting system for servicing needs. Hence procedures and lines of communication for reporting had to be clearly spelt out.

A record system was incorporated into the Programme so that a history of repairs for each well could be filed. The records were used as a basis of administering the routine servicing of each well. Other users were for stocking of spares, upgrading maintenance procedures and for programming future maintenance activities throughout the region.

The total cost of the implementation was approximately 8 million Ghanaian Cedis (₵4.75 - 1 Naira, December 1979).

Operating Costs

As well maintenance was established as an integral part of the GWSC regional maintenance organization, it was difficult to assess the exact operating costs of the programme. Even though effort was made at the initial stages to keep separate accounts of its operations, things fell apart due to lack of interest and control by the responsible officers.

The nature and scope of operating costs however involved:-

(i) operating cost of service vehicles;

(ii) operating cost of workshop and repair facilities; and

(iii) manpower costs.

Being part of regional maintenance, facilities such as personnel, buildings, equipment and vehicles were shared with other units. For example, some of the head-quarters management, accounting and records personnel, had regional responsibility. Also, in order to avoid duplication of functions in the districts some of the staff such as accounting, sotres and security personnel were shared.

4. EVALUATION OF THE MAINTENANCE PROGRAMME

4.1 Pump Performance

Pump performance and well site conditions are a reflection on the efficiency of the Maintenance Programme. These were monitored monthly and annually through the record system. A survey was conducted at the end of the third year's operation of the programme to assess the performance of the hand-pumps and to assess the prevailing sanitary conditions. The highlights were as follows:-

(i) 83% of all the pumps in the region were in operation. The relative performance by districts indicated a variation between 68% and 90%.

(ii) For these pumps out of service 11% involved features above the pipe flange and could be repaired by the Motorcycle Inspector. The remaining 89% needed service trucks to hoist below-grade components.

(iii) A visual inspection of these pumps which were still in operation revealed that:

(a) 63% were in good condition
(b) 28% were in fair condition
(c) 5% were in poor condition
(d) 4% were in very poor condition.

These results were considered very satisfactory as compared with results of surveys conducted in East Africa and Bangladesh, where some systems actually failed at a more rapid rate than they were installed.

The survey results verified the accuracy of the on-going District Maintenance Records and the monthly reports pertaining to percentage of pump operating at any point in time. It also provided an accurate picture of the field situation.

4.2 Site Conditions

It was observed that 56% of all wells had some site improvements carried out. Of the wells inspected 38% had back-fill placed around the concrete pad, while an additional 18% had extended concrete pads constructed by the villagers. Well site sanitary conditions were considered to be:

(a) 52% in good condition
(b) 35% in fair condition
(c) 13% in poor condition

The problem of creating insanitary conditions around standpipes in urban distributing systems is not very different from this!

4.3 Field Operations

(i) To optimize the efficiency of the inspectional services preventive maintenance and minor repair capability was added on. Additionally, to avoid unnecessary duplication of site visits, service crews conducted some inspectional work on these hand-pumps which were in close proximity to defective units, which had been programmed for complete field servicing.

(ii) Field records were analysed and general statistics were developed on the down-time on:

(a) pumps, motorcycles and service trucks,

(b) number of pumps visited per day worked by motorcycle and truck;

(c) percentage of pumps inspected which required service trucks.

These were used to establish time-targets for repairing pumps in each district. (See a sample of some of the forms which were completed monthly at the district level, for the records, in the Appendix).

(iii) Due to the ever-increasing cost of fuel and sometimes its unavailability in the region, it was decided to change from using petrol trucks to diesel trucks; The benefit was in terms of lower operational cost and more reliability.

(Would it not have been worthwhile using horses and donkey-carts in some peculiar environments!!)

(iv) The hand-pump water supply systems installed in this dry region were not designated to include the provision that livestock could be watered and small gardens irrigated.

Nevertheless, it was observed that small dug-outs or water holes existed at about 70% of the well sites. Of a total of 1178 water holes, 792 of them (67%) were considered unsatisfactory because they were less than 20 feet (6 metres) from the well.

However, evidence of excessive animal excrement around the well heads was observed at less than 1% of the wells, in spite of the fact that animals regularly came to many of the well-site water holes. It was similarly observed that the number of small vegetable gardens in the vicinity of the well sites (in some of which fertilizer was applied) was multiplying. Even though these activities would most probably have significant economic impact, their nearness to the well sites, generated insanitary conditions and presented likely pollution hazards to the water supplies.

(v) The routine inspections provided the necessary public relations and training input required with the introduction of the new supplies to the villages. For example, an element of training was imparted to the rural populace who were not accustomed to using mechanical equipment such as hand-pumps.

(vi) Certain aspects of the records system such as measurement of static water levels would prove useful to future hydrogeological considerations regarding changes in the water resources of the region.

(vii) The personnel involved in the maintenance programme coped very well with the new concepts and tasks. They acquired such a high social status at the village level as was not envisaged at the on-set of the programme. Their visits to the well site proved useful in communicating with the villagers and educating them regarding pump usage, water conservation, well head sanitation and maximising the health benefits of the newly established water supplies.

4.4 Villager Involvement in Hand-Pump Maintenance

It was evident that most villagers were willing to participate in maintenance and could improve the overall pump performance and well site conditions if encouraged to do so.

Based on recent experiments which showed that the below grade components of hand-pump could be removed, repaired and replaced manually, without using a service truck, it is feasible that the villagers could one day provide a complete maintenance and repair service for their hand-pumps. It should be appreciated that a few locally made special tools would be needed to facilitate manual servicing. But it will undoubtedly take several years training before this can be achieved without outside assistance.

In view of the ever-rising cost of maintenance, the inherent problems of vehicle breakdowns, and the encouraging response by the villagers, this avenue is already being considered.

A Water Utilization Project has been initiated in the region with the objectives of stimulating the villagers towards maintenance of pumps by themselves and involving them in community development and adult and health education.

5. CONCLUSIONS

The Well Maintenance Programme has only been in operation for a little over three years. One is often tempted to evaluate the success or failure of the entire water supply programme by the maintenance performance but in doing so it should be appreciated that more time will be required for the evaluation of the programme. The performance and results to date can only be described as being borne out of the gestation period! It is important to monitor the maintenance on a continuous basis.

The types of hand-pumps installed on the wells are not the best types available yet to the programme. Resulting from the Hand-Pump Field Testing Programme which is currently being carried out in the area, improvements through upgrading and modifications are expected in the design of future pumps and this may affect the maintenance programme concept and field operational strategy substantially.

Even though the villagers could be trained to carry out regular maintenance and repairs of hand-pumps, but first a word of caution! Under no circumstances should consideration be given to eliminating the use of service trucks at this time. And complete maintenance at the village level without the technical know-how of motorcycle inspectors is unrealistic for the foreseeable future. Even if a giant step were taken toward village involvement and most maintenance was being provided at the local level, some service trucks would still be needed in the system for special circumstances and to transport new pumps and unwieldy sections of drop pipes and sucker rods.

To provide an independent maintenance and repair service by competent villagers will require an extensive training programme over a long period of time. Therefore, the present centrally controlled system involving service trucks and motorcycles will be essential for a long time to come.

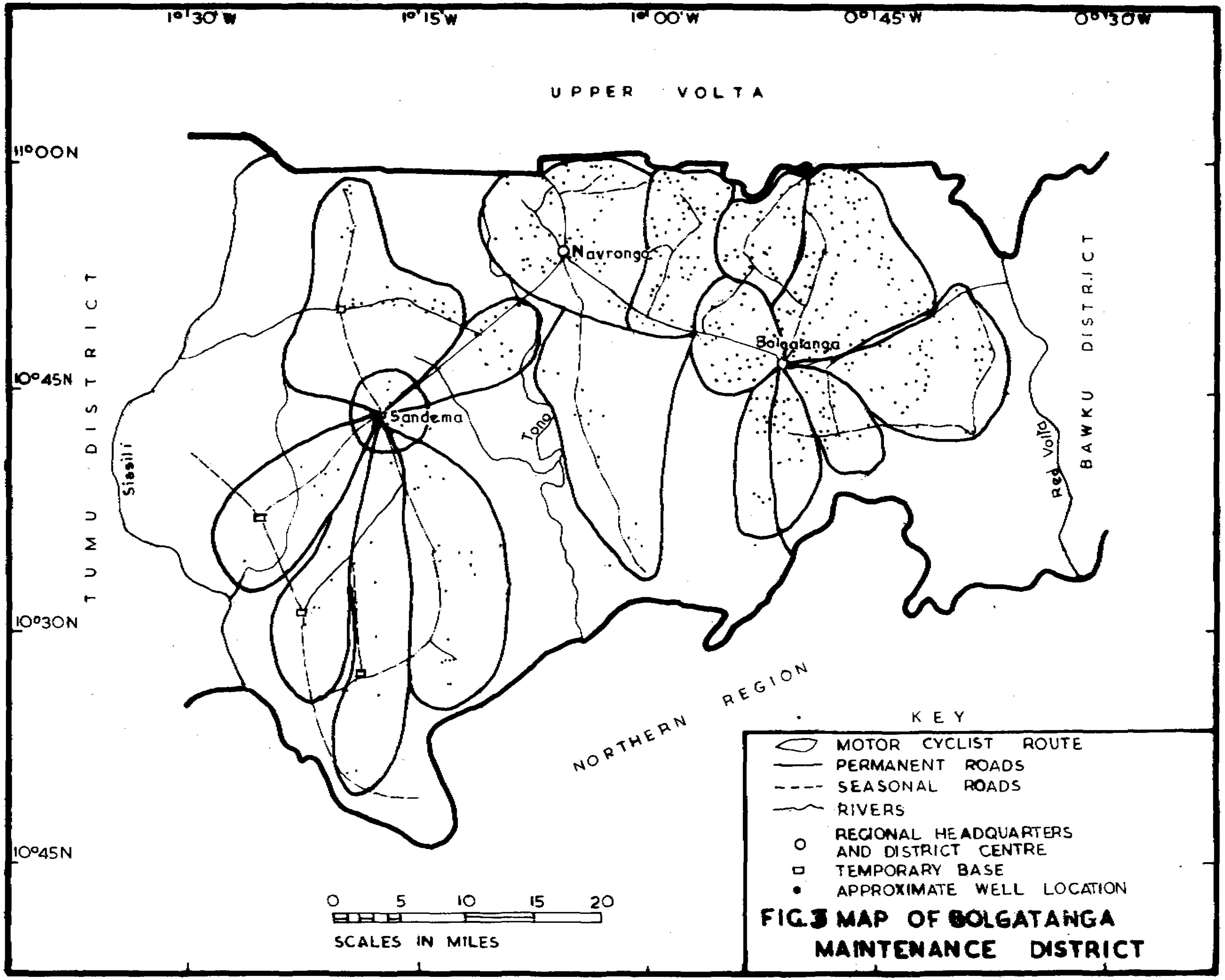


FIG.3 MAP OF BOLGATANGA MAINTENANCE DISTRICT

DISTRICT MONTHLY REPORT

District .... Month ending .... 19..

1. From Motorcycle Inspection Log

a. No. of hand pumps inspected ....
b. No. working on arrival ....
c. No. working but repaired by motorist ....
d. No. not working and repaired by motorist ....
e. No. working but requiring service truck ....
f. No not working and requiring service truck ....

2. a. No of hand pumps reported not working by villagers but not reported by motorist ....
   b. No. of hand pumps reported not working by villagers and also reported by motorist ....

3. a. No. of hand pumps serviced ....
   b. No of pumps requiring service at month end ....
   c. No of mechanical pumps serviced ....

4. Hand Pump Inventory

	TYPES OF PUMPS			
a. Hand pumps on wells in District at end of last month	....	....	....	....
b. Hand pumps removed from old wells	....	....	....	....
c. Hand pumps installed on old wells	....	....	....	....
d. Hand pumps installed on new wells	....	....	....	....
e. Total hand pumps on wells in District at end of month	....	....	....	....
f. Hand pumps in stock requiring repairs	....	....	....	....
g. Hand pumps in stock ready for installation	....	....	....	....

5. Vehicle usage

	miles travelled	gallons of fuel	m.p.g.
a. Motor Cycle No	....	....	......
b. Motor Cycle No	....	....	......
c. Service Truck No.	....	....	......
d. Service Truck No.	....	....	......

SERVICE TRUCK REPORT

Date ....

District .... Service Unit ....

Travelling time .... Time spent on site ....

Well number .... Village ....

Type of pump .... Static water level taken Yes / No (from top of concrete base)

Pump operating on arrival Yes ... No ...

Work done	Parts replaced	
	Number	Name
....	......	....
....	......	....

Comments: ....

3 Copies

1. White to Region Officer
2. Canary to District Office
3. Pink remains in Report Book

....
Serviceman's signature

....
Serviceman's name

VEHICLE DOWN TIME

NOTE: RECORD ONLY WORKING DAYS VEHICLE WAS NOT USED

District .... Month ending ....

Vehicle No .... No of working days ....

No of days worked ....

Date	No work to do	No Operator	No petrol	Mech problem	weather	other
....	....	....	....	....	....	......
....	....	....	....	....	....	......

WELL SERVICE RECORD

Well No ....

District .... Village ....

Well Location ....

Type of pump ....

Date well drilled .... Depth of well ....

Diameter of casing .... Recommended yield ...... Igpm

Date serviced	Pump operating on arrival		Work done	Parts replaced		Static water level
	Yes	No		Number	Name	

RECORD OF BROKEN-DOWN HAND PUMPS

District ...., Month ending ....

Well No	Type	AG	BG	Date down	Date repaired	Remarks
....	....	....	....	....	....	....
....	....	....	....	....	....	....

RURAL WELL INSPECTION LOG

Well No.	Date	Village	Odometer reading	Well operating on arrival		Work done	Parts replaced	Service Truck required	
				Yes	No			Yes	No
....	......	....	....	....	....	....	....	....	....
....	......	....	....	....	....	....	....	....	....

PLATE 1: A HAND-PUMPED WELL WATER SUPPLY

PLATE 2: A TRAIL MOTOR-CYCLE EQUIPPED FOR ROUTINE WELL INSPECTION

PLATE 3: A SERVICE TRUCK EQUIPPED FOR WELL AND PUMP MAINTENANCE AND REPAIR

6th WEDC Conference: March 1980: Water and Waste Engineering in Africa

HUGH C BALFOUR

THE DEVELOPMENT AND IMPLEMENTATION OF WATER SUPPLY PROJECTS IN THE SEHAL AREA OF WEST AFRICA

INTRODUCTION

The author has been travelling extensively in West Africa for the last nine years. Since that time he has travelled in Senegal, Ivory Coast, Mali, Upper Volta, Niger, Cameroons and Nigeria, but his involvement in projects has been confined to Mali and Nigeria so far.
The purpose of this paper is to consider the information that is necessary to develop a water supply service throughout extensive areas in the Sehal region and to develop a system which includes the training of local engineers in construction and maintenance work, it being the intention that completed schemes can be operated satisfactorily and the experience learnt by the local engineers can form the basis of a continuing programme of design and construction.

BASIC INFORMATION

When the author first visited West Africa he was fortunate enough to be in charge of a water supply "sector study" for the World Health Organisation, which required the following information to be obtained and correlated:

1. Drawing up an inventory of the water supply facilities in the country which might in some cases be done on a sample basis.
2. Studying the institutions and organisations in the country which plan, execute and operate water supply facilities.
3. Appraise and identify potential financial resources.
4. Make an inventory of existing manpower and study training facilities available in the country.
5. Reviewing the managerial, technical and financial operation of existing water supply undertakings.
6. Assessment of the country's capacity to absorb external technical and financial assistance, identifying factors which might exercise constraint on developing and executing a national programme.
7. Identification of priorities for water supply development in the entire sector, indicating cities, areas and communities.

Shortly after commencing work in the country we were particularly fortunate to be asked to add a further clause to our terms of reference:
8. Making a tour of the country to ascertain the resources and needs of the provincial towns and to identify priorities.

This additional clause is, in the author's opinion, of great importance as it provided the opportunity for the collection of reliable and comparative information by engineers knowledgable in matters of water resources and supply. As a result of this more intimate knowledge of the problem we were far better equipped for the subsequent discussions on finance and management and were able to keep these matters well controlled because of our detailed local practical knowledge.

PLANNING FACT-FINDING TOURS

In Mali three seperate major tours were planned which covered nearly every settlement in the country. It is important to plan such tours carefully to ensure as far as possible that the maximum benefit is obtained.

It is not possible in the space available to explain exactly what was done and it may be irrelevant to other countries even in the Sehal area, but the following may be of interest:

1) Matters to be considered by personnel undertaking tours.
a) Population distribution.
b) Water resource distribution.
c) Transportation (on a commercial basis).
d) Mineral and other natural resources.
e) Development of existing commercial and agricultural interest.
f) Existing administative system.

The detailed consideration of these matters formed the basis of a questionnaire which was completed at the time of visiting each town or village, and was signed by the local Mayor or Chief as appropriate.

2) Preparation for team.
a) Staff - suitable staff available for tour.
b) Number of vehicles available for the tour.
c) Suitable time of year, bearing in mind condition of the roads and relevant water resource information.
d) Availability of fuel, food, rest houses etc.
e) Communications in case of emergency.
f) Emergency rations, spare parts, de-ditching gear etc.

The length of the tours should be limited within reasonable physical and mental requirements, and we found that tours preferably not exceeding four weeks were acceptible.

PREPARATION OF SECTOR STUDY

On the completion of the tours of all towns and villages, and the careful logging of the relevant information and diaries of the visit, an impressive amount of reliable information is available. The first part of a sector study should consist of a clear statement of the basic facts required in the Terms of Reference.

The next section should deal with design criteria which have to be adopted in order to arrive at basic sizes of structures for estimating purposes.

The estimating section of the study is always a problem, particularly in times of high inflation, as even if the estimates are realistic when produced, those schemes of low priority tend to get estimates which will inevitably prove to be unrealistic. This problem can be minimised by giving the final presentation in numerical order of priority, by giving costs of only those schemes likely to be carried out immediately, the remainder being on a comparative basis using a numerical index.

During the preparation of any study it must never be forgotten that its purpose is to provide economic projects which operate reliably and fulfil the basic requirements for which they were intended, and that the study is not an end in itself.

The efficient realisation of projects in the Sehal area may well require more attention and effort than the design. We should be more aware of this as it seems to be quite common to prepare several reports on the same project and nothing is in fact achieved.

CONSTRUCTION WORK

The construction of projects in remote areas should be designed to be relatively straightforward.

For schemes of water supply a considerable amount of effort has to be put into the laying of pipelines and services. In pipe-laying the main problem is to ensure that the pipe is laid carefully on a satisfactory bed. This is a relatively simple operation but requires patience, care, constant checking and testing.

The construction of wells, small pumping stations, river intakes, treatment works and ground tanks can also be relatively simple if carefully designed, The use of complicated construction techniques should not be considered in remote areas unless they are part of a big scheme and can show substantial savings.

On one occasion the author acted as Consulting Engineer for the design of a scheme and then went on, with the assistance of the local Water Department, to carry out the construction by direct labour. This method was originally proposed as the construction work was in a remote area where local contractors capable of the work were not available, and the value of the contract was not sufficient to attract international companies, This method gave very good experience to local engineers, site foremen and others, and enabled the Water Department to undertake maintenance and repair work. It also provided detailed experience for future schemes. The experiment worked well, but the advantages reaped would have been greater had there been continuity of work.

TRAINING

It is the author's opinion that a lot of the training going on in his own country, and yours, can be seen to be heavily biased towards academic training, and he does not believe that this present balance is an advantage. It is clearly necessary for those in responsible positions to have a good basic academic knowledge, but it is also vital to have skilled tradesmen available on any construction site.

Practical experience is of prime importance and it is suggested that attention should be given to encouraging young men into the practical side of construction. Consideration should be given to making them feel that it is a useful and socially acceptable job which can form the basis of a rewarding and satisfying career.

LORENZ A RAYMANN

EXPERIENCE OF COMMUNITY DEVELOPMENT DEPARTMENT AND SATA –HELVETAS WITH RURAL WATER SUPPLIES AS SELF–HELP PROJECTS IN WEST CAMEROON

PAPER on CD/SATA for the

6th WEDC Conference: 25-26th March 1980
WATER AND WASTE ENGINEERING IN AFRICA
at Ahmadu Bello University, Zaria, Nigeria

EXPERIENCE OF COMMUNITY DEVELOPMENT DEPARTMENT AND SATA-HELVETAS WITH RURAL WATER SUPPLIES AS SELF-HELP PROJECTS IN THE CAMEROONIAN GRASSFIELD

INTRODUCTION

The Community Development Department (CD) - integrated in the Ministry of Agriculture - assists the rural population in the improvement of their conditions of Life. Its Technical Section provides the villages with the required technical assistance for the construction of their infrastructural projects, mainly water supplies.

The Swiss Association for Technical Assistance (SATA-HELVETAS) is a private non-profit making humanitarian organisation, subsidized by the Swiss Federal Government, assisting developing countries in the improvement of their rural areas. SATA-HELVETAS sends out experts to work mostly in the framework of the Ministries and Departments concerned. In Cameroon, vast experience could be gained in the fields mentioned below due to sixteen years of cooperation.

Beside the field-offices, CD/SATA also maintains a Building Training Center in Kumba, South West Province.

COMMUNITY PARTICIPATION IN PROJECTS

The community participation is the central idea of CD/SATA. The participation consists of the following activities:

1. Initiative: The village has to raise the project. It has to apply for technical and administrative support with the Community Development Department. CD and SATA-HELVETAS only take action where the initiative and the application for help is carried out by the community.

2. Administration and Organisation of the community with view to the project. The village has to form a project committee which will take over the further responsibilities. The committee will organise the collection of the cash contribution, keep an account, and transfer the money to the project account of the divisional CD office.

The committee is also responsible for the organisation of the community members on the community work days. Additionally, the committee carries out some administrative work such as organising meetings and writing the minutes.

3. Contribution in cash and in "kind": There are more or less fixed percentages of the overall cost of the project which have to be contributed by the communities concerned. The "kind" contribution mainly consists of labour like clearing of bush and forest, digging of pits and trenches for water supply projects, removing of the top soil for road projects, the supply of local materials like sand, stones and timber, the planting of grass and trees in the catchment areas, and of the administrative work of the project committee as mentioned above.

For further information concerning the cash and "kind" contribution, I should like to refer to the paragraph "FINANCING OF THE PROJECTS".

The importance of the community participation

Community participation in the realisation of a water supply project is enormously important, especially with view to the future maintenance of the scheme. The lifetime of a project is basically depending on the insight of the population into the necessity for maintenance.

Insight into this necessity can be promoted by engaging the people already during construction time. If there is participation, the people see with their proper eyes, and perceive with their proper hands what has to be undertaken to execute a project. And this experience might further the interest and the insight into maintenance work.

To some extent, the special engagement of a few persons, mostly teachers, reverend fathers, midwives and other educated people, is the most efficient "community participation". These persons are leaders together with the traditional leaders for the motivation and education of their co-inhabitants. They thus represent often the key-positions in the committee.

If there are no influential people representing the villagers in the committee, there will never be informative motivation and never a well working maintenance. Our experience shows that the personality of some committee members is the guarantee not only for a good co-operation between community work and the skilled workers during construction time, but also for the future functioning of the maintenance. In the North West Province there are water supplies which are a dozen years old. Most of them are working well, while others are totally out of use due to lack of maintenance.

Our experience also shows that the execution programme has to be based on the output of the community. It is by far better to suspend work on a project if the community participation is neglected in order to give time for further motivation, than to continue and complete work without any support by the community.

The project might be realized in a shorter time if the programme would not be based on this participation. It therefore seems that it would be even more economical not to base on participation, but on paid labour. Only, if we consider the significance of participation for the motivation and education of the villagers, the participation promotes the insight into the necessity of maintenance. Finally, if the lifetime is considered, only a well working maintenance, keeping the scheme running for decades, produces the best possible cost-benefit ratio of a project.

TECHNICAL STANDARD AND MAINTENANCE

The technical standard of a water supply project and the extent of its maintenance are connected with eachother. Therefore, the two fields cannot be separated from eachother.

1. General technical standard for rural water supply projects of CD/SATA: On the one hand, the technical standard of our water supply projects is extensively determined by the local possibilities concerning the availability of building materials and of labour.E.g. in the North West Province, where good quality of Basalt stones and Granit can be found everywhere, but no gravel, most of the buildings are constructed in masonry. Even round storage tanks up to 100 m3 are built in stone masonry and covered with an arch dome in concrete. Whereas in the South West Province where stones can hardly be found but where gravel is available, we apply concrete work.

On the other hand, we choose an appropriate technology which reduces future maintenance to a minimum. Therefore we try to design water supplies where the water runs by gravity, from the catchment through treatment stations, the storage tanks and right to the public taps of the distribution net. Wherever possible, we avoid to install pumps or even turbines. In some of our projects where gravity schemes are not possible, a hydram successfully replaces a pump. The maintenance of a hydram is by far not as pretencious as it is for a pump, generator or turbine. Gravity schemes use to run throughout the whole year, whereas supply schemes which require pumping use to break down from time to time, or for ever, due to lack of fuel or spare parts.

The technology of the tap stations should also be adequate to the public use in remote areas. Both, the construction and the hydraulic installations, need a careful and strong design. On our projects, we apply the following four types of public tap stations:
- public standpipes
- public washplaces
- public fountains
- public shower houses.

All of them are standardized according to the experience made in the past years of application. Standard plans which have been worked out help to construct robust buildings whose quality was improved according to the gained experience. Standardized buildings also have the advantage of simple control of the execution work.

To the most sensitive parts of the hydraulic installations belong the taps. Up to now, the traditional bip cock has proved to be the best solution, if it is of a strong quality. Soaking hoses we never apply due to hygienic inadequacy. Self closing taps have been installed since a few years however. They might be the best solution for very low pressure where no waterhammer has to be expected.

At the beginning, the piping was done mostly with asbestos pipes. But in various projects the aggressivity of water against cement was strong enough to gradually destroy asbestos pipes. Therefore PVC pipes are used more and more. They additionally have the advantage of being very light. Therefore transports are easier than with asbestos pipes, and furthermore, pipes are spoiled less.

2. Operation and maintenance: For the first projects realized some fifteen years ago, no special care was taken for the maintenance, as it is the case for so many programmes in developing countries. Especially some small supplies like waterpoints show now a poor state, mostly caused by an insufficient drainage of the places. Also a few larger

projects broke down almost completely due to lack of maintenance. When we became aware of that, the following measures were taken:

- In each village where a water supply is to be built, a villager will be engaged on the project throughout the whole construction time. He will become the future caretaker.
- This man will not only be trained by the plumber on all the plumber work, but also by masons in masonry work.
- Additionally, the department organizes short courses for caretakers in its Building Training Center. There, the caretakers also learn some theory about water supplies and caretaking.
- "Regulations on Maintenance" were worked out by the engineers and the administrative personnel. As soon as the regulations will be approved by the Ministry, they can be applied within the Department.

The caretaker's work consists of the following:

- control of the intake and catchment areas,
- control, cleaning and repairs of all the chambers, operation rooms, basins, sedimentation and storage tanks,
- running the slow sand-filters if existing,
- control, cleaning and repairs of the pipe network including the low and high points,
- control and maintenance of the public taps.

In his weekly work, the caretaker is supported by the community. So, the responsibility for the clearing of the surroundings of the public taps is always with the quarter concerned.

Technically, the caretaker gets support by the technical staff of the Department whenever he needs help. The Technical Section of the Department supervises the caretakers' work in the villages.

3. Water quality and water treatment in remote areas

(please compare the sketch attached)

Usually, water treatment is suggested if the water has to be taken out of a stream. But if a skillful maintenance of treatment stations cannot be guaranteed constantly due to lack of adequate staff or lack of purification chemicals etc., the water quality might alter again and again (5). While the water quality is better than the WHO standard in case of proper maintenance (5a), it might be reduced to the original poor quality far below the standard in case of breakdowns (5b). Yet, for the health of the consumers it is generally better to supply water of a medium quality permanently (4) than to get the people used to purificated water over a certain period (5a), and suddenly to supply them again with polluted water (5b).

To sum up:

- In remote areas where no spring can properly be caught the streams available shall be caught as far as possible from populated areas and from grazing areas in order to get the purest possible water.
- No purification except sedimentation shall be provided.
- The whole intake area of the stream shall be protected, and trees planted.
- Slow sand filtration might be foreseen if adequate personnel for maintenance and supervision can be guaranteed permanently.

ON-THE-JOB-TRAINING OF SUB-PROFESSIONALS

1. Locally trained caretakers

As already stated under the paragraph "Maintenance", we locally train caretakers on the very project for which they will take care in future. It might be, indeed, a good sample of a sub-professional trained on the job site. On CD/SATA projects, these people first work within a mason group, under the leadership of an experienced headmason or foreman. During that time, he gets accustomed to concreting and masonry work. More importance of course we attach to the training within the plumber group. The future caretaker joins the plumber group as soon as an experienced plumber starts his job on the caretaker's water supply project.
Now he learns the dicing of steel pipes, the laying of the PVC-, steel- and asbestos-pipes respectively. He gets to know all the necessary fittings, where to put and how to join them. He will be present and he will cooperate when all the installations inside the control and operation chambers of the catchments, interruption chambers, treatment stations, and storage tanks are fitted. He gets to know the importance of low and high points, of airation pipes etc. Thus, he learns all the practical work he has to execute himself in future.

Since these caretakers will be dependent on themselves to a large extent after completion of their projects, CD/SATA trains them not only on the job. From time to time, a special course is organized by the Building Training Center of the Department. This course lasts a few weeks and is directed by the plumber instructor of the Building Training Center. The participants are trained again in theory and practical work. Yet, special importance will be attached to the understanding of a water supply scheme as a working unit which has to run without any breakdown. The special duties of a caretaker are explained and exercised.

This combined training, both in practice and theory, has shown very good results. Of course, as everywhere, there will be some people who fail. But almost all of the caretakers, trained in this way up to now, are doing a very good job.

A similar way of training is applied e.g. to masons. Especially in the villages of the North West Province, there are young people who do a traditional apprenticeship with an experienced mason. During two years, they learn the handicraft by working on projects.

2. The Building Training Center of CD/SATA in Kumba

People who completed such an apprenticeship and also others who fulfill certain conditions may attend courses at the BTC. There are two types of courses, some of them organized periodically, others only from time to time according to need.

Periodically organized are the following courses which end either with Trade Test or CAP (Certificat d'aptitude professionnelle):

- A two years course for masons, ending with Trade Test III.
- A two years course for building constructors, joining the two years mason course and ending with the CAP test which is equivalent to City and Guilds intermediate.
- A two years woodworker course, ending with CAP.
- A two years plumber course, ending with CAP.

All these courses consist of a theoretical and a practical part. For its practical training which is not only organized in the BTC's workshops, but mainly on CD and private projects, the BTC is very well known in the South West and North West Provinces of Cameroon. The high demand for such BTC people by private companies is proof of the quality of results reached with such on-the-job-training.

Organized according to need are on the one hand not only the caretaker courses mentioned before, but also courses for locally trained masons having completed an apprenticeship. If they are willing to improve their knowledge and their skill they will be sent to such a course by the engineer of the department.

On the other hand, there are the following courses, also organized according to need in the Community Development Department:

- Headmason / Foremanship course
- Surveyor / Draftsman course
- Road overseer course
- Supervisor / Technician course.

FINANCING OF THE PROJECTS

The financing of Community Development Projects is part of the CD/SATA policy. The agreement between the Government of the United Republic of Cameroon and SATA-HELVETAS states that "the general principle applied to the financing of major community development projects (...) shall be as follows:

- voluntary contributions by foreign organisations and HELVETAS: 40% of the overall estimated cost of the project.
- Contribution by the committee concerned: 20% of the overall estimated cost of the project (10% in cash, 10% in "kind")
- State contributions by the United Republic of Cameroon: 40% of the overall estimated cost of the project."

1. The application for grants by the foreign organisations is generally written and followed up by SATA-HELVETAS. However, the longer the more this administrative task is being handed over to the Community Development Department. There are many organisations and countries supporting CD/SATA projects again and again, as e.g. Bread for the World and MISEREOR, Germany, OXFAM England and United States, NOVIB Netherlands, Dutch-, Canadian- and US Embassies. Since the technical standard and the quality of the projects are well known to these donors due to many years of co-operation and support, these grants are normally paid immediately after having forwarded the necessary reports on the progress of work.

2. Community Contribution: The CD officers and CD assistants are supporting the committees in their administrative duties as e.g. the collection of money among the villagers. The collected money is paid into the project account which is maintained by the CD of the Division. To start a project, it is very essential to have at least 50% to 70% (if not 100%) of the community cash amount to be paid into the project account; the first instalments from foreign organisations and from the Government are only paid after a certain time, due to the administrative proceeding.

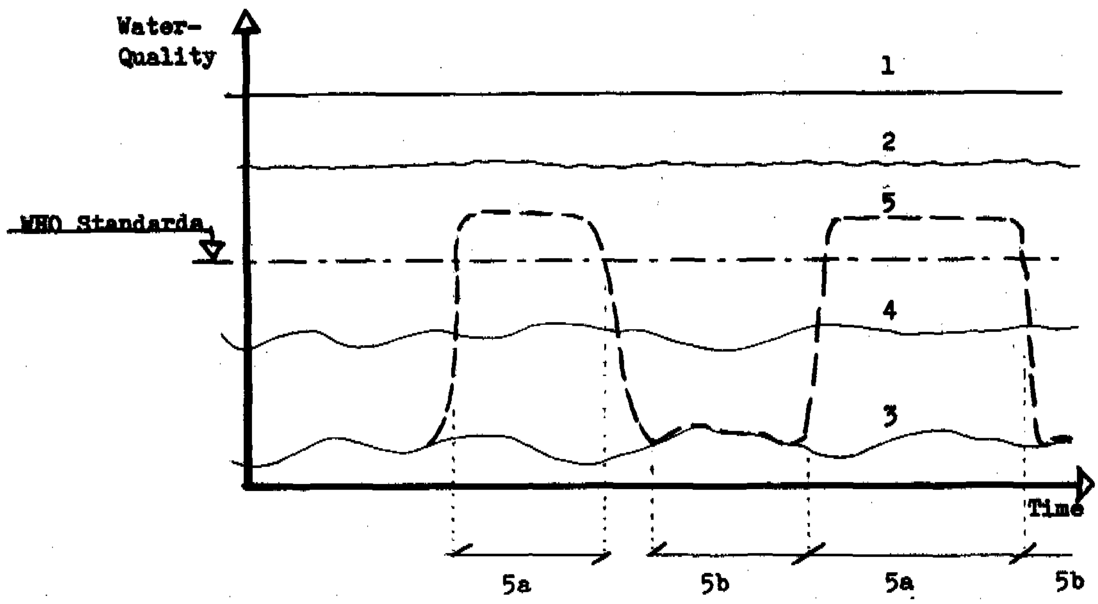
3. Contribution by the Cameroonian Government: The 40% contribution by the Government also consists of a cash and a kind contribution, being around 20% each of the overall estimated cost. There are grants to projects which are part of the annual budget of the CD Department, there are further national grants as FONADER (Fond National du Dévéloppement Rural), and MRI (Minor Rural Equipment), and grants by the Rural Councils concerned. The grants distributed on national level are directly assigned to the various projects. Since in the annual programmes the money available is distributed to many projects in order to serve as many villages as possible, the individual instalments are generally not high enough to guarantee the best possible construction programme. There are efforts made by the Department to get the grants assigned to the Divisions, while the distribution to the various projects shall be done on Divisional level.

The contributions by the three parties are suggested by the responsible officers in charge of the project, based on the shares mentioned above. The percentages may vary to a certain extent, depending on the financial power of the communities concerned. The number of tax payers living in the village gives a clue to the cash amount to be collected by the community. The community shares are discussed with and have to be accepted by the project committee.

Villages in extremly remote areas may contribute less in cash than the average, whereas others in fertile areas with relatively good access and cash-crop cultivations may pay a cash contribution of more than 10% of the overall estimated cost.

The shares may also vary depending on the type of project. E.g. a road built with labour intensive method, causing a comparatively high amount of community work, its value raising above the 10%, may require a smaller cash contribution from the village. On the other hand, with a water supply consisting of wells where it is impossible for a community to supply unskilled labour to a large extent, the cash contribution might amount to 20% of the overall cost.

3. Water quality and water treatment in remote areas



1 Good spring source, high quality

2 Spring source of inferior quality

3 Water from a stream flowing through or near a village, very poor quality

4 Water from a stream flowing high above populated, and far from grazing areas, poor quality

5 Water from a stream with insufficient purification

6th WEDC Conference: March 1980: Water and waste engineering in Africa

'LAYI EGUNJOBI

RURAL WATER SUPPLY AND COMMUNITY DEVELOPMENT: A STUDY OF KAJOLA AREA OF NIGERIA

INTRODUCTION

The objective of this paper is to corroborate the writer's general observations among the people of Kajola Local Government Area that the high degree of enthusiasm demonstrated by the people in community development activities has not been channelled towards solving the area's acute water problems. The paper also attempts to explain why this is so and then offers some suggestions for improvement.

Two sets of data are presented: the first set describes the state of domestic water supply generally in the area using three selected villages as typical examples. The second set reveals the number and type of community development projects recently undertaken in the area and highlights the lack of prominence of water projects.

BACKGROUND

Kajola Local Government Area is situated in the extreme western part of Oyo State of Nigeria. Covering an area of 3,750 square kilometers, it has a 1979 estimated population of 173,643. This gives a population density of approximately 46 persons per sq.km. Compared with the state average density of 505 persons, this area is obviously one of the most sparsely populated. The region falls within the flat of gently rolling grassland belt. Altitude rises steadily from the south-east (200 m) towards the north-east (500 m) while the land surface is sometimes broken by granite inselbergs or lateritic outcrops. The top-soils are light-textured loamy sand or sandy loam; in the sub-soil, the texture usually varies from sandy-clay loam to clay.

Mean annual rainfall is in the range of 1,100 and 1,200 mm. On average, the effective rain-fall duration varies from 185 to 200 days. In general, the area is among the least developed parts of the state even though its environ-mental conditions suggest an immense scope for development.(1)

WATER SITUATION

That Kajola Local Government Area of Oyo State is faced with an acute water problem is axiomatic. A casual visitor to the area especially during the drier parts of the year will see more of the ubiquitour 'water drawers' - mostly women and children - than anything else. It is worthy of note that none of the twenty-seven settlements that constitute the local council enjoys treated water. The sources that provide water for domestic use are mainly shallow, hand-dug wells, springs, brooks and ponds. These are often polluted and unreliable sources. A probable reflection of the poor water situation is the relatively high incidence of diarrhoea, dysentery and guinea-worm in the area.(2)

The magnitude of water problems in the area has recently prompted the local authority to purchase 51 water tanks which were shared among the settlements. These 500-gallon tanks cost the government a sum of ₦15,300. One lorry tanker was also bought at a cost of ₦20,397.50. Water is drawn from Oyo Water Works in the lorry tanker and distributed into the tanks. Obviously, this has represented a frantic effort by the local authority to alleviate the people's suffering. However, the effort has not produced any positive results. First, the distances between Oyo and the various settlements in the local government area (LGA) are considerably lengthy. They vary from 72 km (Okeho) to 120 km (Ijio). Second, most of the roads are not surfaced and can only be tolerated in the dry months. So, it is not possible to make more than one trip to fill only four tanks per day. Third, a continuous use of the only lorry tanker cannot be guaranteed; whenever it breaks down or needs to be serviced, distribution of water is necessarily suspended. In effect, most of the tanks are left dry for long periods in the year.

The general water situation in the area is depicted by data in respect of Isemi-Ile, Ilaji-Oke and Itasa as shown in the following tables. Between November 1978 and June 1979, these three settlements were randomly selected for a general village survey out of which water supply was only a part. Table 1 shows that 18 out of 25 or 72% of the wells found within the villages are seasonal, i.e. they contain water only in the wet season. The remaining 7 or 28% can reasonably be relied on for steady supply of water through-out the year assuming normal climatic conditions. Under abnormal conditions such as

Table 1 - Wells

Settlement	1979 Population	Number of wells	Availability of Water All year	Seasonal
Isemi-Ile	4,895	8	2	6
Ilaji-Oke	1,563	11	3	8
Itasa	1,573	6	2	4
	8,031	25	7	18

Table 2 - Brooks, Springs and Ponds

Settlement	Brooks, springs etc.	Distance range (in km)	Availability of Water	
			All year	Seasonal
Isemi-Ile	5	1.25 - 30	3	2
Ilaji-Oke	3	1.0 - 4.5	2	1
Itasa	7	0.5 - 5.0	4	3
	15		9	6

Table 3 - Average Time Spent in Procuring Water in the Dry Season

Settlement	Number of Households Interviewed	Average Time per day per household	Average time per month per household
Isemi-Ile	60	3.2 hrs	96 hrs or 4 days
Ilaji-Oke	42	3.8 hrs	114 hrs or 4.8 days
Itasa	37	4.5 hrs	135 hrs or 5.6 days

long periods of drought, some of these also dry up completely. Further investigations revealed that only 4 of the 7 'reliable' wells are public; others are privately owned and can only be used by the owners or those authorised to do so. It follows therefore that a majority of the inhabitants rely solely on other sources for domestic water supply in the drier half of the year. Table 2 shows that 6 out of 15 or 40% of the other sources are seasonal. However, the problem with these sources of water is their distance from the built-up areas. According to column two, the distance varies from 0.5 kilometres to 5.0 kilometres. One can then surmise that in order to subsist, a great deal of time and energy has to be expended in walking the long distances and carrying water in heavy vessels. To have a sharper perspective of this problem, an attempt was made to compute the average number of hours spent by households per day in procuring water, using such information as the number of persons usually involved in drawing water for a household, usual source of water and distance away from home, and average number of trips per day. Table 3 summarises the findings. It shows that on average, a household could spend a maximum of 4.5 hours per day or 5.6 days in the month and a minimum of 3.2 hrs per day or 4 days in the month to procure water for domestic use. This implies a drastic reduction in the amount of time normally devoted to productive work. Alternatively, it may mean using up the normal leisure time. From whichever angle one may look at it, the fact remains that the effect of water problems on the people's social and economic life is considerable.

COMMUNITY EFFORTS

In line with what can be observed in several parts of Nigeria, the people of Kajola Local Government Area have adopted community self-help as part of the strategies to alleviate their state of underdevelopment. It usually takes the form of providing local amenities or improving the existing ones. The higher level governments encourage it by subsidising the cost of the projects and by providing community and social officers.

Table 4 - Community Development Projects in Kajola Local Government Area - 1978/79

	Projects by type	No.	% of Total	Estimated cost	% of total est. cost	Amount already spent (₦)	% of total amount spent
1.	Roads and culverts	36	50.7	491.665	54.5	150,080	66.0
2.	Health/Sanitation Facilities	22	31.0	104,000	11.5	10,010	4.4
3.	Recreational Centres and Town Halls	7	9.9	271,800	30.1	57,250	25.2
4.	Market Stalls	3	4.2	18,500	2.1	3,500	1.5
5.	Water Supply	1	1.4	6,000	0.6	3,500	11.5
6.	Schools and Libraries	1	1.4	5,000	0.6	2,000	0.9
7.	Postal Facilities	1	1.4	5,000	0.6	1,000	0.5
		71	100.0	901,965	100.0	227,340	100.0

Table 4 shows the total number of projects embarked on within the Local Government Area as at June, 1979 even though many of these were carry-over projects from previous years. It shows further the estimated cost and actual amount already expended. In summary, there were 71 projects estimated at a cost of ₦901,965 out of which ₦227,340 had actually been spent. These figures indicate the high degree of enthusiasm with which community self-help was adopted. A break-down of the projects into categories shows the level of priority accorded certain types vis-a-vis others. Both in number and money, road projects have received the greatest attention. This is followed by health facility projects and then recreational projects. In terms of estimated cost and money actually spent, recreational type of projects comes next to roads. Those projects that appear to have been least embraced are postal facilities, schools/libraries and water supply. Each of these categories constitutes less than 2% of the total number of community development projects. In an attempt to explain why these projects have not received much attention, one may say that the needs for the projects might not have been pressing. However, if this is true of schools and postal services which are found almost everywhere, it is definitely untrue of water supply as we have seen in the previous section. What then is responsible for the low priority accorded to water supply in community development programmes despite the observable acute water problems? The following section attempts to make some inferences regarding this.

DISCUSSION

What seems to have underlined the choice and execution of projects is the people's felt need and this in turn is a product of their perception of what constitutes community development.[3] Their conception of development is no more than modernisation as illustrated by such practice as substituting cement blocks for mud or lock-up stalls for open-air tree-shade markets. The idea is tied up with tangible and grandiose projects that can be seen, admired and exhibited. In one of the committee areas of the study area, the description of a highly publicised project is "Okeho Ultra-Modern Town Hall". The estimated cost of this project is ₦120,000 or 57% of the total cost of ₦ 209,000 earmarked for all the fourteen projects within the committee area. Furthermore, a sum of ₦40,000 or 61% of the ₦65,600 already spent over the years has been on the ultra-modern hall. Thus, the glamour attached to it is easily seen in the way the project is being described (ultra-modern) and the subsequent high level funding of it.

For the same reason, a keen sense of competition is prevalent among the various communities. The motivation to undertake a project adjoining village. This shows that the importance of relating development efforts to the solution of specific problems is not really grasped. With specific reference to water projects, it can be deduced that there is a lack of the recognition to link health problems to water problems. The incessant water shortages, pollution and relative inaccessibility of existing sources are therefore seen not as hazards but as physical inconveniences.

PROPOSALS

1. Need for Campaigns of Education: The first apparent need that emerges from this study is the infusion of public enlightenment into community development programmes. It is wrong to perceive community development merely as a means of getting structures erected as show-pieces or symbols of prestige. Human development necessarily needs to form an essential part of the whole process so that

the right decisions are made in selecting, executing and utilising development projects. In the example described in this paper, what constituted a problem was the inability to realise the health implications of a good water supply. This presupposes that community development officers should not depend only on what people perceive as their immediate needs. Just as a sick person may not be aware of his sickness until he has been screened by a physician, a community may not be in a position to perceive its true needs until attitudes and opinions are carefully shaped and guided.

2. Role of Engineers: What emerges as the second basic need is the involvement of engineers in community development programmes. As pointed out earlier, state and federal government assistance takes the form of giving grants and supplying social officers. Thus, there has been a continued absence of technical staff and this has served as serious handicaps in executing projects. Water projects in particular require adequate technical support to be successful. Engineers therefore have an important role to play; they need to advise, present alternative solutions and produce simplified, standardised designs that can be widely applied.

However, in making this proposal to get engineers involved, one is aware of the shortage of this category of professionals. Since they are difficult to recruit and retain even at the higher government levels, the local authorities are not likely to be in a position to offer necessary inducements. One possible solution therefore is to organise a corps of 'travelling engineers' at the higher level who will, in the fashion of the 'flying doctors', go from community to community to offer their services. This may go a long way to fill the gap presently being created by the absence of technical support in community programmes.

CONCLUSION

The sets of data presented in this paper have supported two observations:

1. that there is a critical shortage of domestic water supply in the area of study;

2. that although the people in the study area are enthusiastic in community development activities, water projects have not featured in their programmes.

It is believed that this observed phenomenon could have been due to the people's perception of what constitutes development. There is the tendency to embark on building projects that are not necessarily meant to solve specific problems but rather to enhance community status. In particular, there is a lack of recognition of health implications of water problems. Therefore, in order to help the people help themselves in the provision of safe and adequate water and thereby contribute to make the 'International Drinking Water and Sanitation Decade' (1980s) a success, community development efforts have to include a campaign of enlightenment as well as the provision of technical support for programmes.

REFERENCES

1. UDO, R K, Geographical Regions of Nigeria, Heinemen Educational Books Ltd, London/Nairobi/Ibadan, 1970.

2. EGUNJOBI, T O, Implications of Health Resources for Regional Planning - The Example of Oyo Health Zone in Nigeria: Ph.D. Thesis, University of Nottingham, 1977.

3. OKPALA, D C I, Towards a Better Conceptualisation of Rural Community Development: Empirical Findings from Nigeria. Unpublished Manuscript, N.I.S.E.R., Ibadan, 1978.

6th WEDC Conference: March 1980: Water and Waste Engineering in Africa

L DIREKTOR

A STANDARD DESIGN MANUAL FOR RURAL WATER SUPPLY IN A DEVELOPING COUNTRY

Introduction

It is now generally accepted that the health of the general population is very much bound up with the availability of a wholesome water supply.

Since the declaration of the "World Water Decade" which we have now entered, pressure has been created to produce schemes which will bring acceptable quality water to the rural population and to the urban poor. The other aspect of the purpose of the Decade, running parallel with bringing water to the people, is to provide satisfactory sanitation facilities. The two, taken together, it is hoped will lead to a general improvement in health of the population - providing other criteria, such as a minimum standard of nutrition, are also maintained.

The Project

In 1975, TAHAL was commissioned by the World Heath Organisation, acting within the framework of the United Nations Development Programme, to undertake a study of Rural Water Supply and Environmental Health covering six of the nine representative regions of the Republic of Ghana - representing some 80% of the country's area. The project area had a 1970 census population of over six million people.

After three years of intensive work the seven volume Report was presented. A description of the work done for the Report - geological, hydrological, engineering and financial analysis, would in itself require a whole paper, but the scope of the work can perhaps be seen from the titles given to the seven volumes, occupying some 180mm of shelf space:

Volume 1 - Summary
Volume 2 - Development Programme
Volume 3 - First Stage Programme
Volume 4 - Management and Organisation
Volume 5 - Report on Training
Volume 6 - Standard Design Manual
(accompanied by a set of Standard Drawings)
Volume 7 - Supporting Studies and Appendices

The Design Manual

For the purposes of this presentation, attention will be restricted to the "Standard Design Manual". The object of the Design Manual was to provide a guide book for the local designer in a developing country, to the decision processes and design criteria to be adopted in designing a simple rural water supply scheme, and in getting it out to tender. Part of the Manual's purpose was also to point out the limitations of its use - ie to make the designer aware of those items where it is better to seek more experienced advice, as well as providing a uniform basis for design to assist in checking and approval procedures.

The contents of the Manual were based not only only on TAHAL's wide experience in West Africa, but also on the special Immediate Implementation Programme which was initiated and constructed simultaneously with the preparation of the Report.

Analysis of the situation in the rural villages, defined as concentrations of population of less than 5000 persons, showed that a degree of standardization can be effected in the type of water supply scheme which can be adopted, according to the following criteria:

1. Communities of between 200 and 2000 inhabitants would be supplied by non-piped sources.
2. Communities of between 2000 and 5000 inhabitants would be supplied by piped systems feeding one or more public water points.
3. If groundwater was available the smaller schemes would consist of individual tube-wells equipped with hand-pumps, and the larger schemes of one or more deep boreholes with diesel generator operated submersible pumps, elevated water tank etc. These larger schemes were sub-divided into two types depending on whether borehole yields were fair or low.
4. If surface water only was available the smaller scheme would be of an impounded reservoir, sedimentation basin and slow sand

filter, with an adjacent water delivery stand consisting of a storage reservoir with water delivery hand-pumps. For the larger type of scheme both low lift and high lift pumping stages might be necessary.

5. The projected water demand was taken as 22.5 litres/capita/day for the smaller schemes (ie population less than 2000) and 52.5 litres/capita/day for the larger schemes.

Figures 1 to 3 illustrate the basic schemes which were developed:

FIG.1

"HP" MODEL SCHEME

(non-pipe-borne water supply category)

This Model Scheme is intended for:
Communities numbering 200 to 2000 (1500 in the Northern Region) inhabitants.
Locations where groundwater is available.
Projected per capita water demand of 22.5 lpcd.
Total average daily water demand range of 4.5 to 45 cubic metres (about 1000 to 10000 gpd).

SCHEMATIC LAYOUT
(NOT TO SCALE)

LEGEND

ROAD

DWELLING

SHALLOW BOREHOLE EQUIPPED WITH HAND PUMP

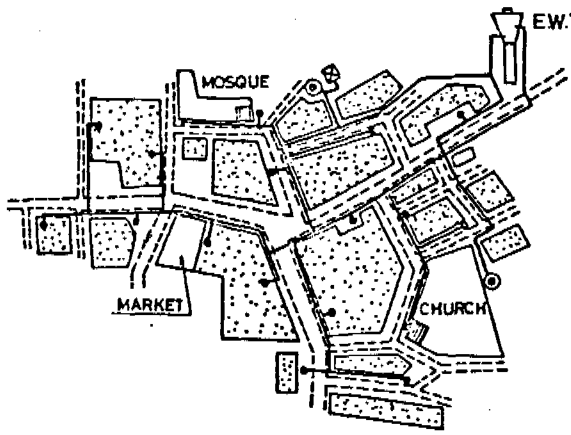
FIG.2

"GWA" OR "GWB" MODEL SCHEME

(pipe-borne water supply category)

This Model Scheme is intended for:
Communities numbering 2000 (1500 in the Northern Region) inhabitants.
Locations where groundwater is available:
"GWA" designated where borehole yields are fair, "GWB" designated where borehole yields are low.
Projected per capita water demand for the year 1992: 52.5 lpcd.
Total average daily water demand range of 105 (78.75 in the Northern Region) to 262.5 cubic metres (about 23000 (17500 in the Northern Region) to 58000 gpd)

SCHEMATIC LAYOUT
(NOT TO SCALE)



LEGEND

ROAD

BUILT-UP AREA

DEEP BOREHOLE EQUIPPED WITH MECHANICALLY OPERATED PUMP

HEADWORKS INCL. CHLORINATION FACILITIES

E.W.T. ELEVATED WATER TANK

PIPELINE WITH PUBLIC WATER POINT

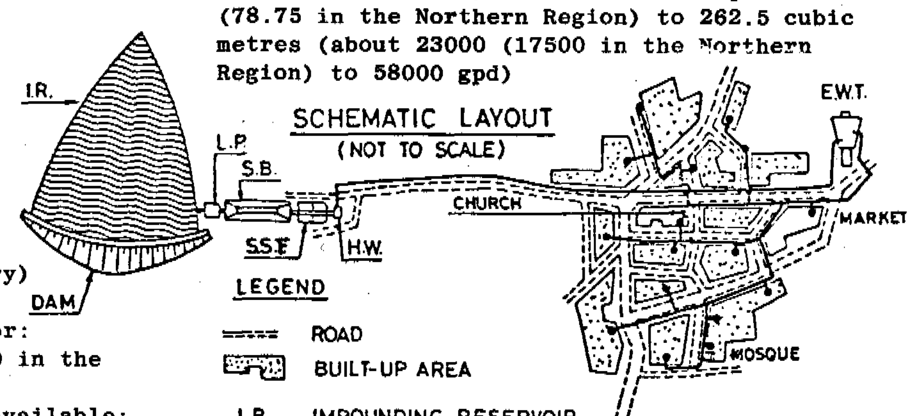
FIG.3

"SW" MODEL SCHEME

(pipe-borne water supply category)

This Model Scheme is intended for:
Communities numbering 2000 (1500 in the Northern Region) to 5000 inhabitants.
Locations where no groundwater is available and surface water is to be used.
Projected per capita water demand for the year 1992 of 52.5 lpcd.
Total average daily water demand range of 105 (78.75 in the Northern Region) to 262.5 cubic metres (about 23000 (17500 in the Northern Region) to 58000 gpd)

SCHEMATIC LAYOUT
(NOT TO SCALE)



LEGEND

ROAD

BUILT-UP AREA

I.R. IMPOUNDING RESERVOIR

L.P. LOW LIFT PUMPING STATION

S.B. SEDIMENTATION BASIN

S.S.F. SLOW SAND FILTERS

H.W. HEADWORKS CONSISTING OF CHLORINATION FACILITIES AND HIGH LIFT PUMPING STATION

E.W.T. ELEVATED WATER TANK

PIPELINE WITH PUBLIC WATER POINT

6th WEDC Conference: March 1980: Water and Waste Engineering in Africa

OKAY C IGWE

MODEL FOR EFFECTIVE COMMUNITY PARTICIPATION IN RURAL COMMUNITY WATER SUPPLY PROJECTS IN ANAMBRA STATE OF NIGERIA

INTRODUCTION

Public participation or involvement in project implementation is becoming a vital aspect the world over. In the developed nations this has arisen out of the need to reach consensus in a sort of collecting bargaining process to avoid sharp criticisms from Conservationists and Environmentalists with regards to not enough consideration for project environmental impact studies. This usually generates conflicts with different interest groups protecting their own partisan interests and this consequently results in costly delays in the implementation of the project or total abandonment of the project. In the developing countries this new trend is not noticeable because of the lack of adequate enlightenment of those who benefit directly from the projects. A greater percentage of the public share the view that the Government of the day ought to take full responsibility for making available all the public utilities required, and hold the view that they have no responsibilities required and hold the view that they have no responsibility in the whole affair.

Recently this trend is changing rapidly in certain parts of the developing nations. There has become an increasing awareness that there is a vital role that non - Governmental agencies can play positively in project planning and implementation. Communitites are waking up to the responsibilities of full involvement and commitment in implementing Government socio-economic and socio-polotical programmes. In Anambra State of Nigeria the need for positive social action is rapidly increasing and this action is clearly seen in the construction by communitites of roads, markets, bridges, rural electrification, rural water supply schemes, and other infrastures. Town welfare unions, development unions, cultural organizations, social clubs, different age grades and other groups have largely been responsible for the initiation and execution of development projects in the different rural communities.

This new trend is very warmly welcome specially in a socio-cultural setting that is highly characterised by acute group competitions such as Anambra State and deliberate efforts should be made by the Government to encourage these groups and improve their output from these projects. More specifically so are the cases of communitites that have embarked on rural water supply projects. Experiences of the past have shown that very often community-inititated water supply projects get abandoned mid-way during execution because of different reasons depending on the pecularitites of the community affected. Some of the causes for this negative undesirable output in rural community water project implementation emanate mainly from "cracks" in the group's solidarity rather than the so-often mentioned reason of lack of funds. This , in turn, emanates from conflict arising mainly from distrust of each other, lack of adequate leadership role, inability to provide adequate conflict models for settling group disputes amicably if and when they arise, absence of specific skills and ignorance of knowing where to go for expert technical advice, and lack of adequate programming of work and supervision of works during construction. This results in waste of scarce financial as well as material resources over extremely irrelevant issues, wasteful rivalries and unhealthy competitions thus delaying the fast execution of the water project. Experience has shown that even if funds are readily available the groups cannot perform in a belated "social climate of crisis."

In Anambra State the number of the on-going and proposed rural community water supply projects by self-help efforts is quite alarm- and represent quite a substantial investment in rural development. The State Government has also recognised this and is currently persuing the policy of providing financial aswell as technical assistance to different communitites in the State which have on-going rural water supply projects. Even the different Local Governments in the State are embarking on similar policies. With the keeness and interest being recently expressed by all concerned one has to see this as a healthy development in the rural water supply sector of the economy. From Table 1 it is to be noticed that greater emphasis ought to be placed on rural water supply since the greater percentage of the population of Anambra State reside in the rural areas 75% (1979),71.5%(1985) & 69.2% (1990).

TABLE 1

ANAMBRA STATE WATER SUPPLY

CONCEPTUAL APPROACH TO DEVELOPMENT TARGETS

DECADE OF WATER SUPPLY

1	2	3	4	5	6	7 STANDARD OF SUPPLY			8
YEAR	ZONE A ERACHY	POPUL. *	% OF TOTAL POPUL.	% WITH NO WATER SUPPLY.	% WITH ACCESS TO WATER SUPPLY	% WITH STAND PIPE	% WITH COMPOUND TAP	% WITH HOUSE CON.	SUB. STAND. SUPPLY
Present (1979)	Urban	1.4 M.	25%	15%	85%	25%		25%	50%
" "	Rural	4.2 M.	75%	85%	15%	75%			25%
"		5.6 M.							
Target (1985)	Urban	2.0 M.	28.5%	-	100%	40%		60%	-
"	Rural	5.0 M.	71.5%	50%	50%	40%	10%		
"		7.0 M.	100%						
Target (1990)	Urban	2.5 M	30.8%	-	100%	-	-	-	-
"	Rural	5.6 M	69.2%	-	100%	70%	30%		
"		8.1 M.	100%						

*Presently about 60% of Urban (0.8 million) and 90% of Rural (3.6 million) do not have a satisfactory standard of water supply.

To record positive outputs from the different communitites and encourage more communitites to follow suit, it has become a necessity to develop a model that is locally applicable and adaptable for the effective development fo rural community water supply projects in the State. A human-oriented, real-life model is called for. Also since one would expect that the goals of the approaching International Drinking Water Supply and Sanitation Decade (1981 - 1990) could be more readily achieved by involving as many local residents as possible, it would be necessary to develop realistic participation models that would serve as a major tool for implementation.

Also past experiences in Anambra State have shown that major failures which have been recorded in rural community water supply projects were due to the fact that the implementation schedules were not properly sequenced and programmed, and the non-involvement of the communities early enough in the planning and construction phases. Non-commitment of the communities as well as lack of community support at the operation and maintenance phase has led to failures of projects like the Achi Rural Community Bore Hole Scheme. , Ogugu-Nenwe-Ndeabor scheme, Amkwe scheme, Ngwo-Abor-Ukana,Nsude scheme, to cite only but a few of these cases.

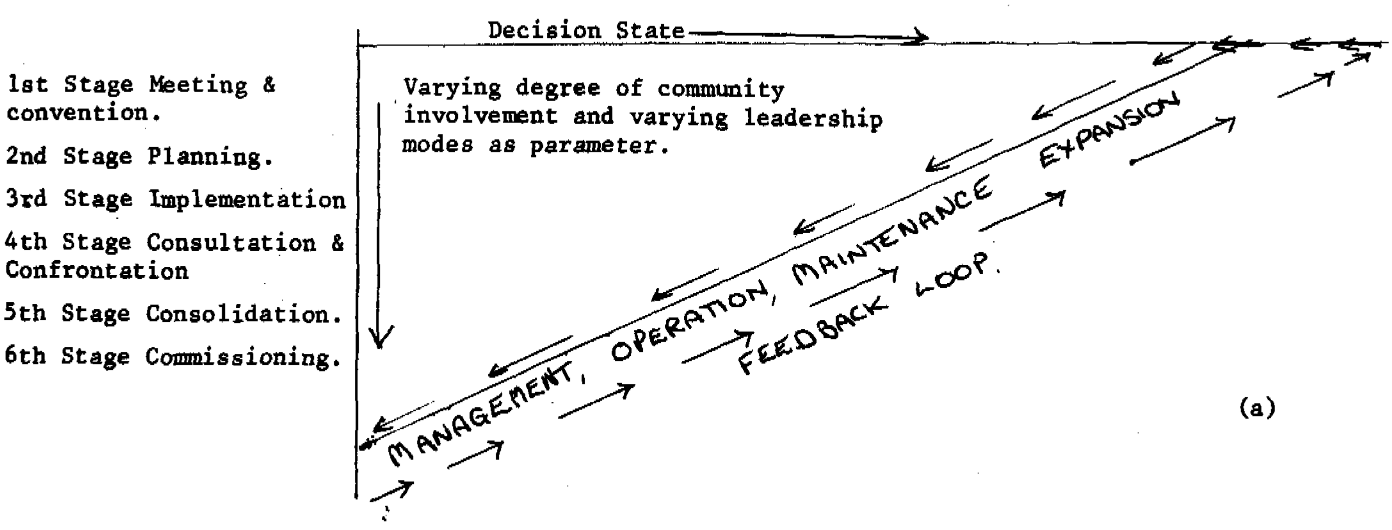
This necessity of involving the communities early enough in the planning and implementation of rural water supply projects, as well as the anticipation of the success of the approaching International Drinking Water Supply and Sanitation Decade led to the development of a Qualitative/Subjective Dynamic Programming Model for effective community participation in planning and implementing community rural water supply projects.

SUBJECTIVE DYNAMIC PROGRAMMING PARTICIPATION MODEL DERIVATION.

The Basic Underlying Philosophy of the Human Oriented Model

The model assumes that communities that will benefit directly from rural water supply projects should be highly involved and interested in the project planning and execution. The involvement should be based on a flexible plan, occasionally being fully open but most of the time being partially restricted. The timing of community involvement is the most crucial factor that will determine success or failure of the model. When to apply the fully open or the partially restricted aspects depends on the nature of the task to be performed. The model is based on task-force-approach that applies mixed mode leadership styles, varying in time as the functions to be performed vary. The model inputs derived from the background tradition, customs and culture of the people as well as physical local conditions with respect to the water supply component systems elements. The model derives from the Perspective III - The Human Perspective which lays more emphasis on the conern for human beings involved in the task of achieving set objectives and goals rather than the structure of the organization or the work-flow. The task force implementation committee leadership should be ased on Fielders Contingency Theory. Close super vision of workers is detrimental and use of reward rather than coercive power is preferred The legitimate, expert and referent powers of leadership should be high. For leadership to be truly successful, the follower must see "something in it for him ". In short, both leader and follower must be adept at the process of social exchange. For each stage and state in the execution phase, the leader-member relationships has to be continuously modified by bringing in subordinates with similar attitudes and beliefs thereby increasing the homogeneity of the group. Group involvement and the extent of involvement are subjectively assessed, timed, and manipulated to keep the community informed, motivated and enthusiastic. A feedback mechanism is vital for the success of the model. Figure I depicts the three dimensional flow diagram of Stage-State-Involvement for sequencing of community participation in rural community water supply projects.

FIGURE I



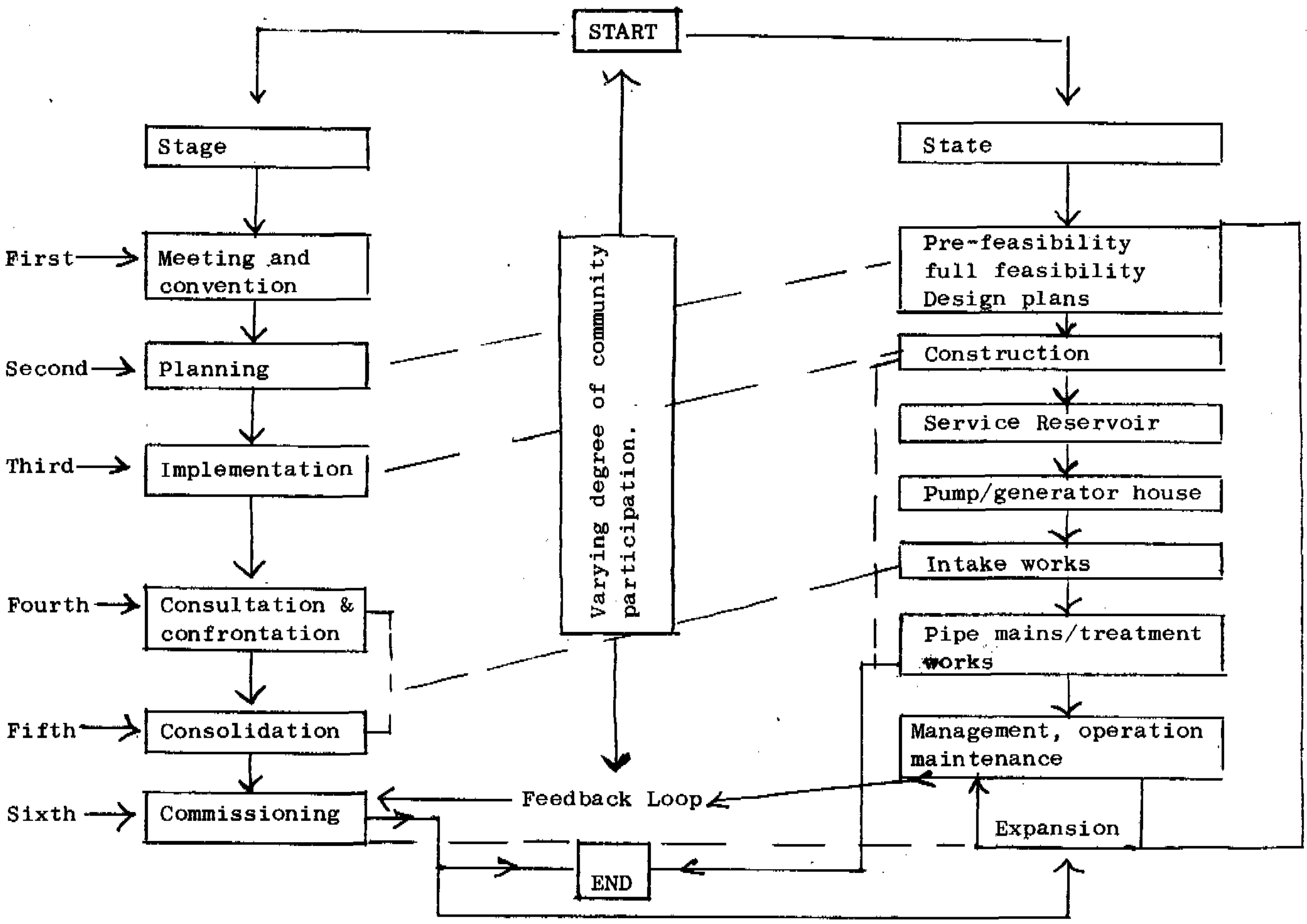


Figure 1. The three dimension flow diagram of stage-state involvement for sequencing of community participation in rural community water supply projects.

THE DERIVED PARTICIPATION MODEL FIELD APPLICATION. THE IHE COMMUNITY RURAL WATER SUPPLY PROJECT CASE STUDY

Figure 2 is the map of Anambra State of Nigeria with the 23 local government areas and the Anambra State Corporation Admin. Zones. IHE is a town located midway between the Anambra State Capital of Enugu and the Awgu Local Government Area headquarters at Awgu, that is about 25 kms. from Enugu on the old Enugu-Awgu-Okigwe-Umn Umahia road. It is located within Awgu Local Goverment Area. The present population is about 18,000 people.

As early as 1962 this community which is made up of twelve big villages realised the importance of moder pipe borne water and rated it as top priority. The community embarked on collection of money by levying all taxable adults, both men and women to realise money for the achievement of this goal. The then leaders of the town were charged with the responsibility of depositing the water project fund with the defunct Awgu County Council at Awgu. Unfornately, owing to lack of technical expertise and lack of preliminary investigations the decision was made to develop bore hole system (merely because the leaders of the day have seen bore holes working in some other areas). In 1965/1966 they went ahead and hired drillers who drilled several test bore holes and none was yielding water. This situation should have been expected since IHE geologically belongs to the Enugu rocks and shales beds which are non-ground water yielding formations. For the hired drillers to earn their money they told the natives that one test bore hole indicated that ground water in one of the villages called Umuogba was adequate as a source of supply for the community. The news was welcomed with a sigh of relief, enthusiasm and high expectation. Unfortunately, after the civil war in 1970 the community started asking questions about the project and more specifically about the money that their leaders have been collecting from them. They demand for an account but they did not get a answer and the bore hole project has also been physically - abandoned and the water that they have expected to flow "soonest", as they were made to believe, was not forthcoming. This situation precipitated a "crack" in the leadership and mistrust set in and the natives became reluctant to pay more money for the project. The project died a natural death !

In August of 1978 a select group of concerned IHE Community elites resident in Enugu got together and scheduled a two day general convention of representatives of all IHE social and cultural organizations from all over the country for the 7th & 8th October 1978. At this convetion the "IHE United Front" (IUF), a cultural body of all IHE youths at home and abroad emerged. A decision was made to revive the plan for IHE community water project. A lot of personalitites with high legitimate power, expert power, referent power, and reward power attended and addressed the convention. Care was taken to eliminate some personalities who had lost the respect of the people to avoid suspicion, mistrust and heterogeneity. Fortunately at the time of inception of this idea, the writer was the Anambra State Commissioner for Works and Housing, and a cocktail party was given at his residence at the end of the convention in honour of the delegates who participated in the sessions. The "modus operandi" for the planning and implementation were set and the date (24th December 1978) for the first fund raising ceremony was settled. The Water Project Force Implementation Committee (WPTIFIC) was set up with role functions and expectations properly defined. The morale was high at the close of the cocktail party. The first stage task was recorded as a very big success.

The second stage was strictly restricted. This was the planning stage which is an expert role. A request was put to the Anambra State Water Corporation to carry out a Project Pre-Feasibility (PPF) study on two alternative Rivers the Isioji and Oboma which were easily identifiable by local residents, including the President of IUF, the first Vice Chairman and the writer, as the only possibilities since the residents already were informed that there was no possibility of water supply from a bore hole source. The PPF study revealed that the Isi-Oji river, though with a smaller dry season flow of 652 cubic meter per hour was a better source than the Obomo River, since the main stream does not carry a lot of silt and sand like the Obono River. Isi-Oji also has the economic advantage of savings in cost of pipe mains to the Community Centre being only 1.5kms away, plus the added advantaged of eliminating the socio-political problem of "right-of-way" from the other neighbouring community of Agbudu through whose land the main pipeline would have to traverse some distance of about 5 km. before enetering IHE community area if the Obono River was to be selected. Thus, Isi-Oji river was preferred. Altimeter spot measurements (not detailed contour survey) indicated the highest point in the neighbour hood and thus the location of the service reservoir was established. Simple schematic design of system elements was evolved for the "intake-service reservoir portion." In the meantime the writer requested the President of IUF to call a restricted meeting of the WPTFIC for education of this subgroup of sequences, and leadership roles, styles and strategies for implementation. The meeting was thoroughly briefed on the relevant issues and asked to form another sub-committee under its supervision to gather population data, on village by village basis and to present the figures in writing from the village remotest from the intake source to the village nearest to the source. A dateline was given for this task to be completed with a promise for reward if the dateline was met. The reason for the population figure on village by village basis was explained and well communicated. Plans were made for the first fund-raising ceremony and intensive campaigns by use of radio, television, press, posters and hand bills were conducted.

The third stage was the start of the implement ation. The IUF's first phase fund-raising ceremoney was held in community centre on 24th December 1978 as scheduled and a substantial sum of twenty thousand naira (N20,000.00) was realised mainly from affiliated social organizations and well wishers from outside the community. The Local Goverment Council Chairman and his Supervisory Councillors were in attendance. Local traditional and cultural dance groups were in attendance to entertain the guests. The plan to use surface water, the Isi-Oji River was exposed before the community. The donations were on voluntary basis. The amount realised was announced at the end of the ceremony and a commitment was made by the President of the IUF that every kobo realised will be put into fast implementation of the project and will be openly and properly accounted for. Every donor got a receipt. As soon as some funds became available a sum of two thousand naira (N2,000.00) was deposited with the State Water Corporation for final survey plans, more comprehensive laboratory water quality tests, and final designs for using the Isi-Oji river source after a meeting of the IUF Executive.

A restricted meeting of the WPTFIC was called to inform them that final working plans are being finalised and educated them on the construction sequence of the system component elements. This was followed by an enlarged WPTFIC and IUF executive open meeting to plan the second fund raising ceremony. In order not to lose momentum and interest the second voluntary fund raising was held on the 15th April 1979, barely three and half months after the first fund raising ceremony and ~~a sum of~~ about twenty five thousand (N25,000.00) was realised. Progress report and financial account were given before donations started. This was followed by restricted meeting of enlarged WPTFIC and IUF executive to discuss the financial require ments for construction. As soon as the final plans were ready and it was confirmed that the Isi-Oji River source was of high natural quality, a sum of N20,000.00 was deposited with the State Water Corporation as part payment for construction of 100,000 gallons capacity Brathwaite steel tank, after a meeting of the IUF Executive with the Management of the State Water Corporation. Construction of tank was started on the 26th May 1979 and completed by the end of September 1979. Simultaneously work was started by WPTFIC's direct labour at the pump/generator house. Sub contracts were given to local residents including women and supervisory role was given to WPTFIC. In the meantime the IUF Executive applied for a matching grant from the Awgu Local Government Council and a sum of about N3,000.00 was granted for the water project. Construction of the pump/generator house was started on 14th July 1979 and was completed on the 31st August 1979. As soon as the house was completed a request was made to the State Water Corporation to give a IUF a generator and pumps. On the 13th September 1979 the IUF got a 137.5 KVA Lister electrical alternator machine and two units of 60 ft. (head), 2970 revolutions per minute (speed), and 15,000 U.S. gallons per hour (capacity) pumps. Installation of these machines are nearing completion.

The fourth stage was consultation as well as confrontation. An open annual convention of representatives of all IUF - affiliated socio-cultural groups was held on 6th & 7th October 1979 at IHE, after a restricted meeting of the IUF executive and WPTFIC to prepare detailed progress report and financial accounts. The convetion started with an inspection of the tank site and the intake works. Reports from the Technical Adviser, the President, Secretary, Financial Secretary, and Treasurer were presented and distributed to delegates. A register of donors on a village by village basis, ranked in descending order of amounts donated, was presented. Strong appeal was made to members not to relent the efforts so that the positive output will continue. Strong accusation was levied on some personalities in the community who have not shown enough interest in the project and there were strong threats to get them involved by force since everybody was expected to benefit from the project once it was completed. These personalities were put to shame. December 23rd 1979 was fixed as date for the third fund-raising ceremony. The convention ended with a party given by an eminent personality in the town, Chief E.M.C. Aniagu.

Shortly after the convention the natives felt that they have not contributed and that their names were not in the register of donors. They requested for a meeting with IUF Executive and at this meeting they by themselves moved for levey system according to the traditional and cultural guidelines normally in use in the Community for division of labour (or sharing of things). A minimum amount that was expected of each person in each category (in several categories that the natives identified) was fixed for both men and women. It was also agreed that the chairman of each village cultural meeting would take responsibility for collecting the money from all the members of the village and that he would also present it openly during the next fund-raising ceremony. This was held, as planned on 23rd December 1979 with representatives from both the State Water Corporation and the State Governor's Office. This was the most successful fund-raising ceremoney. A total sum of about N35,000.00 was raised. The welcome Address presented to the State Government to take over the water project and complete it soonest since the IUF has played a remarkable leadership role and has got practical, physically observable output from its intensive, relentless effort for the past year. Before the fund raising started the guests including the natives were taken on a tour of both the intake and service reservoir sites. What they saw was a real "morale-booster" and spurred them to get money out of their pockets for the rapid continuation of the project.

A restricted meeting of the IUF executive and the WPTFIC was called immediately after the launching to celebrate the success of the third launching. During this meeting it was decided that more money would be deposited with the State Water Corporation for the construction of the intake works, minor treatment works, main pipeline, and major distribution pipe network.

The fifth stage was consolidation. A powerful delegation was sent first to the state Water Corporation Management to deposit more money for the above-mentioned works, then to the Commissioner for Water Resources and Public Utilities, and to the State Governor to submit letters requesting that the project be taken over completely by the State Government, including operation and maintenance after commissioning. This request was granted and it is expected that the 1980 Budget (1st April 1980 - 31st December 1980) will have substantial sum for this project.

The sixth stage will be commissioning of the completed water project, which is expected to be before December this year (two years after the community initiated action).

MANAGEMENT, OPERATION, MAINTENANCE AND EXPANSION PLANS.

The IUF plans to manage the system jointly with the State Water Corporation after the commissioning. The IUF also plans to form a local water management committee from the WPTFIC which will be charged with the responsibility of monitoring faults (like burst pipes, broken stand pipe taps etc.) reading of meters, billing, collection and administration of water rates and private connection charges on village by village basis. It is also hoped that the State Water Corporation Management will provide basic "on-the-job" training for local residents with basic technical ideas who will become assistant operators and some who will read meters and carry out some basic routine repairs. Already two such local community residents (two retired army officers), are participating and understudying the installation of the Lister alternator machine and the pumps.

The big cultural issue of water being "traditionally free" in our society is bound to militate against the efficiency of collection of water rates. However, with the education, the early and continued involvement and more enlightenment on the part of the natives, there is the hope that they will be a positive cultural transformation with respect to paying for the services rendered in operating and maintaining the water works.

The next anticipated problem is a socio-cultural one of adequate controls in water use. It is expected that people from the neighbouring communities of Agbudu, Isu, Agbogugu, Owelli, and Amoli with no water supply facilities will migrate and draw water from the system. Also businessmen who sell water will come to draw water with tankers. The question, then is who pays for this water not directly consumed by the community ?

Since, in our culture it is forbidden to ask anybody, including strangers, to pay for water this aspect of management will pose a difficult problem for the community. Because of this expected unavoidable situation a stand pipe will be provided in the vicinity of the intake to serve this purpose and will be metered to determine the quantity of water "lost" from the system for such "unscheduled usage". In the short-run it will just be "fair" to control this tap and charge the businessmen who draw water by tankers for sale to other communities since they make a lot of profit out of this highly-lucrative business. The revenue realised from the business group will be used to defray the cost of water drawn by the neighbouring communities for pure domestic consumption. In the long run the localwater management committee will schedule meetings with the neighbouring communitites to explain and appeal to them that since IHE community residents themselves pay for the water from the improved pipe-borne water supply system (not for water from open streams and springs) they too will have to advise their own residents to pay for the improved services being rendered to them. This is a very delicate issue and will have to be handled very cautiously since an awkward situation, which is likely to mar the peaceful co-existence and induce animosity between IHE and her neighbouring communities could be precipitated. In the meantime one can only keep his fingers crossed and hope that these neighbours will make a deliberate goodwill effort to understand and co-operate.

The issue of expansion of the schemein the very near future has to be thought of alongside with the management since this is expected to present a lot of problems. It is to be expected that with the water brought nearer to their homes water use will skyrocket in the community,because it, initially will appear as if this "one-time-free" but scarce commodity has now finally become available in surplus quantities and there is no limit to what can be done with it. There will be no reason and no tendency to practice astute conservation in the 'use and waste of this very expensive commodity". The current design water demand per capita per day for IHE community is about 15 gallons/capita/day and the design capacity is based on 1995 projected population of about 32,000, using a compound growth rate of 2.5%. With siting of cottage industries (as expected) in the community, and the corresponding migration of people and improved standard of living it is to be expected that the population will overtake the design demand and there will be the need to provide bigger capacities earlier than the design period of fifteen years. Estimated average 1995 demand (15 year demand) is 50 cubic meter per hour and peak demand is 60 cubic meter per hour (using a factor of 1.2). Since the estimated dry season flow of the Isi-Oji River at the point of intake is about 652 cubic meter per hour expansion plans will be based on the same source and a parallel pipeline will have to be provided with more pumping facilities and two more smaller units of service reservoirs. This would minimise inconvenience during expansion and as well minimize costs. This expansion is planned for the year 1990 (and not for 1995) based on realistic planning which inputs the facts given above. It will be the sole responsibility of the State Water Corporation with the voluntary co-operation of the IHE community to carry out the expansion.

CONCLUSION

The subjective Dynamic Programming Partici pation Model presented depicts a healthy an desirable co-operation between the local community and the State Government Agency (State Water Corporation) charged with the responsibility of supplying water with the community playing the major leadership roles and the Government Agency supplementing the community efforts by providing the technical assistance and guidance promptly. What the model stresses is that "quality of participation" is more relevant and effective than "quantity of it". The model is based on contingency theory and is subjective in the sense that it assesses the inputs subjectively. It is a qualitative dynamic programming model in that it defines the stages and states sequentially in time with the future outputs from the later state-stage (decision) depending on the preceeding state-stage outputs. It is empirical model which is based on the local traditions, customs, attitudes, value systems of the people, and the socio-cultural environment. It is, therefore, a realistic and real-life model which has been derived from practical field observations and experience and is easily adapatable to changing conditions. The model is derived from the Systems Approach of management in social organizations with a bias on the Theory Y (human-oriented) rather than Theory X (productivity-oriented theory, with emphasis on the Structural and Work Flow Components and less concern for the human beings in the organization). Mixed-mode leadership styles were employed, the style to adopt at any given time (legitimate expert, referent, position or coercive power), depending on the "situation" and the nature of the task to be performed. Constant but not too close supervision was an advantage. The three dimensional flow diagram of Figure 1 depicts the State-Stage-leadership mode and sequences which were used to produce the desirable "Hawthorne effect".

By this model the community was thoroughly informed and updated on issues, thoroughly educated, and involved in open meetings most of the time, kept away in restricted speciality meetings, properly motivated and rewarded, to keep the people enthusiastic and anxious all the time. The support and trust of the entire community on the leadership were upheld by adopting the system of open financial accounting, and periodic but constant reports on positive progress and achievements at every stage during the execution phase (occasional set-backs were kept secret to avoid doubts).

The output from the model is a very optimistic one as can be deduced from the case study presented. This should be applied to other communities with similar backgrounds, traditions, and socio-cultural settings. The model has shown that local community support and involvement is a "sine-qua-non" for any meaningful rural water supply scheme, irrespective of the scale of the project and its level of service.

The model has driven one important lesson home to all involved in project planning and implementation in the developing nations - that is, the non-inclusion or non-involvement of the local communities early enough in the planning stages of projects will result in communitites being reluctant to render their support in the management, operation, maintenance and expansion of the schemes. The failures normally recorded during the operation and maintenance stages will be cut down considerably. This should be a "recipe" for both the planners, consultants, contractors and policy makers.

If this model were to be modified and adequately employed in the different communities of Anambra State currently engaged in rural community water supply projects by self-help efforts a lot of positive output will ensue and "crisis situations" and abandonment of projects half-way during execution will become more or less, a thing of the past and a lot of investment in the rural water supply sector must have been saved !

Indeed the most important and significant application of this Community Participation Model will be in the approaching International Water Supply and Sanitation Decade (1981-1990) since all indications point to the fact that more emphasis would have to be placed on the developing countries, with a specific objective of getting modern pipe-borne water (or at least improved water supply facilities) to the remotest rural reas of the developing world.

<u>REFERENCES</u>

1. "Anambra State Water Supply - Conceptual Approach to Development Targets" Brief by Tahal Consultants (Nig.) Ltd. Enugu, November 1979.

2. "Areas of Conflict in Community Projects" A correspondents report dated 3rd January 1980 Issue of Daily Star Page 5.

3. House, and Bowdith "Behaviour in Organizations - A Systems Approach to Managing" Addison Wesley 1973.

4. Igwe, O.C. "Technological and Socio-Cultural Problems in Relation to the Formulation & Administration of Water Rights Law in Nigeria" University of British Columbia, Faculty of Law Documentation April 1976 85 Pages.

5. Kerkhoven Paul, "Third World Tests for Sand Filters" World Water September 1979 Issue Pages 27 - 29.

6. "Rural Water Supply Development Planning Exercise for Investment Estimates" Report by the Anambra State Water Corporation Staff with the assistance of Tahal Consultants (Nig.) Ltd. under the PPF Programme, Enugu November 1979.

Session 2: RURAL WATER SUPPLY: ORGANISATION AND COMMUNITY

Discussion

R R Bannerman

Handpump Maintenance Programme: Ghana

MR BANNERMAN said that for rural, scattered populations in Northern Ghana, the best way to provide a water supply was by ground water reached by wells. He described the project, financed jointly by the Governments of Ghana and Canada, to construct two thousand five hundred wells with handpumps to serve one million people. About two thousand of these pumps had been installed up to now. To maximise their use the pumps must be in continuous operation, so that a maintenance programme was essential. The villagers themselves could not be relied upon to keep the pumps and wells working. Slides were used to illustrate a typical handpump, a service truck and a well site.

2. The motorcycle maintenance system was described as in the paper, and it was emphasised that the villagers must be involved in the project for it to work. They should be encouraged to look after the well and to use it properly.

3. Mr J PICKFORD thanked the author for the detailed information in the paper, saying that it would be applicable to other parts of Africa.

4. Professor B Z DIAMANT commented that in his experience on other projects simple participation was not enough. The people should be encouraged to contribute to the project in cash or kind. If the people were given these pumps for nothing they would not appreciate them, and consequently would not want to look after them.

5. In a similar project in Kenya in which he was involved, Professor DIAMANT said that cash was collected from the people. The amount given was not important;they must simply be made to feel that they were part of the project. People tend to be very suspicious of anything to do with the Government, in case they were asked to pay more taxes, so if a pump or other equipment was Government owned, the people would not bother to look after it. The question was, what involvement was there in this project, and how much direct contribution was made in cash or kind by the people?

6. Mr BANNERMAN replied that the area of the project in Ghana was an area of great need, with the dry season lasting over seven months in a year. The target was to complete 2500 wells in three years, which meant working very fast, and there was no time for people to become involved. Also the handpump types used were very technical, so that the people could only be involved for maintenance, towards the end of the project. Each village was encouraged to elect its own "pump man" to be responsible for the basic running of the pump.

7. Mr A M ABDULLAHI asked for technical details of the wells. Mr BANNERMAN replied that the wells were of 150mm diameter, with a PVC casing. In Northern Ghana the average depth of wells was around 100 feet. The area comprised weathered granite terrain.

8. Professor DIAMANT wanted to know what were the criteria for selection of the two types of handpump finally chosen for use in the project. Mr BANNERMAN outlined the following criteria:

a. The pump should satisfy field tests.
b. It should be rugged and simple to use.
c. Both the above and below ground sections should be easily removable.
d. It must be within the manufacturer's capability to produce 1000.
e. For the future it should be capable of local manufacture.
f. There should be low maintenance costs. The most expensive pump is not necessarily the best.

9. Mr A A UMARU asked what other sources of water were available for the people to use when their pump was broken and they were waiting for the service vehicle to arrive. Mr BANNERMAN said that in most communities there was more than one well. If a pump broke down soon after the motorcycle inspector had been, the villagers were encouraged to report the breakdown themselves so that they did not have to wait too long for the repairs to be done.

10. Dr E A ANYAHURU asked how many people were served by one well. Did Mr Bannerman think that this sort of operation could work in the South of the country where the density of population was higher. Mr BANNERMAN said that the policy of the Ghana Water and Sewerage Corporation was that one

well was needed for every 300 people. In practice this had worked out at around 500 people per well. In one day, a maximum of 2000 gallons could be taken from the well at a steady rate, even at the peak of the dry season. There were usually two peak periods during the day, in the morning and evening. The Corporation was about to start another project in Southern Ghana, and would probably stick to the same criterion of one well to 300-500 people.

11. Mr M S ABU commented that he thought the service truck a rather expensive way of dealing with the problems. Mr BANNERMAN replied that there were 2500 pumps scattered in rural areas with very poor access, especially in the rainy season. The idea of having trucks was that they should carry all necessary spares and equipment. If the pump could not be repaired in the field, the truck must be able to carry replacement pumps, and so it needed the derrick at the back. In view of the size of the area and the scattering of the pump locations, he could not do without the trucks. The trucks themselves were simple diesel trucks with a tool box on the side and space to carry spare parts.

12. Mr K KHALIL asked about the geological formation of the area, and how the amount of water drawn from the wells compared with the recharge of the area. Mr BANNERMAN explained that the area was part of the Basement Complex, and so was reliant on water from wells. From 2500 wells, reports indicate that 2.5% was recharged from rainfall. The Corporation believed that they were not overworking the supply, and were not affecting the ground water supplies by the amounts taken out.

H C Balfour

The Development and Implementation of Water Supply Projects in the Sehal Area of West Africa

13. Mr D YOUNG presented the paper and apologised for the absence of Mr Balfour, who was touring in another part of West Africa. He explained that the paper dealt with a sector survey done for WHO in Mali, where a recent drought had made water supply an emotive subject. A questionnaire, completed for each town or village and signed by the local Mayor, directed attention to the particular needs of each community, and often it was found that these differed greatly from the aspirations of central Government.

14. Because Mali was so remote, the right sort of people were needed to carry out the survey. They needed to be quite confident in the situations in which they found themselves. When these people returned from the tour, they knew as much as, if not more than, the Government about what the people needed. If a water supply already existed, then something could be done immediately to improve the situation.

15. The "top ten" towns of the one hundred studied were identified, where construction work could begin at an early date with most cost effectiveness. Detailed estimates for the towns in which work would not be carried out in the foreseeable future would be meaningless. The proposed schemes went ahead very quickly, with Balfours supervising direct labour gangs. There now existed a basic structure of people at trade level to carry out the work. This was of vital importance for the future.

16. Dr K Y BALIGA asked, with reference to the signing of the questionnaire, what was the reason for the signature and did Mr Young think that the proceedure affected the accuracy of the answers. Mr YOUNG said that Balfours needed the signature to prove the source but they still applied a subjective judgement as to its value.

L A Raymann

Experience of Community Development Department and SATA-HELVETAS with Rural Water Supplies as Self-help Projects in West Cameroon

17. Mr RAYMANN explained that his group had experience in four fields: community participation, technical standards and maintenance, on-the-job training and financing of projects. The central idea of the organization was that of community participation. The organization only became involved in a situation at the express request of the community. When asked for help the Department first sent out experts to assess the problems and needs, and then to organize a project to which the community contributed in cash or kind.

18. Dr ANYAHURU commented that in his experience, Hydrams were being abandoned in favour of other pumps. Mr RAYMANN was surprised at this bad experience of Hydrams. He knew of some Hydrams which had been in operation for ten years. Breakdowns were perhaps caused by the type of Hydram being used. He used British Blake Hydrams and some Swiss types, and they worked well. In the 1910's and 1920's the Germans installed Hydrams which were still in operation now in some places.

19. Professor DIAMANT commented that he had had good experience of Hydrams in Kenya where the terrain was hilly. There Hydrams were installed wherever possible because they saved energy. Their only problem was one of priming; the people must be trained to prime them.

Dr T O Egunjobi

Rural Water Supply and Community Development; a Study of Kajola Area of Nigeria

20. Dr EGUNJOBI explained that the idea for the paper arose from personal observations that the enthusiasm of the people was not being channelled into solving the acute water shortage. This observation posed three questions:
a. Was the observation wrong?
b. Were the people not aware of the problems?
c. Did the people feel that other things were more important?
It was difficult to explain the fact that a great deal of money was spent on other community projects whereas water supply, which was a major problem, was not being attended to.

21. The data given in the tables showed that the wells in the area were mostly seasonal, that surface water sources were at a great distance from the communities, and that a large amount of time was spent actually fetching water, this time being better spent elsewhere. Table 4 showed that the people were very enthusiastic, but that water supply was low on their list of priorities.

22. The basic problem seemed to be that the people wanted to have modernisation in their communities as a status symbol. Their priorities had been misplaced through a different perception of their own needs. There was therefore a need for public enlightenment. Often the people could not see the link between ill-health and poor water supply; therefore they did not see the need for improvement. It was felt that engineers could help to direct the people by being more involved in Community Development Programmes, and possibly by organising a team of "travelling engineers" to serve the communities.

23. Mr L A OLATOKUNBOH asked what advice or recommendations were given to the communities in the case study on how to improve the quality of their water supplies. Also had a follow-up been made of the survey after a period of time. Dr EGUNJOBI answered that this was part of the suggestion made in the last part of the paper, that Community Development Programmes should not consist of construction alone, but should also involve the education of the people. For instance, people must be encouraged to boil water before drinking, until better facilities were available. They should also be told of the link between ill-health and water problems.

24. Dr BALIGA thought the idea of "travelling engineers" very commendable. He liked the analogy made to the "flying doctors", except that the latter usually attended to emergencies, while it was to be hoped that the former would not wait for an emergency. However, an engineer with a means of transport would not necessarily become a "travelling engineer", and special consideration should be given to the proper training of these engineers.

25. Dr EGUNJOBI agreed that there might be problems trying to convince engineers to work in remote rural areas, and we should therefore re-examine the whole system of engineering education. The same thing had happened with regard to medical personnel who did not want to work in remote areas. The problem had been debated in Nigeria for a long time.

L Direktor

A Standard Design Manual for Rural Water Supply in a Developing Country

26. Mr S KESHET gave a brief summary of the paper which outlined the object of the Standard Design Manual as a guide for local designers. He reported that the Manual had been well-received and was now in use.

27. Mr PICKFORD commented that details of the designs given in the paper were very interesting.

28. Dr BALIGA noted that a newsletter last year mentioned that WHO-IRC for Community Water Supply was preparing a Design Manual in connection with International Water Supply and Sanitation Decade activities, for global reference. He believed that Manuals tended to be more attractive than useful, when potential users had not been trained properly in their use.

29. Mr KESHET said the Design Manual came from work and experience in Ghana. He could not say that it was the best, but at least it was something. It was being asked for and used by engineers, and this was the best indication that it was being useful.

30. Mr L HUTTON pointed out that the WHO-IRC manual would not be a design manual. It was very dangerous to preach engineering world-wide, when each site had its own problems. The book would be called "technology". At the design stage, the book would refer readers to case studies etc, rather than detail. If you gave an engineer a design he would use it, whereas he should be using his brain and his experience.

Dr O C Igwe

Model for Effective Community Participation in Rural Water Supply Projects in Anambra State of Nigeria

31. Dr IGWE said that the model had derived from personal experience and observations. It emphasised who should be involved and what he was to be expected to do. Although it was based Anambra State, it could be of general

use with some modifications. The model was based on the systems approach to management, with the emphasis on the human relationship component, with less emphasis on work flow and structural organisation.

32. In Anambra State especially, great emphasis had been placed on self-help projects and there had been much investment in them. The basic philosophy of the model was that the people must be involved from the start. They wanted to be involved, and in the past the extent of their ability had been underestimated.

33. In a written contribution, Mr Terry MURPHY referred to remarks by authors when introducing their papers. One had said that central Government was not always in touch with the people's aspirations; a second had advised community involvement in making and maintaining boreholes; a third that people should be taught to recognize the link between water and health; another that community participation was necessary and another that for effective community participation communities needed to be enlightened and involved.

34. Mr MURPHY deduced that there should be no implementation without adult education, which should be orientated towards bringing change leading to an acceptance of modern ideas in improving health and nutrition, in adding a rational complement to people's ideas of their world - convincing adults of the relationship between water, waste and disease - to '...gradually, hesitatingly and timorously place in doubt the opinion they had of reality and replace it with a more critical knowledge'.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

R FOSTER and T R CROSSLEY

THE ENGINEER IN AN UNDERPRIVILEGED ENVIRONMENT

INTRODUCTION

As is already very well known Urban growth accelerated by migration from rural areas has, in many countries led to the proliferation of low income settlements, often including unofficial or even illegal squatter communities.

The circumstances pertaining to such communities can vary enormously and they are known by a variety of names but they invariably involve severe overcrowding, a lack of adequate municipal services and are fraught with health hazards.

Various attempts have from time to time been made by the respective responsible authorities, usually with only very limited success, to deal with the resultant problems.

The Government of Ghana, in collaboration with the World Bank sought to develop a new approach to the housing of low income groups in major urban areas and in this connection initiated studies in early 1977 by a multi-disciplinary group of Consultants working with a team of Ghanaian specialists, and from these studies there evolved the Ghana Urban Development Project.

The project was concerned with the upgrading of low income housing areas in five cities, namely Accra, Tema, Kumasi, Tamale and Sekondi-Takoradi, and with the provision of sites and services in four of them.

The Studies undertaken were very wide ranging and included an investigation of existing engineering infrastructures, especially water supply, drainage and sanitation, and of the options available for the future.

Because of the very nature of the problems being tackled, namely those associated with low-income sections of the community, the pursuit of low cost solutions was imperative. In fact to be of benefit to anything more than a very small minority of those in need any scheme devised had, after an initial investment of funds, to be virtually self perpetuating, depending for continuing finance very largely upon slightly increased rents, rates or taxes etc. from those who quite clearly could afford but little.

SITES STUDIED

It is not proposed as part of this paper to explain exactly how the particular sites were chosen, suffice it to say that the severity of existing problems and the need for action were largely instrumental in their selection.

"Sites and services" projects were proposed in the following locations:-

Accra - at a site north of Teshie
Tema - at a site in Community 12 and extensive infilling within Ashaiman
Kumasi - at a site north of Kumasi integrated within the area known as Moshie Zongo.
Tamale - Kaladan Barracks site.

Upgrading programmes were proposed at the following:-

Accra - Nima
Tema - Ashaiman
Sekondi/Takoradi - Kwesimintim
Kumasi - Moshie Zongo (existing area)
Tamale - parts of Wards E and F.

Table 1 gives particulars of areas, ultimate proposed population and density for the sites and services projects whilst Table 2 gives similar information in respect of upgrading sites.

Table 1 - POPULATION AND AREA SITES & SERVICES

Site	Area (Acres)	Population	Density (pers/acre)	
			Gross	Net
Teshie	122	10,080	83	139
Tema	32	2,010	63	138
Moshie Zongo	86	6,990	81	138
Kaladan	50	3,930	79	142
	290	23,010	79	139

Table 2 - POPULATION AND AREA - UPGRADING

Site	Area (Acres)	Popul-ation	Gross density (Pers/Acre)
Nima	473	80,000	169
Ashaiman	420	77,100	184
Kwesimintim	120	12,100	100
Moshie Zongo	104	8,650	83
Tamale E & F	95	14,700	155
	1,212	192,450	159

Very early in the studies it became apparent that the problems of one city differed in many ways from those of another. The reasons for such variations are not difficult to understand, arising largely from differences in topography, in cultural backgrounds, in proximity to existing major infrastructure facilities and so on.

Competing financial demands

In the case of both upgrading and of sites and services the financial demands far exceed those of the services considered in this paper and the overall studies extended over a wide range including educational needs, shopping facilities, transport requirements, employment, health clinics and religious considerations etc.

Administering Organisation

The need for an organisation of some suitable type, existing or newly created, to administer any proposed scheme was studied in depth. Amongst the various duties of such an organisation would be the responsibility of ensuring that facilities once provided are satisfactorily maintained.

Maintenance

In the course of our studies we found numerous examples of facilities which had been well intentioned, often well designed and which had failed or fallen into disuse through lack of adequate maintenance or non-availability of spare parts.

In some cases the lack of maintenance was not merely the result of a lack of will to maintain but the result of sheer impossibility. By way of illustration of this point we would quote a well designed communal toilet block with water flush sanitation, septic tank and soakaway, provided by a well meaning authority at Ashaiman (near Tema) which has now been built around so densely that it is no longer possible for the municipal emptying vehicle to gain access.

By way of contrast a much simpler aqua privy block within the same locality to which adequate access is still available has been maintained in a manner which is a credit to the local authority. As a consequence the well maintained unit is also well used.

Yet another lesson is to be learned from a second water flush type toilet block in the same area found to be out of service as a result of theft of some of the sanitary fittings. The authority however well intentioned cannot keep on replacing parts which are regularly stolen.

In this case the simpler type of installation without complex equipment had clearly provided a more satisfactory solution.

Scale of Provision of Facilities

Under-provision of a facility, strangely enough, can often in itself be a cause of maintenance difficulties in that the resultant over-use demands extremely frequent attention which cannot always be provided. This problem is experienced by the Accra City Council in the maintenance of the aqua privy and night soil toilet blocks already existing at Nima. Once over-use has led to a particularly unsanitary condition people tend to stop using the facility and foul the approaches instead which in turn makes maintenance a particularly unpleasant task.

It is thus not necessarily the case that a little provision is better than non at all. If the provision of a toilet block serves only to concentrate pollution at one spot, then one might well be better without it altogether!

Talking to the People

Of all the features encountered in our studies the one which stands out above all others is the fact that in every case, in every city and on every site we are providing for the needs of people, and we feel that the importance of meeting and talking to the people involved cannot be over emphasised.

By the people involved we mean both the residents of existing under-privileged communities (the "Client Population") and those who will have dealings with them in and after the implementation of any proposals emerging from the studies.

It is self evident, but we believe worthy of repetition, that any proposals of the study team will, to have any chance of success, be very much dependent upon the co-operation of the client population. In order to convince someone already very poor that parting with more money, however little, is in his best interests requires that his confidence be gained and that those "best interests" be very well defined and understood.

In our studies contact was made at various levels, with Government Departments, State Corporations, City Councils, Regional Commissioners, Town Development Committees, Welfare Committees, Tribal leaders, acknowledged local representatives, spokesmen and with many individuals.

Needless to say many different points of view were expressed and all were not easily reconcilable.

These contacts provide the opportunity for genuine two way communication and the study team must be just as ready to listen, learn and consider as to talk and endeavour to convince.

Direct discussion with individuals produced one or two surprises as for instance when the occupant of a simple dwelling at Ashaiman placed a supply of electricity much higher in his priorities than a piped supply of water. Once explained, his reasons were understood. His dwelling lacked ventilation on account of the density and orientation of neighbouring buildings, and to possess an electric fan was his greatest ambition. As he put it to us he could carry some water to his home but he could not carry in his ventilation!

Features of Specific Sites

We now propose to mention some of the respects in which various sites were found to differ from one to another.

TAMALE

Unlike most of the other sites the low income areas of Tamale are not so much suburban communities which have sprung up since the second world war but are in the main part of the long established central area. Their problems are much more those of the town on a whole than is the case with the other cities.

The one feature which dominated the whole scene at Tamale at the time of the studies was that of a very insecure water supply system. Water from the White Volta, some 20 miles distant, was arriving only very intermittently and improvements both by way of more dependable pumping facilities and increased local storage capacity clearly constituted the No. 1 priority.

A long term proposal for the Kaladan Barracks sites and services project for implementation when improved water supplies are secured envisages a restricted water borne sewerage system with local oxidation pond disposal. Such a system would follow the general principles outlined in the Ross Institute bulletin "Rural Sanitation in the Tropics" (Ref. 1) but adapted to suit a suburban rather than a rural environment.

TEMA & ASHAIMAN

Ashaiman comprises an interesting mix of formally laid out streets and haphazard informal development largely although by no means entirely on squatter lines.

Adjacent to Tema, a modern new town, it benefits from a well intentioned municipal authority which however is largely frustrated in its efforts not only by financial restrictions but in the sort of way mentioned earlier under the heading of maintenance.

The geographical location has facilitated water supply (almost entirely by public standpipe) and electricity supply. Despite a modern sewerage system at Tema, in close proximity, Ashaiman's sanitary provision is rudimentary and grossly inadequate. The studies however revealed that the topography of Ashaiman lends itself to a comparatively inexpensive system of shallow sewers which however could only be linked to the existing Tema system at great expense.

The solution devised in this case used two main collecting sewers (more or less one each side of the highest area) each of which could be kept quite shallow whereas a single trunk collector would have involved deep excavation. Each would deliver approximately half the total pollution load to an adjacent site where there would be provided facultative and maturation ponds along the lines described by Mara (Sewage Treatment in Hot Climates - Ref. 2) This solution would permit of ultimate connection to the Tema sewer system should funds become available later.

KUMASI - MOSHIE ZONGO

The most notable feature here is that Moshie Zongo is still comparatively rural in nature and depends upon wells for its water supply. Although piped water will undoubtedly come eventually, appreciable off-site infrastructure costs will be involved. These can only be met if sufficient economy of scale can be achieved i.e. if the cost is shared by many. It is proposed that this should be achieved by the development of sites and services on a site immediately adjoining the proposed upgrading site.

In the meantime the paramount need is to develop sanitary facilities, refuse disposal services and surface water disposal in a way which will not pollute the streams and wells which will remain the only source of drinking water for some time to come.

SEKONDI TAKORADI - KWESIMINTIM

A typical example of non-use of facilities provided but not adequately maintained was noted here where a well designed and well built communal aqua-privy was being shunned by all and sundry who preferred resorting to indiscriminate defaecation rather than facing its unsanitary condition. That condition no doubt arose partially from earlier over-use but could have been prevented with a daily swilling down from a simple hose pipe - and there was a piped water supply quite close to hand!

ACCRA - TESHIE AND NIMA

Land close to the city suitable for new sites and services, as would be expected, is difficult to find which is why the site eventually selected, north of Teshie is a considerable distance from the city. Apart from the associated problems of travel which result from the selection of this site it presents no insurmountable engineering difficulties. Water and electricity supplies are found within reasonable proximity, gentle slopes facilitate drainage and land for a waste stabilisation pond can be found.

It is however at Nima that the severest problems are encountered and from which some of the most interesting conclusions can be drawn.

The area lies to the north of the Accra ring road, approximately two miles from the city centre. To the east it shares a common boundary with the upper income Kanda Estate; to the west it is separated by the Odaw Stream from the middle income New Town area; and to the north it is limited by the boundary wall of the Accra Girls School and the Achimota Road. The land north of the Achimota Road is a very low density high income housing area.

Nima itself constitutes an extremely crowded densely populated area without room for expansion, surrounded as it is by areas of a very different character.

The very density of Nima however helps to answer at least one of the problems in that, perhaps surprisingly, a water-borne sewerage system proves to be the least expensive of the sanitary options studied, albeit with continued dependence upon communal toilet units.

Surface water drainage is a major problem but improved protection to existing earth channels at key points will provide a vast amelioration.

Existing small dia. water supply pipes, often visible to view, tend, on account of the narrow passageways, to run close to or even actually within grossly polluted drainage channels, constituting an obvious pollution risk in the event of bursts or leakages, and clearly indicate why the provision of piped water to each and every dwelling would be unattainable without unacceptable levels of demolition.

Three alternative refuse disposal systems are recommended for experimental application and a degree of one-way traffic circulation is advocated to enable the satisfactory development of narrow traffic routes.

Cost Recovery

To finance the improvements envisaged it would be necessary to levy a special development charge bringing the total monthly outgoings for most households on rents and rates, development and commodity charges etc. to something of the order of 9% of total household income (or 13% if individually connected to water and sewerage).

Bearing in mind that the project as a whole includes proposals designed to increase the earning capacity of the Client population this does not appear an unreasonable level.

Overall Impressions

In a paper of this length it is impossible to detail all the techniques investigated in the search for inexpensive solutions to problems but we would summarise the most interesting findings of the studies as follows:

There are no universally applicable solutions - each site must be carefully studied and "tailor made" solutions sought.

Whenever there is a choice of site, engineering considerations should feature in the very earliest stages of site selection.

Layouts should take maximum advantage of topographical features and existing infrastructure facilities.

Simplicity is frequently the best solution.

Traffic engineering (e.g. one way circulation) is well worth looking into.

Expensive measures can often be restricted to key points (e.g. concreted bends upon an otherwise earthen drainage channel).

The views of the client population and other interested parties should be sought and respected.

Very impressive results can often be achieved through "economies of scale".

Engineering measures should not be pursued in isolation.

REFERENCES

1. Rural Sanitation in the Tropics. (Bulletin No. 8) published by the Ross Institute, London School of Hygiene and Tropical Medicine.

2. Sewage Treatment in Hot Climates by Duncan Mara, John Wiley & Sons, London.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

B Z DIAMANT

THE NEED FOR APPROPRIATE ENVIRONMENTAL HEALTH TECHNOLOGY IN AFRICA

INTRODUCTION

The need for appropriate environmental health technology has been steadily growing in recent years in many third-world countries, following repeated failures in trying to copy solutions to environmental problems without paying due attention to local conditions and needs. Most such failures have been recorded in rural areas, where the need for environmental improvements is particularly urgent.

Unlike the developed countries, where most people live in urban zones, the majority of developing countries populations live in rural areas. It has been estimated that 72 out of each 100 people there live in rural areas (ref. 1). In the African continent, this ratio is far higher. Out of the 235 million African people not less than 195 million, or 83 % live in rural areas (ref. 2). The environmental problems in Africa are, therefore, more severe and urgent than in any other continent.

Environmental health surveys carried out in Africa in recent years, have revealed that the situation was not improving and was even getting worse. According to the findings of a World Health Organisation global survey on Water Supply and Wastewater Disposal in Developing Countries, that has been carried out in recent years (ref. 2), the ratio of rural African people provided with proper waste disposal facilities, had dropped from 23 % in 1970 to 21 % in 1975. The survey predicted an improved rate of 25 % for 1980, provided considerably large investments are made to meet this expected target (Table 1).

In view of the serious environmental conditions that exist nowadays in Africa, it has become, apparently, clear that only solutions based on, and planned according to, appropriate technology principles, can provide satisfactory results. This technology must not be confind only to technological matters, but also embrace social, economical and even political aspects that are usually involved in almost every large-scale environmental development. The various aspects of appropriate environmental health technology, can be grouped into the following major categories : Priorities ; Water Supply ; Waste Disposal ; Agricultural Irrigation ; Manpower and Legislation.

PRIORITIES

National budgets contain, normally, more or less suitable allocations for health development. Two major health trends usually compete on these allocations: curative medicine and environmental health. The latter is mainly geared towards preventive medicine. It is beyond argument that developing countries at present, are in urgent need for preventive, rather than for curative medicine activities. The latter are not only far more costly, but turn to be even less effective in the existing circumstances. For example, there is little use and

Table 1 Safe Drinking Water and Wastewater Disposal Facilities in Africa 1970-1980 (According to W.H.O. Survey)

FACILITY	PERCENT URBAN/RURAL POPULATION			ESTIMATED COSTS *) OF THE 1980 TARGET (in £)
	1970	1975	1980	
Urban water supply	67	65	80	800,000,000
Rural water supply	13	21	35	750,000,000
Urban waste disposal	69	80	95	410,000,000
Rural waste disposal	23	21	25	70,000,000

*) According to 1975 prices.

doubtful benefit in treating and curing a person infected with schistosomiasis, when he is released from hospital to his old infected environment, where he will be re-exposed to the disease. A small fraction of the huge costs involved in curative medicine (hospitals, medicines, medical staff etc.), can be quite often sufficient to control the disease in the area. Nevertheless, one always finds that priority is given, as a rule, to curative medicine that receives the lion's share of the health budget.

There are, ofcourse, various reasons, among them political considerations, for this strange and disturbing phenomenon. A modern hospital building has a much more impressive view, than say, proper pit-latrines installed in all housholds in the area. This view is particularly more demonstrative during election times, when the community leaders incharge of public expenditure, are eager to be re-elected. This may be also one of the reasons why numerous new hospitals were built in the continent in recent decades, though medical manpower to run them was not available. At the same time very little attention was diverted to environmental health activities. A serious repercussion of this policy is, no doubt, the preference of most medical doctors to practice curative, rather than preventive medicine.

This does not mean, however, that curative medicine is not needed in the developing countries. Vice versa, hospitals are very important establishmentsfor any community. But in the existing severe health conditions in Africa nowadays, national health budgets should, at least, be equally divided between curative medicine and environmental health.

Health as a whole, is sometimes found to be inferior to other development fields, even at the responsible international level. The United Nations Development Programme Progress Report for 1978 (ref. 3), has on its front page an impressive definition for development, which stated that "development has one end goal - improving human condition and bettering individual human lives." But a glance at the breakdown of the UNDP annual global investment, that amounted to over £ 200 million, reveals that among 11 various development fields benefiting from this amount, health has been ranked the 10th, with only about £ 5.7 million, or 2.7 % of the total investment. One can only wonder how the "bettering of individual human lives" can be achieved, when the health aspect in this multi-purpose process, is lagging far behind agriculture, economy, industry, transport, natural resources, science, education, labour and social security. Only international trade was found to be inferior to health... The Report includes, however, also a highlight. In the division of the investment to continents, Africa has won the largest share - 34.7 %.

Safe drinking water and proper waste disposal are considered to be the most important environmental health aspects in the developing countries. Their main appropriate technologies will be discussed later in this Paper. Water supply and waste disposal are two interrelated and complementing mutual activities. Proper waste disposal is, as a matter of fact, protecting the quality of the water supply. Therefore, some authors believe that the provision of proper waste disposal facilities, is more important and therefore should preceed the installation of the water supply (ref. 4). In practice we often find that priority is given, as a rule, to the water aspect in all development programmes. Very seldom are the two carried out together in the same development stage. In most cases the waste disposal is postponed to the "next stage" which is due for years to come. Meanwhile, the new water supply is constantly exposed to severe contamination.

This is a situation that exists mainly in the rural areas. According to one explanation to this paradox (ref. 5), the blame lies with the planners of the development programme, that do not find sufficient professional engineering challange in the design and construction of rural waste disposal devices (pit-latrines etc.) and, therefore, tend to neglect them. On the other hand, even the smallest rural water supply requires engineering design, such as capacity of pumps and diameter of piping.

The appropriate technology for the development of water supply and waste disposal, is to plan them simultaneously along all stages of design, construction, operation, maintenance and surveillance.

WATER SUPPLY

The lack of safe drinking water in Africa is considered to be one the main reasons for the high intestinal disease rate in the continent. Intestinal diseases are the second cause, after malaria, for the high infant mortality rate in Africa. The urgency of the safe water supply situation is indicated in Table 1, where targets for 1980 for rural water supply, that involve tremendeous investments, still leave 2 out of 3 African rural people without safe drinking water.

Water supply, unlike rural waste disposal, is a costly construction. In view of the poor economic stage of rural Africa, the relevant appropriate technology has to based first of all on low-cost solutions. Mechanized devices such as motorized pumps should be avoided as far as possible in therural areas. These devices are not only costly, but they also require skilled maintenance, which is not availalbe in most rural areas. However, if pumping can not be avoided, then solutions such as hydraulic rams, should be preferred on motorized pumps that require fuel (not mentioning electricity) which is costly, and in most cases not availalbe in the rural area.

Only minimal treatment can be applied to pumped surface water, under existing local conditions. This will include slow sand filtration and chlorination with bleaching-powder. The filter media will be ungraded river-bed sand. A load of 2 cubic metres of water per 1 square metre per day, can remove most parasites from the water. The maintenance of the filter is quite simple and a local man can easily be trained to perform it as a part-time job, together with the chlorination.

For emergency cases, such as outbreak of cholera in remote rural areas that can not be reached by road during rainy seasons, a flown portable water treatment plant has been proposed (ref. 6). The device cosists of a folding children swimming pool made of plastic sheets, a small portable motorized water pump, bleach-powder, a reel of barbed wire to protect the "plant" and a 100 ft. (33 metres) 1/2 " diameter plastic hose for transporting the water from the infected water course to the 500 litre capacity plastic container,for chlorination and distribution to the people. The whole lot can be flown in a light aircraft to destination. The device has been operating successfully during the cholera outbreak in Northern Kenya 8 years ago.

Wells

Wells seem to be at present the most appropriate solution to the rural water supply problem in Africa. Due to economical reasons, most wells will have to be dug shallow wells. If a hand pump can not be provided for a well, then at least the following arrangements must be performed: The top of the well should be protected by a 60 cm wall, to prevent contamination and children from falling in. A drain should encircle the well to move away flood water. A public bucket and rope only should be allowed to enter the well. Experience has shown that private containers and ropes caused serious contamination to wells. The well should be roofed and a pully can be fixed in the roof to allow safer drawing of water with the rope.

The best method for disinfecting wells is by means of clay-pot chlorination (ref. 7). The device uses the capilarity of the clay to pass gradually controlled quantities of chlorine to the water.

Hand pumps

A large research activity has been carried out in recent years, with the aim of designing the ideal hand pump (ref. 8). The golden rule for this expected design is that the hand pump should be economical, durable and locally repairable. The handle, for example, should be made of replaceable wood, rather than of breakable cast iron. The piston should be designed so that a local piece of leather should be fit to replace the washer. The pump must be easily disassembled with simple tools that should be provided with the pump. It might be worthwhile to experiment other pumping devices such as the Chinese Chain and Washer pump, that was specially designed for shallow lifts (ref. 9).

Roof catchment

The roof catchment is an ideal source for safe drinking water. This requires a corrugated sheeting roof to replace the straw roof. The method provides, therefore, a safe water supply source, as well as improved housing. Some 80 % of the rainfall can be collected through the roof in closed containers made of galvanised sheets. The users should be instructed to use the rain water only for drinking purposes and use water from other sources for domestic purposes.

WASTE DISPOSAL

The most urgent environmental health problem in rural Africa, is the human waste disposal. Less than a third of the rural population have adequate facilities for this purpose. A mass-solution is therefore, required in this respect.

Due to lack of piped water supply in most rural areas, the solutions are limited. The proper solution must be economical and simple so that it can be built by the future user. The known aqua-privy does not fit, therefore, for this purpose because it is too costly and requires craftsmen for the construction.

The most suitable device is the pit-latrine of the Ishara type (ref. 10). This device can be constructed by the user and built of local materials, apart from a half bag of cement required for the casting of the slab. The mold for casting the slabs will have to be provided by the body that organises the campaign (usually the Health Office). A properly prepared health education programme has to preceed and then follow the campaign, to ensure that the people will not only build the pits but will also use them.

It is not recommended to attach syphons to the slabs' holes, because the syphons can not be made by the users and because they require flushing water that is scarce. It is further not recomended to add to the pit domestic refuse for the production of compost. The proper disposal of the human waste is far more important than the production of compost, the domestic refuse portion of which, competes on the pit's capacity volume.

Urban waste disposal

Most people in Africa still drink water from raw sources such as rivers and lakes. It is, therefore, entirely forbidden to use any water course in the continent for the disposal of any wastewater, whether raw or treated. Fully treated sewage can achieve a maximum purification of 95 %. The remaining 5 % still pose a very serious health hazard when they reach and contaminate water used raw for drinking purposes (ref. 11).

Due to favourable climatical conditions in most parts of Africa, the oxidation ponds purification method should be used,as far as possible, for all small and average sized urban wastewater treatment plants. The treated effluent should not be disposed of by dilution in a water course, but by means of application to land in the form of irrigation.

AGRICULTURAL IRRIGATION

Growing shortages in locally produced food stuffs, have been noticed in recent years in many developing countries. This alarming trend has given rise to a fast increase of modern agriculture development programmes, involving large-scale irrigation projects. Not always has the environmental aspect these projects,been adequately considered and as a result many of these costly operations have caused increased prevalence of water-borne diseases in the developed area. For example, since the impoundment of Lake Nasser near the Aswan Dam in Egypt in 1965, the bilharzia prevalence in the area has risen from

Table 2 Expansion Forecast of Irrigated Areas in the Third World (in million hectares) [12]

Z O N E	1962	1975	1985
Africa (South of the Sahara)	1.1	1.6	2.1
North-West Africa and the Mid. East	12.8	16.1	17.8
Asia and Far-East	49.5	75.0	102.7
Latin America	8.2	11.4	16.2
T o t a l	71.6	104.1	138.8

6 % to 60 %. In the Lake Volta area, near Akosombo Dam in Ghana, the incidence of bilharzia rose from almost nothing to 90 % in only 2 years after the completion of the dam in 1966 (13).

In view of the fast expansion predicted in irrigated areas in the Third World (Table 2), immediate appropriate technology measures must be introduced in the irrigation programming. These should include administration and professional management and proper design of the irrigation system and the cropland.

Adminstration and management

National irrigation projects are very costly investments that run into hundreds of millions of pounds. Though agriculture may be the major concern in these projects, other important aspects such as health can not be overlooked. Therefore, the executive agency for such projects should not be any specific ministry but the Prime-Minister's office (11).

Most irrigation projects constructed in recent years did not consult environmental health engineers and the few that did, asked the latter to join the projects as short-term consultants at the final stages of construction when nothing could be altered. Environmental health engineers must be permanent staff members of the project all along its development.

Design

The design of irrigation systems must consider the important vector control aspect. The impounded reservoir, as well as the irrigation channels, must be planned in respect of banks, slopes, lining ect., so as to prevent vector diseases organisms,such as mosquitoes, snails and black-flies from breeding in the systems.

The main channel should rather be designed as a closed underground pipe. Automatic shyphon spillways should be preferred on ordinary spillwaysin the dams, so as to disturb the quiet-water habitat,favoured by most vectors, by means of intermittent fluctuations of the water surface.

The types of raised crops in the irrigated land should be decided also according to environmental considerations. Rice that requires flooded irrigation, should not be raised in bilharzia infected areas. As far as possible,the irrigation method should be by sprinklers, rather than by flooding that encourages the breeding of disease vectors.

MANPOWER AND LEGISLATION

All above mentioned recommendations can not be executed without the professional advice of environmental health engineers. The training of these engineers should be carried out in local universities, rather than abroad in the developed countries, where stress is laid more on sophisticated matters, such as radioactive wastes and air-pollution, than on basic sanitation problems that mainly exist in the African continent. Environmental health engineering studies, have to be developed, therefore, in all African universities that provide engineering studies.

Legislation is a powerful means of imposing the above-mentioned recommendations. Special legislation has to be prepared for the various environmental health fields, such as, stream-pollution, irrigation development, water supply and waste disposal. Legislation is a time consuming operation and until it is completed, use can temporarily be made of the existing Public Health Law. This Law entrusts considerable power with the medical officer of health and his public health inspectors. They should be trained in environmental health engineering principles, so that they may, meanwhile, control all relevant urgent matters, until the long training of the engineering manpower and the legislation are completed.

REFERENCES

1. WHO (1973). World Health Statistics Reports. Vol.26 p.720-83. Wld Hlth Org., Geneva.
2. WHO (1976). Community Water Supply and Waste-water disposal.WHO Chronicle, Vol.30/8.
3. Morse, B. (1979). UNDP Progress Report - 1978. UNDP,New-York.
4. Feachem, R. and Cairncross, S. (1978). Small Excreta Disposal Systems. Ross Bul. No.8 .
5. Environmental Quality Division (1976). Research Proposal on Rural Excreta Management Systems. Univer. of Science & Tech., Kumasi.
6. Diamant, B. Z. (1972). Portable Unit for the Supply of Drinking Water in Emergencies. WHO/CWS/72, Wld Hlth Org., Geneva.
7. WHO (1972). Chlorination Pot. IRCCWS Newsletter No. 18, Leidschendam, Holland.
8. Potts, P. W. et al (1978). Progress Report on the Unitlization/Evaluation of an Aid Operated Water Pump. Proj. A-1894. USAID,Washington.
9. Watt, S. (1976). Chinese Chain and Washer Pumps. Intermediate Technology Pub., London.
10. Diamant, B. Z. (1978). Pit Latrines - The Need for Rural Areas. In: Sanitation in Developing Countries, Ed. A.Pacey. Wiley,Chichest.
11. Diamant, B.Z. (1979). The Role of Environmental Engineering in the Preventive Control of Water-borne Diseases in Developing Countries. Jr. Royal Society of Health. Vol.99/3.
12. FAO (1970). Provisional Indicative World Plan for Agric. Development. Vol.1 p.58. FAO, Rome.
13. New Civil Engineer (1979). Water Disease Escaltes in Lake Nasser. NCE Intern. Jan. 1979, London.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

C E EGBORGE

ENVIRONMENTAL POLLUTION PROBLEMS OF SMALL COMMUNITIES IN THE NIGER DELTA

Environmental Pollution problems of small communities in the Niger Delta

C. E. EGBORGE

ABSTRACT

This paper discusses the seemingly negligible but important environmental problems of the small communities in the Delta region of Nigeria and stresses the need to introduce measures that will make the inhabitants conscious of the preservation of the environment as a means of checking the occasional outbreak of diseases such as cholera. Some simple measures and systems are suggested which if introduced will go a long way towards improving the quality of the environment in these communities. The author concludes that the achievement of the objective depends much on the simplicity of the system and their effective management.

INTRODUCTION

In nearly all the developing countries the world over, finances are generally so stretched that social amenities are the prerogatives of the capital cities and a few other urban centres. Pipe-borne water, electricity, solid waste disposal systems even where provided are usually a far cry from what a well organized system should be. The constraints on finances imposed by national priority development projects and technological limitations in these countries have sort of 'doomed' the rural communities to a state of utter neglect.

The plight of the small communities living in the delta areas of the Niger river as it empties into the Atlantic ocean is worth giving some consideration. Perched, as small fishing villages, on the higher levee soils along the banks of the numerous meandering rivers and creeks, the inhabitants seem resigned to fighting their annual battle against the ravaging floods and destructive erosion. While in some areas, houses have been built on stilts because of the floods, in other portions of the delta region some sections of villages have been forced to either retreat to lower grounds more susceptible to flooding or to move to areas less threatened by erosion. Such is the magnitude of these natural hazards that the evolution of any large communities in the region have been greatly hampered. The problems of flooding and erosion coupled with the remoteness of the region and the difficulty of transportation which is only by river craft or dug out canoes, will continue to retard the pace of any meaningful development of the region. This paper however is not intended to suggest solutions to the enormous problems of flooding and erosion, but to draw attention to the comparatively negligible but important problems of water supply and environmental sanitation of the riverine communities. Finding simple solutions to these problems will greatly enhance the health of the people. The first part of the paper discusses the water supply and pollution aspects, while the second part touches briefly on the solid waste disposal and air pollution aspects. In the concluding section, the planning aspect as a means of ensuring a healthier and more attractive environment is discussed. Although examples have been drawn from the Rivers State, the delta communities referred to in this paper can be found in the Cross Rivers, Bendel and Ondo states of the Federation of Nigeria. The population of such communities range between 100 to more than 5,000 inhabitants.

WATER SUPPLY AND POLLUTION ASPECT

Lack of potable water supply and proper sanitation practices are two environmental problems common to the communities of the delta. In the freshwater zone of the region, the groundwater is highly mineralized while the coastal and mangrove areas experience the problem of salt water intrusion. Most of the communities rely on the collection of rainwater in drums or other small containers for domestic use during the wet season. In some areas, shallow wells tap the infiltrated rainwater which overlays the local groundwater, but this too becomes unsuitable for drinking when the salt or mineralized water resurfaces after such infiltration water is exhausted. All the communities however depend on the rivers and creeks as the only sources of water during the dry season which normally extends from about

December to March.

The most disturbing aspect of the use of the river water for domestic purposes is that the quality is highly questionable because the same river receives the untreated human wastes of the communities. The common practice is to build family privies supported on wooden columns and protruding from the banks over the water courses. In the larger communities, a series of these privies line the banks from one end of the village to the other with a good number of them located immediately upstream of where water is withdrawn for domestic use by those living downstream. This method of waste disposal is particularly dangerous in the creeks where the waters remain relatively stagnant with little or no mixing and replenishment during the dry season. The reported cases of the outbreak of cholera in these areas usually coincide with this period of the cessation of rainfall and scarcity of good drinking water when the communities are forced to resort to the polluted streams as their only source of water supply.

The need for a healthy environment has for a long time past been realised by the various communities, hence the practice of collection of rainwater for domestic use and the provision of family facilities for the disposal of their human wastes. A community organized water supply scheme is imparative for the elimination of water-borne diseases in the area. Even where it is possible to obtain drinkable water from shallow wells, the high water table and water logging conditions precludes the simultaneous use of these wells and privy pits or septic tanks for the disposal of human and domestic wastes. Some attempts have been made to provide water from boreholes in both the freshwater and coastal areas but many of these had to be abandoned because of the poor quality of the water. The use of river water for domestic purposes would involve costly and sophisticated treatment plants which the communities can ill-afford to maintain at the present economic level of subsistent living conditions. The use of rainwater seems to offer the cheapest, less complicated and the most reliable alternative of all the water supply schemes attempted in the region under consideration.

The only attempt in this region to provide a working community with rainwater is the Peremabiri water supply project which has so far been successful in providing enough water to tide over the entire dry season. It consists of two underground storage tanks of total capacity 910 m^3 (200,000 gallons) in which rainwater is collected via down spouts from the guttered eaves of the roofs of a rice mill with a total roof area of 929m^2 (10,000 sq. ft.). An overhead tank (13.65 m^3), a pump and distribution lines complete the w water supply system. The design was based on an average annual rainfall of 3430 mm (135 in.). The simplicity of the system makes it an attractive alternative as a water supply scheme for such small and remote rural communities. Table 1 gives the average annual rainfall and the seasonal distribution in some selected towns of the area. The table shows that there is abundant rainfall to meet the needs of the communities. The major problem is the provision of collection and storage facilities to meet the demands of the community during the dry season

Table 1 :

AVERAGE RAINFALL(MM) FOR SELECTED STATIONS IN THE NIGER DELTA

MONTH	BONNY	DJOBO	PEREMABIRI	YENAGOA
JAN.	102.4	71.1	54.5	31.1
FEB.	142.9	45.7	143.9	120.4
MAR.	194.1	236.2	140.4	132.8
APR.	350.8	345.4	354.4	212.3
MAY	320.4	429.3	270.9	247.1
JUN	736.6	535.4	[illegible]	345.7
JUL	411.3	533.4	255.8	256.5
AUG	628.5	292.1	408.6	250.0
SEP	684.8	520.7	439.3	429.8
OCT	646.5	553.7	416.0	322.9
NOV	309.2	368.3	261.8	106.0
DEC	115.8	81.3	46.9	48.8
MEAN ANNUAL RAIN-FALL	4622.9	4013.1	3203.2	2506.8

For a fairly large community, it may be necessary to have several catchments and storage tanks. Where the community can afford it, the individual tanks may be buried underground and all interconnected to one overhead tank and pumping plant for distribution. Otherwise it might be necessary to have several overhead tanks each serving the conglomeration of houses from which the rainwater was collected. With regards to the smaller settlements, it will be unwise to design a system requiring the use of a pumping system to raise the water to an overhead tank for distribution. It would be preferable to install a supply system that will lead the water from the catchment directly into elevated storage tanks so that distribution will be by gravity flow only and the maintenance will not be more than occassional cleaning of the storage tanks. If it becomes necessary to supplement the rain water with river water for domestic use, sand filtration units could be built close to the points of withdrawal. This could be followed by coagulation with small doses of alum and chlorine to render the water fit for consumption. A type of arrangement for the distribution of such water by gravity flow is also recommended for the smaller communities.

SOLID WASTE AND AIR POLLUTION PROBLEMS

The problem of solid waste disposal in these small communities is not very acute. For one thing, the quantity of waste produced per household is quite small, and secondly the type of refuse generated in these areas is mainly organic in nature. A cursory examination of the waste in one of the communities revealed some rags, fish bones, plantain peelings and corn husks, sea shells, coconut and palm kernel shells, broken glassware, paper cartons etc. These are usually disposed of in the nearest convenient places or bushes surrounding the houses. While waste disposal is presently not a serious problem, it creates unsightly conditions and odours and is likely to attract flies, rodents, cockroaches and other disease spreading vectors.

Careful consideration must be given to an early organised system of refuse disposal in anticipation of improved economic situation of the people with the resultant better purchasing power of items which are usually more difficult to dispose of. An open dump suitably located away from the residential areas in which the refuse is occasionally burnt would be preferable to the present habit of indiscriminate disposal. With the recent attention to rural areas through the creation of local government authorities some of these communities may well be centres of activities in the not too distant future.

It would appear that it is unnecessary to even mention pollution in any discussion relating to rural communities in the developing countries since there are no industries to pollute the air in these areas. Yet, every day the inhabitants, mostly the women and children, are exposed to intolerably high concentration of smoke from the kitchens. The wood used as fuel for cooking gives out such smoke in the small, poorly ventilated kitchens that would make the concentrations of particulate matter, and carbon monoxide in the much publicised 1952 London smog and Donora Valley smog a child's play, especially during the rainy season when the kitchen windows are often locked. Sometimes the entire family is exposed to this smoke as either one room of the house or the corridors usually serve as the kitchen. Available records show a high rate of infant mortality, about 20% on the average, in these areas. Respiratory infections as a result of such air pollution may well be one of the many causes of the high infant mortality. It is not unlikely that cases of lung cancer, bronchitis and other respiratory diseases are common among children and women in these areas, because of the long term effect of inhaling the kitchen smoke. Provision of well ventilated fireplaces to ensure more complete combustion and the entire separation of the kitchens from the living rooms will reduce the degree of exposure to high concentrations of smoke.

CONCLUSION

Various suggestions on the improvement of the water supply and sanitation practices in the delta have been made in this paper. Emphasis has deliberately been laid more on the design of simple systems that can function with minimum of attention than on complicated but technically sound systems because of the problems of the availability of competent personnel to manage the systems.

Much can be achieved through careful planning in the task of making these areas more attractive to live in. Because land is a premium in these areas, there is an urgent need to evolve a land use zoning system whereby certain areas are alloted to specific uses. From the onset, industries must be located in areas where their effluents can be taken care of either by treatment or otherwise to avoid creating adverse pollution problems for the communities. If for example, the use of rainwater is contemplated, the communities must draw up guidelines as to the type of houses that should be erected in order to provide for the collection and storage of adequate rainwater. It is through such planning and involvement of the communities in the organisation and management of projects that the objectives of providing a better environment could be achieved. In conclusion, it is recommended that the project of collection and use of rainwater as the source of water supply on a community level be given serious consideration, as this would be a step forward in the effort to make life worth living in these areas.

REFERENCES

1. ANDERSON B. Report on the soils of the of the Niger Delta Special Area. NDDB 1967.
2. GRAVA S. Urban Planning Aspects of Water Pollution Control. Columbia University Press 1969.
3. MALONE P. Investigation of the Niger Delta Special Area. NDDB. 1966

HAROLD H LEICH

APPROPRIATE SANITATION FOR HUMAN SETTLEMENTS IN AFRICA

Despite the known disadvantages of centralized sewerage systems in the industrial nations, they are still being recommended for adoption in cities of the developing world (ref. 1). And what are these disadvantages?

Cost

Installation of new gravity sewers through densely built-up sections of a large city would be extremely expensive.

Waste of water

Where houses are served by a piped-in water supply, some 40 per cent of the water used goes down the flush toilets. Many developing nations are already short of water, and the notion of supplying vast additional quantities of potable water to transport body wastes for millions of inhabitants is not realistic.

Depletion of ground water

Where water supplies are pumped from ground water and the resulting wastewater is released into surface waters, there is a gradual depletion of ground water because the water table is not re-charged. In some arid regions of the United States, the ground water level is dropping three metres a year and the water table is already 260 metres below the surface, because of over-pumping.

Incomplete sewage treatment

Even with expensive secondary and tertiary treatment, the effluent from a treatment plant contains unwanted nutrients that cause eutrophication in the receiving waters. Sewage treatment plants are subject to interruptions such as power failures, employee strikes, and by-passing during high water, any one of which can send millions of litres of raw sewage into receiving waters. For example: "In San Francisco, up to 90 per cent of the city's wastewater during storms goes untreated and fouls the bay and the ocean. A new treatment system under consideration would cost $1.93 billion." (ref. 2)

Accumulation of sludge

Municipal sewage treatment plants produce large quantities of sludge, representing a serious disposal problem. Agricultural use as fertilizer may be foreclosed because industrial plants discharge toxic materials into sewers.

Risk of disease to downstream users

Pathogenic organisms such as viruses can survive chlorination, and the very act of chlorination may create carcinogenic compounds in the public water supply.

ALTERNATIVES TO CENTRAL SYSTEMS

The developing nations of Africa have an opportunity to learn from the mistakes of the industrial world by adopting waterless or water-saving sanitation methods. Fortunately ingenious people in many nations, developing and industrial, have given thought to this problem. New sanitation devices are now available that avoid all the disadvantages listed above and that would be appropriate for the prosperous sections of cities in the developing nations. Some examples follow:

Recycling systems

One type purifies all "black water" (wastewater from toilets and urinals) so that it can be re-used for flushing. (Wastewater from wash basins can also be accommodated, but not the "gray water" from kitchen sinks, bathtubs, or laundry.) Such a device would be suitable for a large office building, for example, providing a self-contained sanitation system needing no sewer connection and a limited supply of piped-in water.

Another type purifies all wastewater (both "black" and "gray") to the point where it can be used for all purposes, including cooking and drinking. Such a system would be appropriate for large hotels, apartment houses, and mansions in prosperous areas. Again, no sewer connection is required and only limited additional water is needed to replace water lost through evaporation, etc.

Subsurface disposal systems

The septic or anaerobic tank with its subsurface tile drain field has been used successfully for many years in areas where the soil permits absorption of the effluent. Recent adaptations have allowed installation of septic systems even where soil conditions are unfavorable; for example, building two drain fields which are used alternately to allow each a period of recovery, use of mounds or evapotranspiration beds where bedrock is near the surface, and use of pressure sewers to collect effluent from several tanks for transport to an area where a satisfactory drain field can be constructed.

A different approach is to convert the tank from septic to aerobic action by using an electric pump to inject air into the tank and break up solids. Makers claim the following advantages over septic systems: longer periods between pump-outs, reduction of odours, use of a smaller drain field, and reduced danger of a clogged and failing drain field.

Both systems, of course, require adequate land area near the building served.

Waterless toilets

Several new toilet systems do not need any water. The composting toilet, originating in Sweden, has two principal forms. The large model uses no electricity and produces finished compost, formed from body wastes and kitchen garbage, in about two years. The small model uses electricity for heating body wastes and for ventilation, and finishes the compost in about six months. Compost from either model is largely free of pathogenic organisms and makes a valuable fertilizer.

Several Swedish and U. S. companies make incinerating waterless toilets, fired by oil, electricity, or piped or bottled gas. They reduce body wastes to a sterile ash but there is some release of gases and odours to the air. They completely solve the water polution problem but consume considerable amounts of energy.

Some American companies make closed-loop toilet systems that use a low-viscosity oil as the flushing medium. Wastes are piped to a gravity separation tank where the oil floats to the top and the wastes sink to the bottom. The oil is drained off the top, filtered, and recirculated to the toilets. Wastes are stored until they can be removed for land or other disposal.

All these dry toilets have the great advantage of solving the problem of disposing of body wastes, but leave unsolved the problem of "gray water" disposal. One solution where land is available is a dry well or small subsurface drain field. Inventors are working to devise a simple filtration system for cleansing such wastewater so that it could safely be used for irrigating lawns and gardens, or drained into surface waters.

Vacuum or pressure systems

Inventors have developed the use of differential air pressure to move body wastes through sewer pipes without the need for large quantities of water. Vacuum and pressure toilets need only a litre or two of water per flush. Such systems can be used for individual homes or apartment or office buildings, with the wastes directed to a holding tank for periodic removal. Or vacuum or pressure sewers can be used for an entire community in lieu of gravity sewers; in addition to water savings, such lines can move wastewater up moderate grades and thus reduce the cost of ditch-digging, as compared with gravity sewer lines.

INSPECTION AND MAINTENANCE OF ON-SITE SYSTEMS

The on-site sanitary systems described above require systematic inspection and maintenance to insure that they are functioning properly. In the United States public sanitary districts are being organized in some areas for this purpose. An alternative approach is to require the owner of each system to have a valid service contract with the manufacturer's representative.

NEED FOR EXPERIMENTATION

It would be helpful if some international body such as the United Nations Environment Programme, the World Health Organization, or the World Bank would test these various devices to determine whether they can be successfully used in cities of the developing nations. In the absence of such an international effort, an African nation could conduct its own experiments. It is likely that no one system would satisfy all sanitation needs; one can visualize a spectrum of solutions determined by such factors as comparative costs, density of population, soil conditions, and size of buildings to be served.

LOW-COST SANITATION NEEDS

The cost of all the devices mentioned above, although much less than that of a central system, clearly rules them out for the great majority of inhabitants of the developing nations, both urban and rural. Simple and inexpensive toilet systems are needed for the cities, towns, villages, and rural areas of Africa, and much thought and experimentation are being given to this subject (ref. 3). One very promising device is the double-vault privy, originating in Vietnam (ref. 4). Another system, a dry indoor method costing very little per household, might also be the subject of experimentation. An adaptation of the British "earth closet" of the nineteenth century, this toilet uses dry, pulverized soil to cover body wastes and thereby eliminate odours, unpleasant sights, and insect infestations. It could take several forms; the following is one suggestion:

-- A small enclosed space, for privacy, is set aside in the dwelling.

-- A wide-mouthed bucket or box, its bottom covered with a layer of dry soil, is provided. The sides of the container are low enough to allow the user to squat over it. Or if desired, a raised pedestal seat could be built over the container.

-- At hand is another container of dry, pulverized soil and a small trowel or paddle. Each user is trained to cover the new deposit with a layer of soil to begin the composting process. Sand, sawdust, or wood ashes could be mixed with the soil, but lime should not be used since it tends to preserve the wastes.

-- If the dwelling has land available, a member of the household buries the contents when the container is nearly full. Burial under 30 centimetres of soil should be sufficient. Garden crops can then be grown on the enriched soil but edible root crops should not be planted for a year or so.

-- Where no land is available at each dwelling, a collection system is organized. In this case the bucket or box is lined with a bag containing the layer of soil, and each bag is tied shut and collected periodically. Simple hand carts can be used to transport the bags to farmland for burial. In several years the same field can be used again.

-- In places where dwellings do not have enough space indoors to install the system, public toilets will be needed. They can operate on the same principle as the household system.

-- Costs of the system should be paid by the public sanitation agency.

The importance of experimentation as a first step should be emphasized before any such system is widely used. The public sanitation agency of a developing nation could undertake such an experimental programme, reviewing the following points:

-- What absorbent mixture of dry soil and other materials is best adapted to local conditions?

-- Is it preferable to separate the functions of urination and defecation by providing a special bucket for urination (possibly including a small quantity of water for dilution)? Such a bucket could be emptied, when nearly full, into a small dry well outside the dwelling.

-- When bags are needed for the system, what material should be used: cloth, plastic, reinforced paper?

In introducing such an indoor system, a society should conduct an intensive information programme and obtain the support of political and social leaders.

REFERENCES

1. MUIGA M I AND REID G W. Cost analysis of water and waste water treatment processes in developing countries. Water Resources Bulletin, 1979, June, 838-852.

2. Washington Post, 1979, December 27.

3. RYBCZYNSKI W, POLPRASERT C, AND MCGARRY M. Low-cost technology options for sanitation. International Development Research Centre, Ottawa, 1978.

4. NIMPUNO K. Private correspondence, 1979.

G H READ, R G FEACHEM and D D MARA

ASPECTS OF LOW COST SANITATION IN AFRICA

INTRODUCTION

1. Conventional sewerage is the most expensive form of sanitation and one which is unaffordable by most urban and rural communities in developing countries. In 1976 the World Bank, aware that the benefits of its lending programme in the water supply and sanitation sectors were not reaching the urban and rural poor, undertook a two year research programme into appropriate technologies for low cost water supply and sanitation in developing countries. The results of this research programme (Ref. 9) show that low cost technically viable alternative technologies to conventional sewerage do exist and that these technologies can have a public health impact similar to that of conventional sewerage.

2. Following the research programme, the United Nations Development Programme (UNDP), as part of its preparations for the International Drinking Water Supply and Sanitation Decade (1981-1990), has sponsored a global project of demonstration programmes in low cost water supply and sanitation in developing countries. Under this project, which the World Bank is executing, the Bank established a Technology Advisory Group (TAG) in late 1978 to facilitate the design, implementation and monitoring of these demonstration programmes in selected parts of the developing world.

COUNTRY WORK

3. The UNDP Global Project has so far been endorsed by 13 countries: Bangladesh, Botswana, Brazil, Egypt, India, Indonesia, Lesotho, Malaysia, Nepal, Nigeria, Philippines, Sudan and Tanzania. In this paper we present very brief summaries of aspects of TAG activities in Africa, and raise some issues of importance to sanitation programme development. The work of TAG has concentrated on sanitation programmes rather than on water supply programmes since appropriate approaches to sanitation are less well understood.

BACKGROUND

4. TAG is working on sanitation planning and development work in African countries in a wide range of social, economic, demographic and climatic situations; wide variation in some aspects is contrasted by remarkable similarities in other aspects. For example Sudan with an area of 2.5 million km^2 and a population of 7 persons per km^2 contrasted with Lesotho with an area of 30 000 km^2 and a population density of 43 persons per km^2. The countries have largely rural populations (generally over 85% rural) and a low per capita Gross National Product (GNP) of under US $ 500 per capita.

TABLE I: LATEST ESTIMATES OF LEVELS OF SERVICE OF POTABLE WATER SUPPLY AND SANITATION IN VARIOUS COUNTRIES+

	% of Population with Safe Potable Water		% of Population with Adequate* Sanitation	
Country	Urban	Rural	Urban	Rural
Botswana (Ref.7)	90%	28%	30% to 50%	less than 25%
Egypt	80%	50%	n.a.	n.a.
Lesotho (Ref.7)	65%	14%	51%	3% to 17%
Nigeria	n.a.	n.a.	n.a.	n.a.
Ghana (Ref.6)	86%	14%	95%	40%
Sudan	49%	45%	less than 10% (Ref.5)	less than 30% (Ref.5)
Tanzania (Ref.2)	88%	36%	n.a.	40%

+Unless indicated otherwise, source is Ref. 8.

*"Adequate" is the definition used in compliation of official statistics. It does not imply that the sanitation facility is sufficient in terms of current TAG thinking.

5. Life expectancy is generally under 50 years with much of the population undernourished, and generally with poor curative and preventative medical facilities. The infant mortality rate is generally greater than 120 per thousand live births and in a few countries greater than 180 per 1 000. The human misery and sadness which this brings has a serious debilitating effect on society as well as on individual families. Between 40% and 50% of the population is under 14 years of age, with fewer than 50% at primary school; adult literacy is low (generally under 40% literate).

6. Existing service levels of safe drinking water and adequate excreta disposal are variable but not particularly good as shown in Table 1. Rural areas in particular have very poor water service levels and almost negligible excreta disposal facilities. In urban areas, service levels are highly skewed in favour of high income households who consume well above basic need levels and in many cases receive free services which the poor have either to pay for or do not receive at all.

7. The countries are all low income countries. The outlook for improvement in per capita CNP, particularly when compared with the industrialised countries such as USA or the United Kingdom, is poor, due to slow economic growth combined with high population growth. A major feature of this growth has been the trend towards increased urbanisation; this trend is projected to continue such that in sub-Saharan Africa the estimated 1975 urban population of 80 million (about 21% of total population) is expected to grow to over 250 million (about 40% of total population). The countries also have a variety of different religious, political, economic and socio-cultural environments which affect planning and implementation of sanitation programmes.

COUNTRY PROGRAMMES

8. Against the rapidly changing background described above, the need for affordable, appropriate and acceptable sanitation services will become ever more pressing. TAG work in Africa has been concentrated in Botswana, Egypt, Lesotho and Tanzania. We describe below some aspects of this work.

Botswana

9. Botswana is an arid country characterised by very low population density, a few small but rapidly growing urban areas and a cattle population of some five times the human population. Low cost sanitation developments date back to the early 1970s when Government did initial development work on glass fibre aqua privies. The prototype has various technical problems and in 1976 Government, together with the International Development and Research Centre (IDRC) of Canada, undertook an investigation into alternative forms of low cost sanitation, constructing and testing single pit Ventilated Improved Pit (VIP) latrines, Reed Odourless Earth Closets (ROECs)*, cement block aqua privies (single chamber with soakway) and composting toilets.

* A variation of a VIP with an asbestos cement seat cum chute built integrally into an offset ventilated pit.

Monitoring the long-term performance of the 175 units constructed is in progress. From an initial assessment of the results, broad recommendations which related sanitation type to income level were made. It was also found in 1977 (Ref.12) that the economic cost of waterborne sewerage in Botswana was some 3 times higher than the cost of sanitation using VIP latrines and almost twice the cost of aqua privy systems. On-site systems were therefore considered appropriate for urban development.

10. The Ministry of Local Government and Lands (MLGL) is responsible for urban and rural development, and for developing sanitation as part of new infrastructure. Existing urban excreta disposal services comprise a range of systems including water-borne sewerage and septic tanks (generally for high income households), a few aqua privies with soakways (both the early prototype glass fibre model and the more recent Type B privy) as well as improved and traditional dry pit latrines. Many low income urban households (some 40% to 50% of all households) have no sanitation facilities. It has been found (Ref.9) that sitting is preferred to squatting and anal cleansing is by paper, leaves or other dry materials.

11. Government has developed extensive on-site programmes in the capital, Gaborone; a variety of VIP latrines, ROECs and Type B aqua privies have been constructed on different development projects. In the most recent project, Government is, with CIDA assistance upgrading an unserviced low income high density housing area (plot sizes are between 400 m^2 and 800 m^2). Sanitation is by some 450 contractor-built twin-pit emptyable VIP latrines with glass fibre sitting pans (designated the REC 11). The twin-pit design was developed in conjunction with the Building Research Establishment. (See the additional Conference paper by R E Carroll). There is one latrine per household and it is proposed that householders will complete the superstructure. Detailed site investigation was undertaken for this project and a number of prototypes constructed to establish householder preferences.

12. The twin-pit latrine has considerable advantages over a single-pit latrine; the first pit is used till full, then while put contents are biodegrading the second pit is used. If each pit is sized for at least a two year life, the pits can desludge alternately, when the pit contains a well degraded and innocuous humus+. Government is proposing to extend this programme. Pit emptying has yet to be undertaken and still needs rigorous investigation.

13. TAG has been working with Government on developing proposals for urban sanitation on a World Bank-assisted urban project in Francistown and Selebi Pikwe, northern Botswana, where a multi-disciplinary programme with technical assistance for self-help implementation is being considered. Government is concerned about potential environmental pollution problems associated with on-site sanitation. Some work has already been done in this area and TAG has been advising on possible future investigations.

\+ Excreta pathogen biodegradation is well documented in Reference 9.

Government is also proposing to develop long term sanitation plans for the major villages in Botswana. These will be implemented in a phased programme over the next ten years.

14. Rural sanitation is still largely undeveloped. However, in response to a specific district level request, Government has, with USAID assistance recently started implementing a pilot rural Environmental Sanitation and Protection Programme (ESPP) on which TAG has worked. The programme will be based on the use of multi-communication media together with an action component, and will develop latrine types in response to householder preference.

15. In response to a Government proposal to promote sanitation developments, improve sector coordination, benefit from existing sector experience and develop long term plans, UNDP has agreed to fund a Public Health Engineer in MLGL. The engineer who will focus on low cost sanitation developments will take up post in April 1980, following briefing by TAG.

16. Botswana had made considerable strides towards developing sound long term sanitation strategies. A number of aspects remain unresolved but Government is committed to make progress in the sector over the next decade, bringing improved health and well-being to a small but rapidly growing population.

Egypt

17. Most urban and rural development in the Arab Republic of Egypt has taken place along the River Nile and in the Nile Delta. Rural communities have ready access to irrigation water but access to potable water of adequate quality is limited. Regional water reticulation schemes supply water intermittently; handpumps are used extensively for potable water and in many areas the water table is high; most groundwater north of 31^{o} latitude is saline.

18. The majority of the rural population live in small high-density communities (ezbas) to avoid using scarce agricultural land for housing. Rural sanitation, which is the responsibility of the Ministry of Health is generally poor or non-existent; the excreta disposal profile of a typical Egyptian ezba is:

- much of the population is Muslim; anal cleansing is generally with water and squatting is preferred to sitting;
- the men defecate in the mosque which has squatting plate pit latrines. The latrines are unvented, generally don't have a water seal, can be emptied through a honeycomb brick soakage pit; in some cases the pit may be offset from the squatting slab;
- a few high income houses which have water connections have septic tanks with soakaways;
- a few houses have pour flush latrines with soakaways inside the house;
- a few houses have simple pits open to the air, but partially covered by a squatting plate formed from logs, sticks and mud bricks. These latrines have no superstructure, but may have privacy walls;
- the majority of women and children use the cattleshed or yard within the household, the fields or other area with reasonable privacy.

When pits are full, they are dug out by farmers, the contents mixed with soil and organic matter, spread out to dry (in a few cases partially composted) and then applied to the fields.

19. Over the past two decades a number of rural sanitation programmes in Egypt have been unsuccessful, even though there is an extensive system of rural health clinics where staffing includes sanitarians. The sanitarians have many other duties and have consequently devoted little time and effort to sanitation. Precast concrete squat slabs and pipework for the construction of latrines with water seals are currently available but not extensively used in rural areas, probably due to shortage of finance, sound designs and technical assistance: cement shortages have in the past also considerably hampered developments.

20. TAG is working with the General Organisation for Potable Water (GOPW) and UNICEF in the design and implementation of low cost sanitation programmes in conjunction with water supply programmes in Upper and Lower Egypt. The most likely technical solution is the pour-flush latrine (PF) with twin soakage pits or the twin pit Ventilated Improved Pit (VIP) latrine. It will be necessary to line pits in many areas of high water table. Standing dirty water (such as in soakage pits) is the preferred bredding site of Culex pipiers mosquitoes, the vector of Bancroftian filariasis (elephantiasis). It is proposed to monitor filariasis as part of these programmes. Sullage disposal is also a problem in high-density high water table areas; proposals for sullage management will be developed as part of the programmes.

21. Many local government functions are currently being decentralised and GOPW recognise a strong need to ensure adequate sector coordination. TAG is working with GOPW in developing proposals to form a unit to assist in this coordination.

22. Urban sewerage and sanitation is the responsibility of either the national drainage authority (GOSSD) or urban and regional government. Most urban areas have waterborne sewerage systems serving portions of the population. Single chamber septic tanks* are also fairly common in both high density and high income areas; poor ground conditions and high water tables often cause clogging and flodding of septic tank effluents. Much of the urban population is not served, particularly in fringe areas; sanitation here is by using community facilities (such as mosques) or informal. Most of the waterborne sewerage systems require substantial upgrading; this together with extending many of the existing networks is now being done by Government through a number of very large programmes, which at the moment do not include sanitation.

23. Government commitment to improving excreta disposal is expected to increase due to increasing decentralisation of local government. If improved designs and financing facilities are made available it is likely that a strong private sector will develop to assist latrine construction.

* Septic tanks generally either drain to soakage pits or are left open jointed; they clog over time and act as cesspits.

Lesotho

24. TAG has been working on both urban and rural sanitation developments in Lesotho following a specific request in December 1978 from the Government of Lesotho. The Ministry of Interior is responsible for urban excreta disposal in Lesotho. There are limited waterborne sewerage systems in some urban areas (the principal urban area is the capital, Maseru which has a current population of 60 000, 5% of whom have sewerage). High income households which do not have sewerage have two chamber septic tanks with soakaways. A bucket latrine system serves some 25% of the Maseru population. The remainder of the urban population either have on-site dry pit latrines (an estimated 20%) or use open ground for excreta disposal (an estimated 40% in Maseru and rather higher elsewhere). These latrines are generally shallow unlined pits with superstructures, open to the atmosphere (i.e. without adequate cover slabs or piped ventilation), and sitting pans constructed in timber; superstructure materials vary from dressed sandstone masonary to hessian or galvanized corrugated iron.

25. Government is embarking on a number of urban upgrading and sites and services projects with assistance from CIDA and the World Bank. Sanitation will be developed on these projects as part of the infrastructure. On the CIDA assisted project in White City, Maseru, 200 single-pit emptyable VIP latrines with sittingpans are being constructed. Following extensive discussions with project beneficiaries, substructures are being built by contract labour, and superstructures completed by the householder (some of whom may prefer to employ small-scale contractors for this work).

26. As part of World Bank-assisted Maseru Urban Project on which TAG has been working with Government, a multi-disciplinary Sanitation Implementation Team will be formed in the Ministry of Interior which will assist implement urban sanitation. Following initial assessment of a range of alternative sanitation systems including waterborne sewerage, aqua privies, ROECs and composting latrines, the optimal solution for the Maseru Urban Project (in terms of affordability, technical suitability and householder acceptability) was found to be either a single-pit or twin-pit VIP latrine. A cost comparison between these two is shown in Table II.

27. It is anticipated that the sanitation for the Urban Project will comprise twin-pit emptyable VIP latrines with sitting pans; plotholders will where possible provide labour to reduce construction costs, and the technically more complex work will be undertaken through the Implementation Team. Building materials loans (received at 9% interest rate over 20 years) will be made available under the Urban Project, and the programme will include site investigation, detailed analysis of socio-cultural factors, information and health education delivery systems, training, monitoring and evaluation. Pit emptying will be undertaken approximately every 4 years by the Municipal Council; emptying methods and institutions will be developed through the Urban Project. This urban programme is the first phase of planned long term improvements in urban sanitation; Government is developing a phased long term sanitation plan for all urban areas in Lesotho.

28. Service levels of rural excreta disposal in Lesotho are low; where latrines exist they are generally squatting type unimproved dry pit latrines.

TABLE II COST COMPARISON OF SINGLE Vs TWIN-PIT LATRINE (JANUARY 1980 PRICES)

	Substructure Construction $US	Net Present Value of[2] emptying costs $US	Total $US	Monthly Charge[3] to Householder $US
Single Pit	162.5	61.3	223.8	2.03
Twin Pit	218.8	8.8	227.6	2.05

On health and institutional grounds the twin-pit is preferable and only marginally more expensive

1. Anal cleansing is with paper, leaves, grass or other dry materials; water is not generally used in Lesotho.
2. The twin pit will need far less frequent emptying and negligible sludge treatment compared to the single pit during the 20 year period considered.
3. Loan recovered at 9% interest rate over 20 years.

Government is about to approve and start implementation of a long term phased rural sanitation programme developed with TAG which will complement the rural water programme. Development will initially take place on a small scale in a number of villages which have either on-going rural development or rural health worker programmes. Latrines will probably be twin-pit VIP latrines. The programme will include training, monitoring and evaluation, and strengthening the Ministry of Health in health education, epidemiology and socio-cultural aspects of sanitation programme development.

29. TAG is working with Government on the development of other activities in the sector such that the long term development needs of sanitation and water supply programmes in both urban and rural sectors will be clearly identified. Of major concern to Government is the current shortage of trained manpower; considerable attention is being focussed on this issue.

30. Government commitment to the sector is high, and if manpower and financial constraints can be overcome substantial progress will be made in Lesotho over the next decade.

Tanzania

31. The Government of the United Republic of Tanzania is fully committed to the provision of safe excreta disposal facilities for both urban and rural populations by the development of long term sanitation programmes. Rural excreta disposal is the responsibility of the Ministry of Health (AFYA). The need for improved excreta disposal in Tanzania is substantial. A recent survey of 10 rural districts found that 39% of houses surveyed had "satisfactory pit latrines" (over 6 feet deep, good walls, proper door, good squatting slab), 25% had unsatisfactory pit latrines, while 36% had no latrines. The proportion of houses in different districts having a satisfactory pit latrine ranged from 75% to 1% indicating an enormous variation in sanitary conditions. Rural latrines are constructed by householders, mainly by putting logs over an excavated pit to form a squatting slab; traditional materials are used for constructing the superstructure. Health officers (Bwana Afya) in AFYA have many duties and are unable to devote much time to sanitation.

32. TAG has been working with the Government of Tanzania to promote the sanitation sector since November 1978, and is advising AFYA on rural sanitation. AFYA has formed a Rural Sanitation Unit (RSU) with a staff of three experienced health officers. It is envisaged that rural sanitation projects will develop in conjunction with a number of on-going or planned rural water projects.

33. Urban excreta disposal is the responsibility of the Ministry of Lands, Housing and Urban Development (ARDHI). A few urban areas have limited sewerage systems; however the majority of the urban population (which is 12% of total population) have pit latrines.

A recent survey (Ref.7) of the capital, Dar es Salaam, found that 76% of households had pit latrines, 12% waterborne sewerage, 10% septic tanks and only 2% were unserviced. With the support of TAG, ARDHI has created a Low Cost Sanitation Unit (LCSU) to plan and coordinate urban excreta disposal programmes. The LCSU at present comprises a Tanzanian civil engineer, an expatriate civil engineer, two health officers and a technician. ARDHI has commissioned consultants to prepare master plans for sanitation and sewerage in Arusha, Dar es Salaam, Morgoro, Moshi and Mwanza. TAG is working with ARDHI on these projects.

34. It is concluded that the strong commitment of the Tanzanian Government to low cost sanitation is likely to ensure considerable progress in providing adequate excreta disposal facilities for both urban and rural populations over the next decade.

ISSUES OF NOTE

35. The country work described above has raised a number of issues most of which are as yet unresolved; it has also enabled some broad conclusions to be drawn for future work.

Manpower development and training

36. Sound manpower development and training programmes have long been recognised as crucial for economic growth and development in developing countries. Low cost sanitation developments in the countries discussed are still in the formative stages; training and information dissemination is therefore essential at all levels. Decision makers, planners and engineers need orientation, technicians and operators need to be trained and householders need to be informed. TAG work with Governments in programme design has specifically integrated manpower development and training at all levels into programme design; the impact of this on project costs is substantial however and could often best be borne by central government.

Self-Help

37. "Self-help"* which (together with "community participation") has tended to become the development planner's surrogate for sound programme design has a major role in sanitation programme development. The two major objectives of self-help are:

- to reduce system costs by having the householder undertake part of system construction, operation and maintenance; and
- to achieve householder commitment through involvement, thereby improving the chances of adequate system usage and maintenance, thereby realising investment benefits.

* Self-help inputs to sanitation programmes in the context of this paper are defined as inputs by beneficiaries in the form of householder labour and materials in the construction operation and maintenance phases.

38. A number of self-help orientated sanitation programmes in Africa have experienced implementation problems principally due to insufficient technical support thereby stretching householders beyond their capability. In these situations the waste of resources and squandering of householder goodwill will have a long-term detrimental impact on sector development. In many African countries the traditional method of trying to improve low cost sanitation has been for the Health Ministry to verbally exhort householders to build latrines; in a few countries, sketches are provided (generally very poorly 'engineered' structures) after which the householder is left to his own devices with no access to technical backing, materials purchasing or financing. Latrines, when built, often collapse; in some cases children fall into the pits.

39. What is needed in reality is sound, well-illustrated designs (bearing in mind adult literacy rates) preferably modelled in 3 dimensions, together with access to building materials, tools, low level technical assistance, finance and supervision. The level of input required will clearly vary in each country and programme. It is crucial to successful programme development that self-help is not stretched beyond its capability, and that the correct level of resource support is provided to assist participants.

Socio-cultural aspects of sanitation

40. A sound understanding of socio-cultural aspects of sanitation at community, household and individual level is essential to ensure effective programme design and subsequent successful implementation. TAG has been working in the countries in multi-disciplinary teams. All programme design work has proposed socio-cultural inputs throughout project life to enable sound implementation.

Communal Facilities

41. Consideration has been given in many African countries over the years to the construction of communal or shared facilities. With the exception of the well documented and unique "Comfort Stations" programme in Abadan, Nigeria, communal facilities have either been a failure or have been rejected by the community. However since community facilities are substantially more cost effective than individual household facilities, it is felt that their development should be explored further in African programmes, such as programmes in which each household has a private room which it maintains.

Beneficiary Oriented Information Systems

42. Crucial to success of sanitation programmes is the development of beneficiary and community oriented information systems. It is generally agreed that health education is an essential complementary input to water and sanitation investments; however TAG work in a number of countries is now being orientated to the development of more broad-based information systems which will include health education and will:

- introduce the sanitation programme to the community
- stimulate interest and encourage participation
- provide technical information and identify benefits
- identify financing mechanisms and sources of materials
- promote continuing facility use by all the family.

A range of communication media are available for this including radio, cassette tapes, pamphlets and posters. Urban authorities, and "hardware" oriented authorities (Ministries of Works) have limited experience in this area; sanitation project design in future will need to strengthen these functions.

Latrine Emptying

43. Latrine emptying remains an unresolved problem in Africa. There is no recent experience of emptying well engineered latrines and the recently developed twin pit latrines have yet to complete a life cycle. There is a marked reluctance in Africa to handle excreta (fully decomposed or otherwise) and in investigations done in the IDRC Research Project into the acceptability of alternate sanitation systems, composting was rejected as being unacceptable due mainly to a reluctance to handle fresh or decomposed excreta.

44. In both urban and rural areas, latrines are currently moved when they are full; this is clearly uneconomic when they are well built, and also unacceptable to householders who have put substantial effort and finance into latrine construction. As urban plot sizes reduce* it becomes both technically difficult and expensive to reexcavate pits and move superstructures. The development of twin-pit latrines will overcome the problem. The BRE (UK) is planning to evaluate pit emptying methods in Botswana, and TAG is planning to investigate this elsewhere; this work is crucial to the development of low cost sanitation.

Environmental Pollution Hazards

45. Extensive improvements of service levels of water supply and sanitation in developing countries can only be undertaken if groundwater sources are substantially developed and low cost on-site systems of excreta disposal adopted. These two strategies are in conflict in that on-site excreta disposal will in many circumstances pollute groundwater sources. Insufficient is known at present about these potential hazards in developing countries, and consideration is being given in a number of countries (in particular Botswana and Egypt) to assessing the impact of on-site systems on the environment in general and groundwater in particular.

* Site and service plots sizes in low income urban Africa have reduced from over 1 000 sq m in the early 1970's to currently under 200 sq m.

The recent improvements in membrane filtration techniques (making them simple, inexpensive, reliable and rugged) together with more reliable methods of sampling (such as the Water Research Centre UK in-situ sampling device) has meant that the rigorous monitoring programmes needed can be relatively easily undertaken. TAG is working with various governments in addressing this issue.

Cost Recovery

46. Policy and mechanisms for effective administration of sanitation cost recovery are in the formative stages in many of the countries in which TAG is working. A common decision criteria has been that the monthly household financial cost of water supply and sanitation services should not exceed 5% of monthly household income. Low cost sanitation projects aim to deliver services to the rural and urban poor and by implication are aimed at households near or often below the poverty threshold; cost recovery policies for this population group are intrinsically difficult to develop and administer.

47. There is little point in developing a cost recovery policy which requires effective institutions for implementation if these institutions do not exist; in countries in which TAG is working therefore, institution strengthening is considered a major project objective concurrent with the development of cost recovery policies.

TYPICAL PROGRAMME DESIGN

48. From the work undertaken in the various countries, and experience to date in the sector it is concluded that a general structure for sanitation programme development should include the following key elements:

- a central sanitation steering committee comprising the ministries or departments responsible for finance and planning, health, urban and rural development, water supply and sewerage;
- sound project management, technical assistance and site investigations;
- preinvestment assessment of socio-cultural factors, and beneficiary sanitation preference;
- information systems development and community dialogue;
- access to and delivery of building materials and mass produced components, combined with financing mechanisms;
- integration of sanitation designs with related physical infrastructure development (particularly water supply, storm water drainage, and housing layouts);
- integration of sanitation programme management with existing administrative structures (such as town councils);
- monitoring and evaluation programme;
- a programme for briefing central government personnel, and training engineers, technicians, artisans and extension workers.

A number of proposed programmes designed by governments with TAG inputs in Botswana, Egypt, Lesotho and Tanzania will be developed along these lines.

CONCLUSION

49. While the need for improved sanitation in much of Africa is substantial, the Governments in countries in which TAG is working have shown a commitment to develop programmes to meet these needs. Although developments are still in the formative stage, institutional structures and technical options are emerging which it is anticipated will prove successful. Crucial to success in this new area of development will be high government commitment combined with sound planning, sensitive implementation and considerable support by multilateral and bilateral agencies. These efforts will produce effective programmes only if sustained householder commitment to programme development is achieved by culturally responsive design and implementation.

Acknowledgements

The authors would like to express their thanks to the many Government officials in the countries in which TAG has worked for their assistance and for much of the information contained in this paper. The views expressed however are those of the authors alone as are the omissions.

REFERENCES

1. WORLD BANK, "1979 World Bank Atlas", World Bank, 1979, 23 pp.
2. WORLD BANK, "World Development Indicators", World Bank, June 1979, 51 pp.
3. WORLD BANK, "World Development Report, 1979", World Bank, August 1979, 188 pp.
4. WORLD BANK, "World Atlas of the Child", World Bank, 1979, 39 pp.
5. AGIB, A.R.A., "Some aspects of Sanitation in the Sudan", Proceedings of Cairo International Regional Seminar on Sanitary Engineering, May 1979, 30 pp.
6. WORLD WATER, "International Drinking Water and Sanitation Decade 'Dossiers' ", December 1978, July 1979, August 1979.
7. WORLD BANK, "UNDP Global Project GLO/78/006 Technology Advisory Group International Country Reports", various reports from November 1978 to January 1980 inclusive.
8. WORLD HEALTH ORGANISATION, "World Statistics Report", WHO, Vol, 29, No. 10, 1976, pp 543-603.
9. WORLD BANK, "Low Cost Sanitation Research Project Reports", Volumes I to VI inclusive; RES 22; Drafts, October 1978.
10. WORLD HEALTH ORGANISATION, "Sodium, Chlorides and Conductivity in Drinking Water", WHO ENRO Reports and Studies 2, WHO, 1979, 63 pp.
11. LEWIS, W.J., FARR, J.L. & FOSTER, S.S.D., "A Detailed Evaluation of the Pollution Hazard to Village Water-Supply Boreholes in Eastern Botswana", G.S.10, Department of Geological Survey, Botswana, June 1978.
12. WORLD BANK, Internal Memorandum S.E. Daher, December 1977.

OKAY C IGWE

RELEVANT WATER DEVELOPMENT TECHNOLOGY IN RELATION TO OPERATION AND MAINTENANCE ASPECTS UNDER UNCERTAINTY

INTRODUCTION

Uncertainty is a characteristic feature of our every day life. It is constant factor in all decisions we make, whether implicitly and explicitly expressed. In adequate information with respect to several outputs required in decision-making usually results in uncertainty and the attendant premises of risk. Thus, in evaluating any investment project there is sure to be some uncertainty about the future streams of costs and benefits. Changes in the different decision input variables such as tastes, discoveries of new sources of supplies, and technological innovations, all act overtime to raise or lower the prices of goods produced by and inputs used by, the project, in question, in ways we may sometimes guess at but cannot foresee.

The issue of uncertainty as it relates to water resources projects cannot be overemphasised. This is the sole consideration in the usual provision called "factor of safety" in systems engineering design. This provision usually escalates the system capacities in design and this normally results in escalation of costs during construction. Even with this provision the net effect of many of the waterworks may end up to be negative rather than positive as had been anticipated by the designers. Natural hydrological uncertainty is the most predominant and common type of uncertainty in all waterworks projects all over the world. The optimal size of a reservoir or dam will depend on the "uncertain future" of expected flood magnitudes which vary rapidly in time and space. Even where one has historical hydrological records going back forty-fifty years or more years, the uncertainty of future events is still high and the optimal size of hydraulic structure will have to be determined on the basis of prior probability of flood damage in the future.

In the developing nations, with practically no long history of water control, no reliable hydrological records, and no data bank, the issue of uncertainty is more severe. Again since a major characterisation of all developing nations is the non availability of adequate local technologies there is the added dimension of "technological uncertainty" resulting from lack of adequate manpower required for proper management, operation and maintenance of "imported technologies" from the developed nations. This also results in uncertainty in prices of imported construction inputs and uncertainty with respect to the future availability and supply of the necessary spare parts, even if scanty manpower were to be produced by more intensive educational programmes. Another characteristic parameter in describing a country as developing is the country's low Gorss National (product (GNP) which inherently implies lack of adequate financial resources for the execution of her developmental projects. Thus, there is the uncertainty associated with non-availability of funds. Also uncertainty associated with changes in political power and the associated premises of changes in policy contributes to complicate the problem further. The problem is really multi-dimensional.

One, therefore, is forced to ask : "How can we cope with natural hydroligical un-certainty as well as the 'incidental' technological uncertainty, or rather how do we prosper in the face of these uncertainties in our determined effort to develop our abundant water resources?" "Should we accept that the trick and challenge is to learn to prosper with these uncertainties, or are there better answers to the characteristic problem ?"

CONSIDERATION AND ANALYSIS OF THE MULTI DIMENSIONAL PROBLEM OF THE DEVELOPING COUNTRIES

The complexity of the situation of uncertainty in the developing nations is such that no adequate planning decisions can be effectively made without "sufficient"consideration for this. A lot of complications have arisen during operation and maintenance of waterworks projects because the approach employed in the preceeding phases of planning and construction was not relevant to the particular environment. Many things are usually taken for granted with over-optimistic assumptions that adequate problem solving techniques or project implementation technique employed "somewhere sometime in the past" would suffice. This has been shown to be an over sightedness and has manufested during the operation and maintenance.

The author is of the opinion that technology is is a way of life. It has a cultural base and bias. It must be developed in tune with the existing value systems, traditions, educational standard, available resources, and manpower, that characterise the environment. The interest and co-operation of the people must be ascertained. In the event that a technology has to be imported from one culture to another, the "lender" of this "expensive good" must be available to educate the "borrower" on the features and must be prepared to work hard to make the beneficiary to accept this "good" wholeheartedly and be contempted with it.

In the Western countries the historical perspective on the invention, and growth of modern waterworks technology indicates that the technology has evolved over time, and against a background of characteristic high labour costs, and a desire of the population to obtain water with the least trouble to themselves, and without upsetting the socio-cultural equilibrium of their environment. The method of financing was such that the revenue was collected by means of "water rate" based on the "value" of the property. Because supervisory labour is expensive, the tendency has been in recent years to instal instrumentation and automation for collecting flow and treatment information and to control the processing and distribution of the water. This level of supervision in operating and maintaining these complicated and sophisticated technologies is beyond the technical absorbtive capacity of developing countries to supply. In developing countries population growth rates, migration of rural hierarchy to urban hierarchy, industrial and commercial development are often difficult to forecast not only because there is often a paucity of reliable data existing, but also because of "fluid" political conditions which result in grandiose planning proposals but no effective decision-making and no effective implementation.

In the developing countries, anxious to provide for themselves an infrastructure to enable their inhabitants to improve their way of life and the level of health, the demands on available finance are many and thus the availability of funds is limited and uncertain. This is bound to delay timely execution of planned water project designs until the designs become overtaken by the fast increasing population. Thus a "vicious circle" is created.

In any scheme of water supply there are the on-shore components (items which can be paid for by local currency e.g. local labour) and off-shore components (items which can only be paid for by foreign currency e.g. imported pumping equipments, machinery or materials). Foreign currency availability is a restricting factor. On many instances different Water Corporations have placed orders and opened letters of credit for pumping plants from Overseas Manufacturing Firms only to discover in time that the assumed financial commitment that was made sometime in the past is no longer being honoured. This introduces complications and uncertainty as regards the future completion of the project. In such cases much public money must have been expended for little or no output (return) since the project has not been utilized by the supposed beneficiaries.

To plan or design adequate water supply systems under such conditions of uncertainty as are prevalant in the developing countries requires more ingenuity than is normally possessed by an engineer alone. Team effort involving different experts and local community support is necessary. Established conventional techniques being used in the developed western countries to cope with "simple uncertainty" will not suffice for the "multiattribute compound and complicated uncertainty" of the developing countries. Since there is lack of reliable data with respect to all the componenets of uncertainty one has to compe with, be it process (natural) uncertainty, statistical (information) uncertainty, uncertainty induced by external circumstances (resulting mainly from changing policies, future technological innovations, social changes and future economic conditions), or uncertainty in factors reflecting human elements (such as urbanization rate) an analyst cannot even make an estimate of prior probabilities and the corresponding probability distributions that are vital for analysis. Thus there is the urgent need to recognize the role of uncertainty in planning decisions and realise that we are going to have to learn to live much more intelligently and realistically with subjective probability and uncertainty in the developing countries. If this aspect of planning is not weighted enough, inadequate management, operation, and maintenance of waterworks in the developing countries will always be the most likely cause of failure.

TOWARD A MORE EFFECTIVE APPROACH IN THE DEVELOPMENT OF RELEVANT TECHNOLOGY FOR APPLICATION IN DEVELOPING COUNTRIES

RELEVANT TECHNOLOGY PHILOSOPHY

The author prefers the terminology "Relevant Technology" to the more conventional terms of "Appropriate Technology" "Intermediate Technology" "Low-Cost Technology" and "Alternative Technology" because the objective here is to accept that what is required in the developing countries should be a departure from the conventional approaches of the developing countries. If the basic philosophy is that technology should have a cultural orientation, then it follows from simple deduction that what is needed is "that which is relevant to the culture of the region" and which can easily be integrated within the society without much inconvenience. Thus, Relevant Technology can be defined as that technology which evolves in consonance with the cultura and tradition of the people and which intends to provide the most socially and economically acceptable level of service to humanity with least inconvenience. Relevant Technology should, therefore, be characterised by the following :

1. Involvement of the local community residents in the decision-making process early enough in project planning. Proper consultation and communication channels must be established to stimulate community participation. Participation of the community should start right from the pre-feasibility and full-feasibility studies and data collection, through the design and construction stages, to the permanent management, operation and maintenance of the waterworks installation. The objectives of community participation can best be achieved by :

a. Identifying and recognising the formal and informal community leadership and communication channels.

b. Determining the existing socio-cultural practices in water.

c. Determining the community's "willingness to pay" for improved water supply facilities and the mode of payment preferred either by cash and/or the "substitution of labour and materials.

2. Designs should be based on simple approaches with the involvement of local experts and based on the principle of "planned-staged development" of short intervals, e.g. 5 year, 10 year instead of 30 year design capacities. This will reduce to a minimum the amount of capital invested but un-utilized, and will also reduce the financial burden to the barest minimum.

3. Possibilities of using local construction materials which can be manufactured locally. This would reduce the off-shore cost component preserve foreign currency and simplify operation and maintenance. This would also facilitate easy, speed erection and would also minimise the extent of abandonment of "revious" plans resulting usually from changes in policies.

4. More emphasis should be placed on the simplicity of operation and preventive maintenance. Beneficiaries should participate in the management, operation and maintenance of facilities and collection of revenues. This would reduce water waste and encourage proper conservation practice in water use.

5. An educational programme to enlighten the operators and the beneficiaries is of utmost importance. Special on-the-job training programmes should be organised for local residents who are interested, dedicated, and committed to the efficient management, operation, and maintenance of the facilities.

6. Planners, designers, and policy makers have to make a deliberate effort to recognise the implicit effect of uncertainty in the developing countries. In the absence of reliable process and statistical information, determinisyic approaches are inadequate. Therefore approaches have to be devised for subjectively assessing the situation. Thus subjective estimate of probabilities must be introduced. This calls for the establishment of acceptable techniques that could be employed in decision-making under uncertainty, in the developing countries. If this were to be achieved then the objectives of "Relevant Technology" will be attained.

FIELD OBSERVATIONS WITH RESPECT TO OPERATION AND MAINTENANCE, MAINTENANCE PROGRAMMES IN ANAMBRA STATE OF NIGERIA

The Anambra State Water Corporation has eight administrative zones and twenty three local Government areas. In these zones there are many schemes which have been commissioned and are operational. However, field observations indicate that the output from these schemes could be improved by improving the operation and maintenance schedules. The constraints originate mainly from lack of funds for purchase of fuel required for plant operation, for purchase of water treatment chemicals, for adequate transport, for effective communication equipment, for metering output of stations, for purchase and speedy supply of spare parts, pipes and ancillary equipment, for provision of workshop facilities, as well as lack of skilled motivated engineering field staff and artisans. Table 1 is an estimated typical required annual operations budget and Table 2 is an estimated financial requirement for general maintenance for the eight zones. However, in the past the estimates provided for operations and maintenance have fallen much lower than the figures shown.

Field observations also reveal that the level of education of the operators is not adequate for proper and astute operation of the system. Usually operating schedules are not available at the pumping stations and the pumps are operated uneconomically. There are no installed water meters and pressure meters. Cases of submersible pumps sinking inside boreholes are common. Failures of pipe mains in the distribution system are common as is usually shown by broken pipemains.

Also the general observation of manpower in the operations and maintenance field is that the present establishment is sufficient in numbers to operate and maintain the systems. However there is a shortage of skilled senior artisans, particularly in the mechanical and electrical departments. It is the author's belief that on-the-job training could be ideal in the lesser skilled manpower, such as pumping station operators and plumbers. Extra technical staff is required.

Generally supervision of the labour force is inadequate. The situation could be improved by making more funds available for the provision of better transport and communication facilities.

The collection of water rates if the most difficult administrative problem for the Anambra State Water Corporation. This emanates from the cultural beliefe that water is "traditionally free" and consequently "evasion" is high. This issue needs immediate attention if the revenues from water rates are to improve for more efficient operation.

TABLE I TYPICAL ANNUAL OPERATIONS BUDGET

Budget Item	Schedule No.	ZONE ALLOCATION Abakaliki	Aguata	Awka	Enugu	Nnewi	Nsukka	Onitsha	Udi
Fuel (diesel oil)	15	3 000	118 000	35 000	21 000	107 000	99 000	115 000	46 000
Power NEPA	16	89 000	-	-	299 000	-	56 000	346 000	-
Repair and replacement of plant	9 10 11	100 000	60 000	60 000	250 000	60 000	225 000	170 000	60 000
Chemicals incl. Chlorination Stage 1)	17	38 000	10 500	8 500	225 000	-	-	34 000	2 500
Gen. Maint.	6	16 000	6000	18 000	66 000	10 000	12 000	90 000	10 000
Mains Replacement.		-	-	-	10 000	-	-	10 000	-
Chlorination Stage 2	18	-	-	-	2 000	4 000	8 500	7 000	4 000
Transport (Replacement & additional vehicles and running costs)	20	29 000	28 500	29 000	187 000	58 000	80 000	85 000	28 500
ZONE TOTALS		275 000	223 000	150 500	1060 000	239 500	480 500	857 000	151 000

Workshops (14) 75 750

Total : N3 512 250

Updated to 1st April 1980 (15%). N4 039 000

BAYESIAN DECISION THEORY APPROACH AND RELEVANT TECHNOLOGY FOR DEVELOPING COUNTRIES

Since the philosophy of Relevant Technology lays more emphasis on what is culturally acceptable and emphasises community participation ,as a basic necessity, the decision making is a collective responsibility of both the planners, designers, policy makers and the beneficiaries. Maximization of economic returns from the project is not the dominant objective function. Rather miximization of aggregate consumption (utility) is explicitly emphasized and the sole objective function is to maximise utility. Since uncertainty is predominant characteristic, a stochastic analysis is required. Thus, the objective function should aim at "maximization of expected utility values." Since interdependant and interelated uncertainty components come into play, the approach ought to be capable of assessing probabilities subjectively. Compound subjective probability estimates will be the highest input in the approach.

Under the constraints of the above stipulation Bayesian Decision Theory Approach is most relevant, and should be readily applicable to the situations of the developing countries. Decision Thoery is most adequate for solving the key problem of operation and maintenance. This decision analysis approach will serve as a final departure from the conventional benefit/cost technique which is obsolete in an environment of complicated compound uncertainty matrix. The problem of water supply ought to be viewed more as a social problem rather than a regional economic efficiency problem. Therefore, the decision matrix should consider, in addition to costs and benefits, other attributes such as socio-cultural acceptance, growth considerations etc. for total evaluation.

Decision analysis technique is relevant to problems of uncertainty because it provides an objective analysis of subjective considerations. In complicated, compound decision problems it allows the decision makers to break the problem into many smaller and easy-to-handle decision problems which can be quantified by subjective utility assessment. Once this is achieved the parties involved in the decision are in a much better position to develop mutual understanding and better perception of the problem. Thus it provides an effective medium of communication for interested groups with overlapping and diverging articulated preferences and backgrounds.

The whole process of Decision Theory takes cognizance of the value of the information, making best use of limited data while indicating the areas of greatest uncertainty, areas in which the need for additional information is most pressing. Moving backward in time, the decision maker can evaluate the outcome of certain observations, and in doing so can update his information and modify his actions so that the choice which he actually makes is most likely to be in harmony with the realised event, or to be an improved decision. The decision reached is more in line with public interest and thus the approach is further justified by the "Principle of Pareto Improvement", a socio-economic undertaking that makes everyone in the social organisation better off.

REFERENCES

Halter A N and G W Dean, "Decisions Under Uncertainty", South-Western Publishing Co., Cincinnati, Ohio, 1971.
Igwe O C, "Optimal Long-Term Development and Operation of Irrigation Systems with Storage under Hydrological Uncertainty", PhD Dissertation, Department of Civil Engineering, University of British Columbia, Vancouver, December 1976.
Mishan E J, "Elements of Cost-Benefit Analysis", Part V: "Uncertainty", Union University Books, London, June 1971.
White G F, "Prospering with Uncertainty", Proceedings of the First International Conference on Transfer of Water Resources Knowledge, September 1972, USA. Edited by Evan Vlachos, Water Resources Publications, Fort Collins, Colorado, USA.
Woolhiser D A, "Decisions with Inadequate Hydrological Data". Proceedings of the Second International Hydrological Symposium, September 1972, USA. Water Resources Publications, Fort Collins, Colorado, USA.

Session 3: GENERAL PROBLEMS AND THEIR SOLUTION

Discussion

R Foster and T R Crossley

The Engineer in an Underprivileged Environment

Mr CROSSLEY explained that the paper dealt with the problems of urban environments, where very insanitary conditions existed. These problems were caused by squatters and other factors peculiar to urban areas. The project was initiated by the Government of Ghana, to look at all aspects of the problem, and so a multi-disciplinary team was used. The team sought to find answers by looking at the permutations and combinations of some well-tried ideas.

2. The long-term answer was to try to persuade people to go elsewhere, but this was not possible immediately. The most important part of the study was to meet and talk to the people involved. A huge cross-section of the community was contacted, and it was found that the people's priorities were not always as the team had anticipated. For instance, water supply was not always considered of prime importance. All sites extending over five cities in Ghana were visited, and it was found that the problems varied from city to city, so that there was no standard solution to be found. The great need was to convince people that they should contribute to any scheme. This worked best in a small area where even a small improvement would benefit a lot of people. Slides were used to illustrate the nature of the problems in particular areas, as described in the paper.

3. Dr T O EGUNJOBI thought that the Ghana Urban Development Project could be a very good guide for use in other areas.

4. Mr CROSSLEY pointed out that the Authority set up for this project was intended to be permanent, to continue to co-ordinate all ideas and parties concerned.

Professor B Z Diamant

The Need for Appropriate Environmental Health Technology in Africa

5. Professor DIAMANT pointed out that the main problems were rural, not urban. An estimated 154 million people in rural Africa live without safe drinking water and sanitation facilities. This meant that "appropriate" technology must be applied, eg pit latrines were a good mass solution, together with improvement of existing wells. The wells could be supplemented with roof catchments. It was essential that water supply and sanitation should always be considered together.

6. Legislation was needed to control such things as irrigation, to try to prevent the serious health hazards which irrigation was causing at the moment.

7. Mr R R BANNERMAN said that tests had been carried out in West Africa on the use of different materials for pump handles. It was found that wooden handles broke too easily, and that metal was much better. He had read that wooden handles were often stolen by the local people.

8. Professor DIAMANT pointed out that if a wooden handle was broken or stolen, it could be replaced immediately by the local carpenter, whereas it might be months before a replacement metal handle could be found.

9. Dr K Y BALIGA said that Professor Diamant had mentioned that a clean bucket should be available at the well and that users should not bring dirty buckets from home. What use was this if the water collected in the clean bucket was then taken home in a dirty bucket? Should not more emphasis be placed on the education of the users into using clean buckets? Professor DIAMANT answered that the importance of having only one bucket per well was that one dirty bucket put into a well could contaminate the water for the whole village, whereas if someone only carried his water home in a dirty bucket then he would only contaminate his own home.

C E Egborge

Environmental Pollution Problems of Small Communities in the Niger Delta

10. Mr EGBORGE said that for this type of community the use of rainwater from a controlled catchment could be a very important source for drinking, especially where there was much pollution of the ground and surface supplies. In other areas where pollution was not so great, boreholes and pumps could be used. However, now that the problem of water shortage had become so serious, more economical use of available water must be encouraged. One idea was that people could use river water for washing clothes etc, while rainwater could be kept for drinking and cooking.

11. Dr BALIGA asked whether in view of energy loss and needs, the possibility of storing the rainwater in elevated tanks had been considered instead of having to pump the water from the underground tanks. Also, with reference to the use of river water for washing and flushing, in a situation of severe water shortage, surely a water closet system needing flushing should not be used? The disadvantages of using a dual water supply of two different qualities for different purposes must also be considered.

12. Mr EGBORGE answered that the point about wasted energy was true, but the space needed for a large tank must also be considered. It was often only possible to keep the tank underground, out of the way.

13. Mr J O OYENNGA thought that he should bring up the question of the taste of the water after four months' storage in these tanks, although he thought the idea of water storage a commendable one. Mr EGBORGE said that the choice was one of either having the water, or not having it. So far there had been no complaints about the taste of the water. Regular disinfection might be needed, but there was provision for ventilation at the top of the tanks, so this would not be too great a problem.

H H Leich

Appropriate Sanitation for Human Settlements in Africa

14. Mr LEICH said that the message of the paper was to persuade the African countries not to adopt the waterborne sewage disposal systems used by the industrial world. These caused great problems of cost, waste of water, depletion of ground water, incomplete treatment and disposal of sludge. Several good alternatives were available as described in the paper. Mr LEICH stressed the importance of continuing experimentation and monitoring.

Read G H, Feachem E G and Mara D D

Aspects of Low Cost Sanitation in Africa

15. Mr READ said that it would be a problem to provide adequate water and sanitation for all by 1990. With the present increase in population the question was posed as to how it could be done. The ideal system was one which was well designed, easily maintained and used continuously by the whole family. It should also be appropriate, affordable and acceptable.

16. The World Bank had been concerned with compiling a report on a research project, producing useful manuals and documents. Mr READ worked for the Technical Advisory Group, formed to work specifically in a number of countries to look at the options available and to formulate programme design. Emphasis was placed on the need for financing, technical support and socio-cultural appropriateness of technologies; water supply, excreta disposal and disposal of wastewater (sullage) should be planned and implemented simultaneously.

17. Dr BALIGA commented that the cost figures given in the paper were not really applicable to all countries and situations, since cost of materials and labour varied widely in developing countries. Mr READ agreed with this and answered that each situation had to be considered individually. The figures showed an order of magnitude. The idea should be to cost out several alternatives and then use the most cost effective over a long period.

18. Dr K O IWUGO wanted to know whether Twin-pit latrines had been successfully operated anywhere yet and what was the difference in nature of the humus obtained from Twin-pits and composting toilets. Mr READ answered that twin-pits had been used extensively in India and Egypt, as pour-flush types. Twin-pit dry latrines were relatively recent. A programme was being developed in Botswana, and they were being considered in Tanzania and other parts of Southern Africa. The pour-flush type was known to work well and the humus produced was pathogen-free, and fairly easy to handle.

19. Dr E A ANYAHURU observed that since the walls of the pit of the VIP latrine were not sealed, it would not be possible to use them in a place such as Lagos where the ground water level was high. Mr READ said that it depended on the particular situation. If the water table was high the main concern would be the structural stability. Most of the Indian and Egyptian latrines were lined. Where lining was necessary, it must be ensured that there was enough surface area left for leaching of liquids. Where there was concern that pollution of groundwater might occur, it was possible to build the pits above ground, as had been done in Tanzania and parts of Egypt, or other solutions might be more appropriate.

20. Professor DIAMANT said that since VIP latrines needed frequent emptying, this might pose a problem in Africa. Could the design not be made lighter, so that the slab and superstructure could be removed, from a filled pit, and re-erected over a newly dug pit? Mr READ realised that this was a problem in Africa, where in some places there were strong objections to handling fresh excreta. It was necessary to look at a whole range of possibilities. In some parts of the country, excreta removal might be acceptable, and in other parts other technologies would have to be considered.

21. Mr L HUTTON issued a word of caution for areas where the ground water system was shallow, regarding the suitability of a pit latrine. Little was known about pollution from pit latrines into ground water, but it was certain that bacteria and pathogens never understood economic analysis. Mr READ said

that an International Working Group had been set up to investigate this. However the key to the problem was to plan both water supply and the disposal of sullage and excreta simultaneously to achieve long term benefits. Health education inputs were also important.

Dr O C Igwe

Relevant Water Development Technology in Relation to Operation and Maintenance Aspects under Uncertainty

22. Dr IGWE commented that many previous speakers had been referring indirectly to the uncertainty which prevails. We were living in an environment of uncertainty, and any planning must take account of this. There were several relevant uncertainties:

a. Natural hydrological.
b. Process.
c. Information (due to lack of data).
d. Human.
e. Future policy.

The term "relevant technology" was better than the popular conventions of "appropriate", "low cost", "intermediate" or "alternative". This was because the technology evolved with the culture and traditions of the people, and provided socially and economically acceptable solutions.

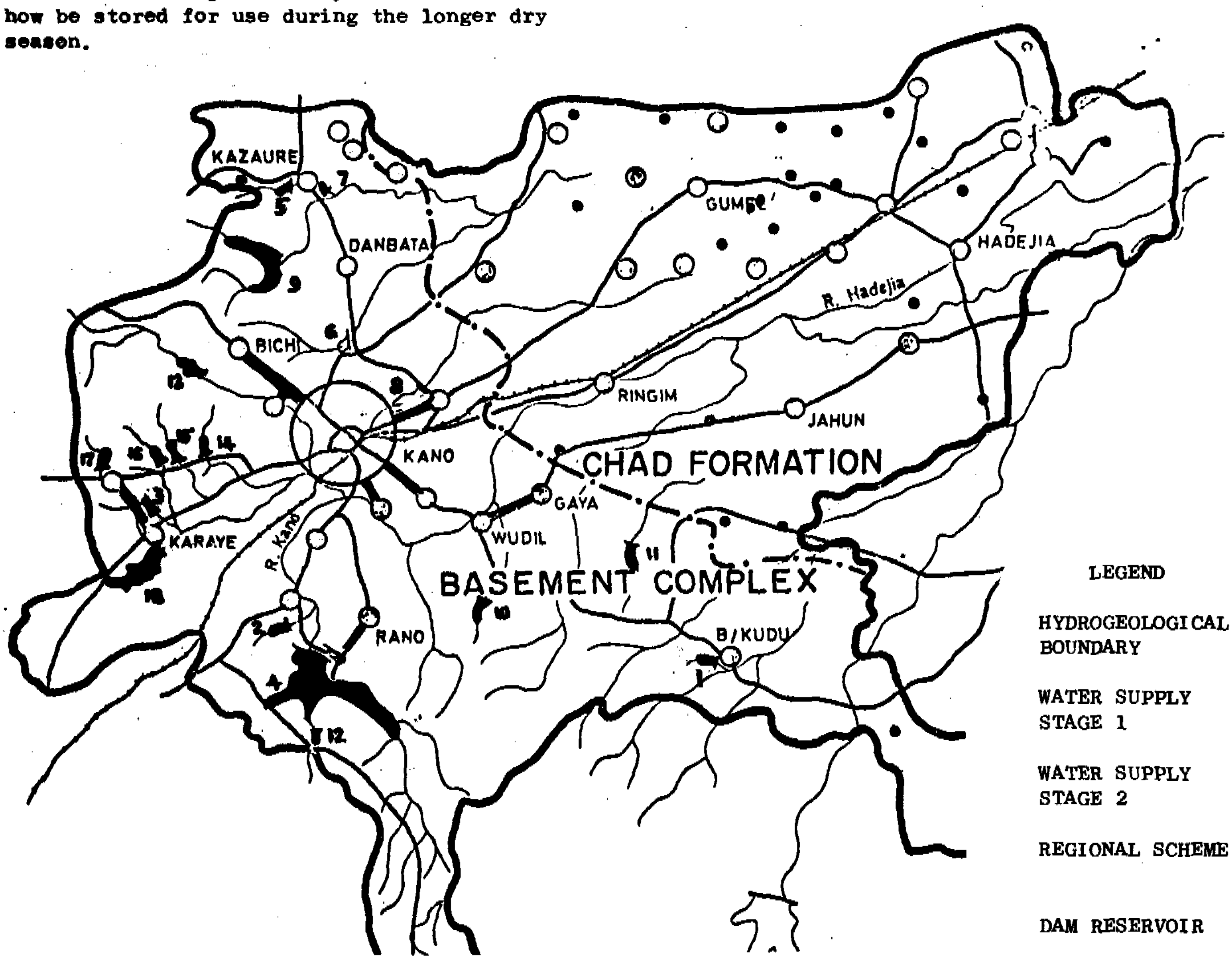
M A ABDULLAHI

ENGINEERING MEASURES FOR THE DEVELOPMENT OF SURFACE WATER RESOURCES IN KANO STATE

Kano State is a small state with a large population dependent mostly upon agriculture for existence. The fact that the northern parts of the State are situated in the semi-arid zone of West Africa makes the provision of water for both domestic, industrial and agricultural purposes of paramount importance. The State has 4-5 months of rainfall during the summer and 6-7 months of dry season. Unless adequate groundwater is available the water that comes during the rainy season must somehow be stored for use during the longer dry season.

Kano State is underlain by two contrasting geological formations. These are the crystalline basement rocks covered by a layer of decomposed rock of varying depth; and the Chad Basin which is underlain by alternative layers of sedimentary clays and sands.

The imaginary line of demarcation between the two formations divides the state into two; running from the North-Western to the South-Eastern part of the State. (Fig. 1).



DAMS 1. BIRNIN KUDU. 2. BAGAUDA. 3. KARAYE. 4. TIGA. 5. IBRAHIM ADAMU. 6. TOMAS. 7. MOHAMMADU AYUBA. 8. JEKARA. 9. GARI. 10. KAFIN CHIRI. 11. WARWADE. 12. TUDUN WADA. 13. WATARI. 14. GUZUGUZU. 15. MAGAGA. 16. PADA. 17. MARESHI. 18. CHALLAWA GORGE.

Figure 1 Water supply schemes in Kano State

The area east of this line is the Chad formation which is very rich in groundwater. Very high yield is obtained from boreholes sunk in this area, while the area west of the line has very small pockets of groundwater and if boreholes are sunk they have very poor yield.

Therefore the Geological conditions and socio-economic patterns of Kano State makes a complete range of water management techniques possible. Thus schemes ranging in scale from the multi-purpose, multi-regional Tiga Dam Project to local well digging and from surface storage to the tapping of artesian water supplies are being pursued under the direction of the Kano State Water Resources and Engineering Construction Agency (WRECA).

Throughout the state over 5000 open walls have been dug into the surface layer on both the crystalline basement rock and the upper strata of the Chad Basin formation and more than 212 teams of men are responsible for the construction and maintenance of these local wells which have provided the main water supply for decades. The depth of wells varies considerably. In the West of the state the average groundwater table is seldom more than twenty metres below the ground surface; but in the Chad formations the depth of the water table frequently exceeds thirty-five metres.

The depth of the groundwater table indicates that within the layer overlaying the Crystalline basement groundwater moves towards the major valleys, showing that percolation from the surface contributes significantly to the recharge of the water table. Within the Chad Basin formation groundwater frequently moves away from the major rivers which are a source of groundwater replenishment. While the variation in the depth of the water table during the course of a year is relatively small open wells experience a very slow yield rate of less than 300 litres per hour. Although their diameters of 1.3 metres allow a large storage capacity and they refill overnight, particularly during the rainy season, alternative water supplies must be established to satisfy the rapidly increasing domestic, agricultural and industrial demand for water.

In the part of Kano State which lies within the Chad Basin the chief concern of WRECA is the discovery and tapping of groundwater supplies. The location of borehole programmes is primarily determined by demand, and towns which are administrative and district headquarters are the centres of initial activity. In the average: towns with a population of 5000 and above are supposed to benefit from the borehole drilling programme. The borehole drilling programme was actually started during the 1972-74 drought when the northern half of the State was declared a disaster area. The State government bought six mud-flash drilling rigs which were used to construct over 160 boreholes within the Chad Formation. Drilling is not very difficult in the largely unconsolidated sands and clays and suitable aquifers are invariably reached within a depth of 100 metres.

As well as providing an adequate yield, the best aquifers are composed of relatively coarse material in order to avoid fine sand; which is extremely abrasive; being washed into the water supply and causing subsequent damage to well casing equipment.

The groundwater in the Chad Formation of Kano State is largely sub-artesian and submersible pumps have to be installed to lift the water to the surface.

In high yielding boreholes these pumps can extract up to 100 cubic metres per hour without lowering the water table; although often the water demand is less than the full capacity of a borehole.

There are well over 70 water supply schemes utilising borehole water. About 60 per-cent of them are described as first-stage water supply schemes and the rest are called second-stage or full developed water schemes. The first stage scheme consists of a minimum of two boreholes joined together by submersible pumps powered by diesel generating sets. This set up provides water through a few standpipes located around the pump house. WRECA has standardised on the design of a reliable generating/pumping station that could be quickly and efficiently installed, serviced on site and maintained at a base workshop. The station is made of prefabricated aluminium sheets and can be erected together with the pumps and generating sets within one to two weeks. The Challawa workshop with its mechanical-, electrical-, machine-, welding-shops and stores sections coupled with its 'on load' test bed carries out in depth servicing of the station bimonthly. By reducing turn round times the much needed water supply in the rural areas is guaranteed. Figure 1 shows the location of some of the first stage and the second stage water supply schemes. The second stage water supply is a development of the first stage when overhead tank and reticulation system is provided.

Due to the drought of 1972-74 the Kan State Government gave a lot of attention to the provision of water to the affected areas and almost neglected the Basement Complex areas. As a result of which the area is now one of the hardest hit as far as water shortage is concerned. As there is very little groundwater in these areas, the only major source of water are the streams and rivers that drain into the Hadejia river system. The fact that these rivers are seasonal makes the conservation of the endless amount of water that flows away during the short rainy season very essential. Before Kano State was created in 1968 there was not a single dam of any significance, save the small cattle through dams temporarily constructed on yearly basis. The state was therefore fortunate that the first Military regime had water supply and agriculture as its priority. Indeed it would have no other choice because the greatest single problem disturbing the very existence and wellbeing of the people in the rural areas of the state has been and is still lack of adequate water supply. In some of these areas people have to travel up to 10 KM in order to fetch drinking water.

Under its water resources development programme; the Kano State Government embarked upon the construction of dams in the Basement Complex areas of the State. So far 20 earth dams have been completed and more are being planned.

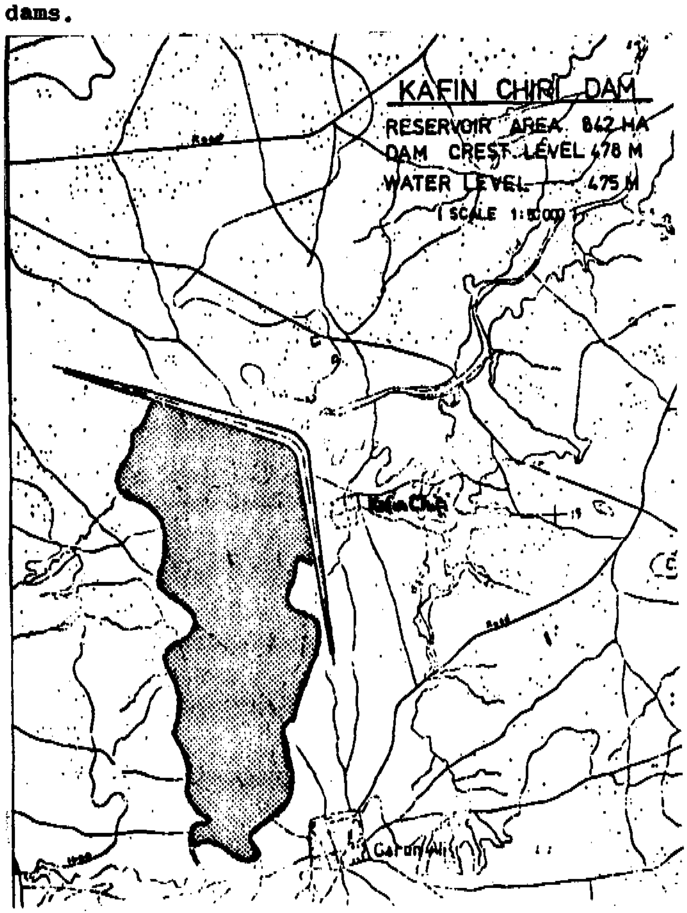
The first earth dam constructed in the State for the storage of water was B/Kudu, about 100 Km South-East of Kano, within the Basement Complex.

This dam was constructed in 1969 by direct labour using a combination of labour intensive and capital intensive methods out of necessity.

B/Kudu was one of the most populated towns in Kano State and at that time it used to experience acut shortage of water during the long period of dry season due to the fact that there is very little, if any groundwater in the area. So all the local open wells become very dry immediately after the rainy season. Life used to be unbearable for the people of the place and there used to be seasonal migration out of the town during the season. The town now has a modern water treatment plant and its size has trebled over the last ten years.

The very few eath moving plants that were used in the construction of B/Kudu Dam became the nucleus of WRECA construction team - then under the Ministry of Works and Survey.

The author was the Project Engineer in charge of two of the dams so far constructed. Below is a brief description of the design and method of construction of one of the two dams.



The name of the dam is Kafin Chiri Dam and it is located about 60 Km South-east of Kano City. The Dam was designed by the Planning and Design Division of WRECA. Figure 2 shows the location of the Dam and Figure 3 shows a typical cross-section of the Dam. The construction period of the Dam was from October 1976 to November 1977. The Dam was zoned earthfill with a crest width of 7.62 m (figure 3). The clay core was central with slopes at 1:1 upstream and downstream. The central core was filled with the best material available locally.

The material used was classified as SC or CL on the USCS triangle. The upstream and downstream zones were filled with miscellaneous material. In all cases the fill was compacted to 95% of maximum dry density. The volume of earth fill was 600 000m^3. It was compacted in 150 mm layers. The upstream slope is 1:3 and the downstream 1:2.5. The upstream face was protected by three layers of sand, fine aggregate and a layer of hand-placed rip-rap in that order. Between the core and the downstream layer there was a chimney-filter of selected coarse sand, 1 m thick; allowing flow into a blanket filter of the same material and thickness under the downstream zone (figure 3). Being a direct-labour construction all the personnel and plant belong to WRECA except the local contract labour that was employed for placing the upstream slop protection.

There were over 100 Agency employees made up of site supervisors; foremen, machine operators, mechanics, greasers, soil laboratory technicians, storekeepers, electricians and survey assistants. The site office consisting of the Project Engineer's office, soil lab, and radio room was made of timber planks and aluminium roofing sheets.

Figure 2 Layout of Kafin Chiri Dam

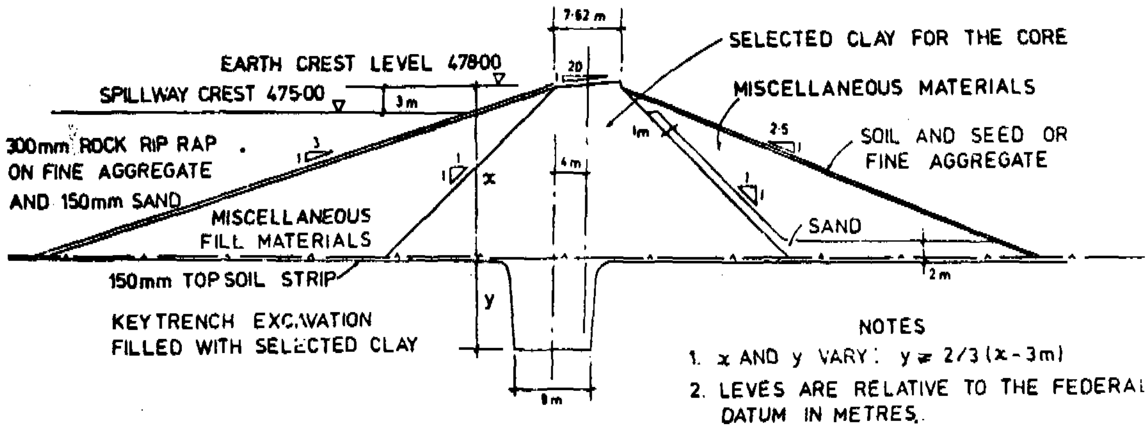


Figure 3 Typical cross section of the dam

The site workshop was made of Aluminium roofing sheets and the store was a mobile store on wheels. The machines used were as follows:

3 D8H/D8K Caterpillar bulldozers
5 621B Caterpillar scrapers
5 TS14 Terex scrapers
2 TS/4B Terex scrapers
3 D6C Caterpillar bulldozers
1 14G Caterpillar grader
3 C450 Hyster earth compactors
2 150 mm dewatering pumps
6 Lister generating sets
2 concrete mixers
4 compressors of union sizes
2 small mechanical vibrators
3 flatt lorries
5 water tankers (various)
2 fuel tankers
4 Land-rovers
2 Mini-moke
3 pneumatic rock drills

The climate of the area controls the timing and methods of construction.

The busiest construction period was late October 1976 to April 1977. As the river was dry during that period there was no need for river diversion, but the river had to be impounded before the first rains.

The earth work construction was divided into two shifts. The first shift worked from 7 am to 1 pm while the second worked from 1 pm to 9 pm under electric flood lights. A record was kept of the number of trips completed by each shift and from these figures an estimate of the production rate and availability of each machine was calculated.

The site workshop was responsible for the day to day servicing of the machines. Any major breakdown had to be reported to the base workshop at Tiga by radio. Facilities were available for a complete repair and overhaul of the machines at Tiga. There were also mobile workshops which can be called for at any time.

For most of the construction period on the site work continued 7 days a week. The day after the payment of salaries and wages was observed as work-free day to enable the workers to go to Kano for shopping every month ending.

Before the earth work was started; three small villages were resettled with a combined population of 890. The resettlement exercise was done by the Resettlement Section of WRECA. Normally this involves the acquiring of a new site for the resettlement and the provision of roads plot layouts; open wells and drainage before the people move and build their houses. WRECA also provide laterite material with which some of them construct their houses. Each house and farmland is compensated for in cash. It is up to the owner to build a new house with the money he was given. The compensation money was paid in installments before and after the rains. This was done to stop the farmers from spending the money on trivials as was discovered in the case of the previous dams.

The Kafin Chiri is about 5.4 Km long and is curved at almost 90% (figure 2), other features of the dam are shown on Table 1.

TABLE 1 KAFIN CHIRI DAM PROJECT

PROJECT DATA

1	Average annual rainfall	864 M:1
2	Catchment area	225 KM^2
3	Average annual runoff	35.67M^3M:L
4	Type of dam	ZONED EARTHFILL
5	Crest length	5.405 M
6	Crest elevation	478.00 MOD
7	Full supply level	475.00 MOD
8	Dead storage level	470.00 MOD
9	Top width	7.62 M
10	Maximum height	16 M
11	Maximum base width	96 M
12	Total storage capacity	31.12M^3M:L
13	Dead storage capacity	6.52M^3M:L
14	Active storage capacity	24.60M^3M:L
15	Surface area	842 HA
16	Total volume of fill	0.6M^3M:L
17	Spillway	475 M
	Level	475.00 MOD
	Type Concrete - ogee	
18	Outlet works: Submerged concrete intake with two 600 mm outlets.	
19	Estimated total cost 2.5 million	

A key trench was excavated below the core of the embankment with its centre-line 4 m upstream of the embankment centre-line. The aim was to reach impermeable basement rock but this was only possible over a half length. Where the depth of water expected at any cross-section the trench was considered deep enough unless some unusual geological features were discovered.

Two soil technicians were resident on the site. One at the borrow-pits and the other at the construction site. The one at the construction site was monitoring the dry density of the compacted material using sand-replacement method. Samples of the fill material were also sent to the well-equipped soil laboratory at Tiga where permeability tests, etc. were conducted.

The only controlled outlet consists of two 600 mm diameter 6 mm thick aslphalt lined steel pipes embedded in mass centre with a re-inforced concrete headwall fitted with a week-screen at the upstream and butterfly valves at the downstream end. The mass centre was 0.8 m thick and increased to 1.5 m locally to form three cut-off walls 0.8 m thick in the core zone.

A 50 m long concrete ogee type spillway was constructed about 1.4 Km from the right-hand end of the dam. The site was selected because about 2.5 m below the spillway level there was an impermeable layer of hard rock. A 500 m long spillway channel was constructed to join a tributary of the main river down-stream.

The crest access road was given downstream of 1:20 towards the upstream side (figure 2), as this was found to reduce the erosion at the top of the downstream slope due to rain.

The dam was almost filled up during the first year. The area-capacity curve for the dam is shown in figure 4.

Kafin Chiri Dam is now over three years old and is performing very well. The primary function of the dam will be to provide raw water for a treatment plant that will supply Garko and Sumaila towns with potable water. Pipeline works from the dam site to the two towns will be starting soon. The Ministry of Agriculture will also be using the water from the dam to irrigate about 1000 acres. Already a booming fishing industry has been established in addition to fore-shore irrigation by some of the displaced farmers.

Kafin Chiri dam is just a typical example of the many earth dams constructed by WRECA. At the moment WRECA is undertaking the construction of the 35.7 million naira Challawa Gorge Dam for the Hadejia Jama'are River Basin Development Authority. The dam is going to be half the size of Tiga Dam and would have a capacity of 1 billion cubic meters. Challawa Gorge Dam is also a multi-purpose dam. The second dam under construction by WRECA is the Kagara Dam for the Niger State Water Board. It is also an earth dam and is being built at a cost of 6 million Naira. The construction wing of WRECA has well over 70 scrapers and other earth-moving plants and equipments and has over the years become the fore-front contractor as far as earth dams are concerned. Already WRECA has gone into road construction, where it hopes to take the lead very soon.

The experience of WRECA by using DIRECT LABOUR methods to achieve quite a lot at a cheaper rate is worth emolution. Already other state governments from Bendel to Bauchi have started copying the innovation. Despite its successes in the field of construction WRECA has never neglected it primary function that of providing water to the teeming population of Kano State. Gigantic programmes to provide water to every part of the state are being embarked upon in conjunction with the new Ministry of Rural and Community Development.

The task of providing water to the Nigerian population is a gigantic one. More especially when some of the Engineering measures of getting water, like construction of Dams, entail an enormous amount of capital investment. This often is a handicap because of the limited resources available to the state Governments. The cheapest source of water is from a borehole where it can be obtained. In most cases only chlorination is required to make borehole water potable.

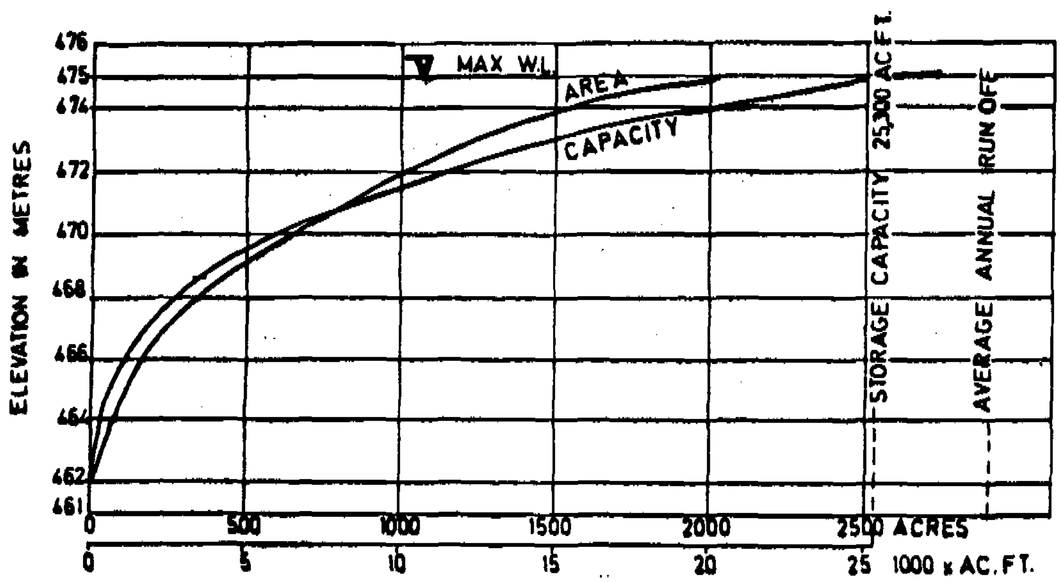


Figure 4 Kafin Chiri Dam, area and storage capacity curves

6th WEDC Conference: March 1980: Water and waste engineering in Africa

E P LOEHNERT

ASPECTS OF ISOTOPE HYDROLOGY IN NIGERIA

1. INTRODUCTION

Environmental isotopes have proved an important tool in hydrological research and practical applications (UNESCO, 1972). Stable isotopes of hydrogen (H-2 = deuterium) and oxygen (O-18) as well as radioactive isotopes of hydrogen (H-3 = tritium) and carbon (C-14) occuring in natural waters are used to assess the inter-relationships of water from various sources within the hydrological cycle. Field work, including sampling and chemical analyses, was carried out by the author during 1978-79. Isotope determinations were carried out in the Institute of Environmental Physics, University of Heidelberg, West Germany, under the supervision of Dr C SONNTAG.

2. PHYSICAL SETTING

Nigeria is a land of widely varying landscapes and climates covering an area of 924.000 km^2. The land rises steadily from the Atlantic coast (Bights of Benin and Biafra respectively) reaching an altitude of 300 - 900m a.s.l. in the north. The highest ground is the Jos Plateau (1800m a.s.l.) almost in the centre. The country is drained by the River Niger and its major tributary, the River Benue. The two river valleys are geologically old features, associated with Cretaceous troughs dissecting the Pre-Cambrian Basement Complex in a Y-shaped pattern. Toward the northwest the Niger valley lies in the Sokoto basin while to the northeast the Benue River traverses the Chad basin. The coastal sedimentary basin is of course located in the south. These basins constitute potential groundwater resources which are not fully developed.

Recharge to the aquifers is reduced in the northern regions due to lower rainfall. Rainfall decreases from 2000mm or more each year in the southern rain forest belt to less than 500mm in the northern savanna areas. Climatic conditions are governed by the movement of the Intertropical Front. Southwesterly winds carry rain bearing equatorial maritime air masses inland to cause a distinct wet season from March/May to October. The dry season ("Harmattan") on the other hand is dominated by tropical continental air masses blown by northeasterly winds from the Sahara (BUCHANAN & PUGH, 1976).

3. PRECIPITATION

The isotopic composition of rain is of major importance because it can indicate the main source of surface and groundwater replenishment, particularly in the southern region. There is only one station in Nigeria belonging to the IAEA/WMO network, at Kano. Early data were interpreted by DANSGAARD (1964) while latest information is published in IAEA Technical Reports. Kano, which has a continental climate, cannot be regarded as representative of the entire country. An "amount effect" can, however, be reckoned throughout Nigeria. It was quantified for Kano with 2.2‰ ^{18}O per 100 mm (DANSGAARD). In the $\delta D/\delta^{18}O$ relationship diagram the isotope for rain at the beginning and the end of the wet season plot along a low slope line (<8) whereas wet season samples follow the slope $\simeq 8$ according to the Meteoric Water Line (MWL): $D‰ = 8\delta^{18}O‰ + 10$ (fig.2). The same tendency was observed at Ife (southwestern Nigeria) with individual samples collected since August 1978. δ-values range between -6.8/+1.8‰ for oxygen-18 and -42/+24‰ for deuterium. This wide fluctuation is narrowed down to $\delta^{18}O = -2.9 \pm 0.2‰$ and $\delta D = -11.7 \pm 1.1$ ‰ and $D = -11.7 \pm 1.1‰$ in infiltrated water as repeatedly sampled in a shallow well in which the tritium content was found to be 16.8 ± 4 T.U.

4. SURFACE WATERS

Streams were sampled only arbitrarily except in southwestern Nigeria where several perennial rivers were regularly surveyed in order to estimate baseflow contribution to dry season discharges (fig.1). The stable isotopes composition of these waters does not differ very much from the springs sampled (fig.2): $\delta D = -9/-15‰$, $\delta^{18}O = -2.6/-3.5‰$. More positive values occur downstream toward the end of the dry season as a result of evaporation. Some streams, sampled in their upper reaches, show tritium concentrations <10 T.U. which reveal contribution by "deep storage" as explained later in this paper. A quantitative approach would have to take into account interflow to be separated from genuine groundwater flow.

5. GROUNDWATERS

At a first glance the groundwaters display a

Figure 1. South Western Nigeria. Frequency Distribution of Deuterium and Tritium in perennially flowing river waters

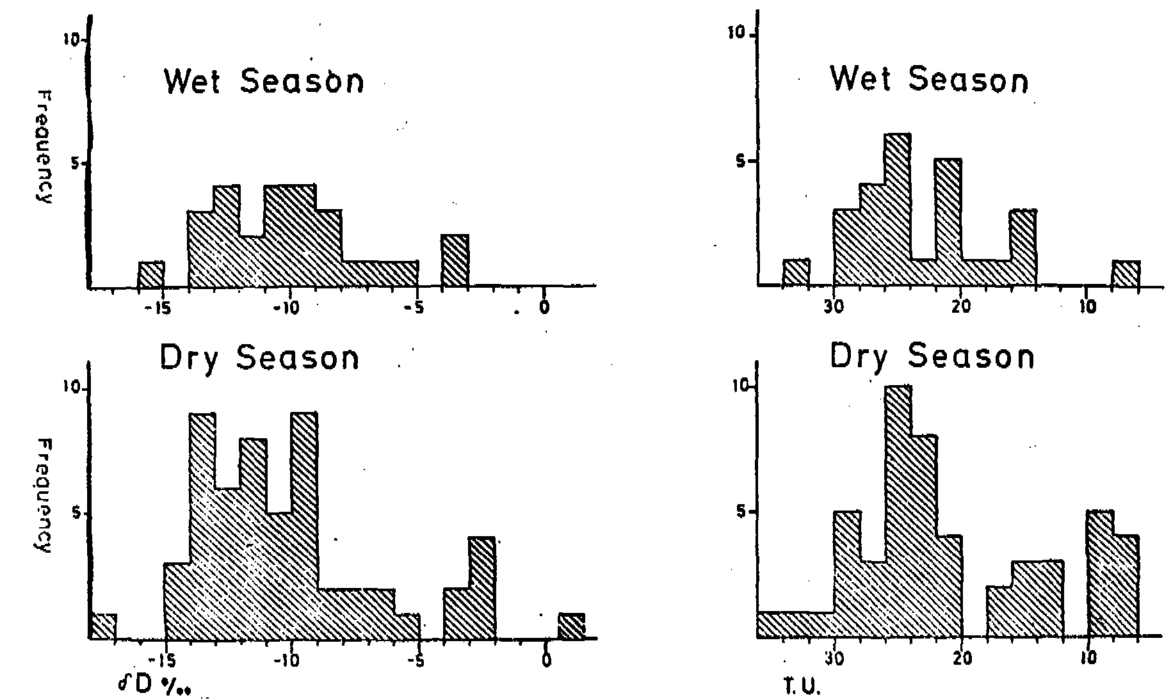
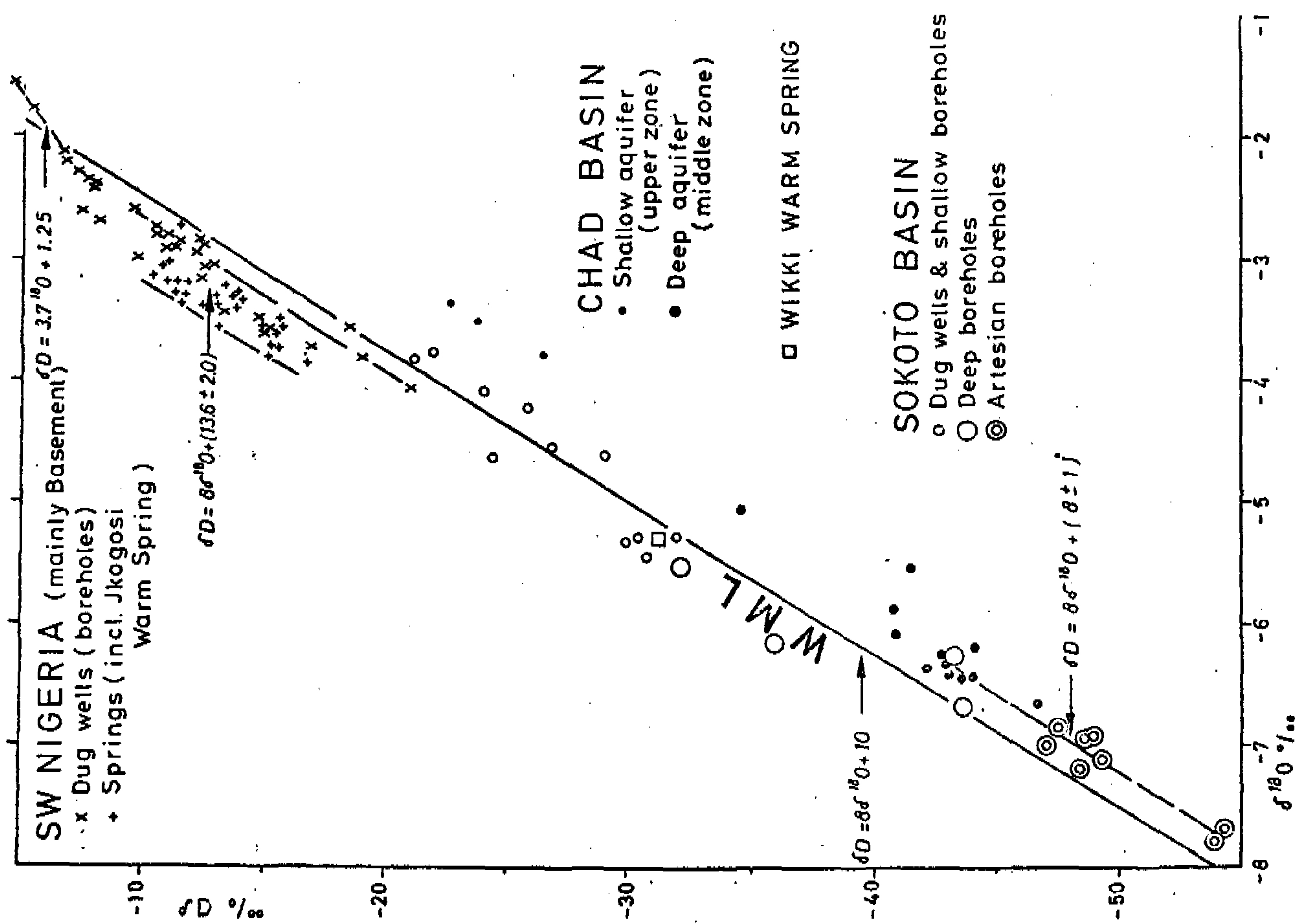


Figure 2. Oxygen - 18 vs Deuterium in Nigerian Groundwaters



wide range of stable isotope compositions (fig. 2). In combination with tritium and carbon-14 some clues are given as to the origin of waters in the three hydrogeological provinces.

5.1. Sokoto Basin

Waters from artesian and deep boreholes mainly tapping the Tertiary Gwandu aquifer are depleted in O-18 and D. The most depleted water in the basin is slightly saline and comes from Kaloye borehole (Cretaceous Rima aquifer). The Artesian waters are free of tritium and their C-14 activities range from 2 - 7.4 p.m.c. (percentage modern carbon) indicating an age of 20.800 - 31.300 years B.P. These are fossil waters infiltrated under humid conditions prior to the ice-age maximum. Their deuterium excess is markedly lower with respect to the WML: $\delta D = 8\delta^{18}O + (8 \pm 1)$ (fig. 2). Wastes from the shallower boreholes and dug wells with more positive stable isotope values either represent mixtures of fossil and recent recharge or just recent recharge, the latter scattered around the WML and with tritium up to 85 T.U. in perched aquifers.

5.2. Chad Basin

Waters from the "deep" aquifer of late Tertiary to Quaternary age (middle zone of the Chad Formation after BARBER & JONES, 1960) are closely related to the artesian and deep borehole water of the Sokoto basin in respect of their excessive deuterium content. The recharge period for both basins thus assumed to be the great pluvial. In fossil Saharan groundwaters, differences in the δ-values are believed to be due to an ancient "continental effect" caused by westerlies (SONNTAG et al., 1978). The Nigerian data do not seem to support this hypothesis of western drift but paleoclimatic information from south of the Sahara is still sparse and inconclusive. Groundwaters pumped from the "shallow" aquifer of the Chad Basin (upper zone) do contain tritium proving local, present-day recharge. Wikki spring yielding warm water from the Eocene Kerri-Kerri Formation is, however, tritium free, with C-14 of 70.4 p.m.c. The water temperature (31°C) corresponds to an aquifer depth of 36m within the Chad Basin (fig. 7 in MILLER et al., 1968).

5.3 Southwestern Nigeria

All the groundwaters in this basin are relatively enriched in stable isotopes (fig. 2), whether from springs, dug wells or boreholes, the latter being located in the sedimentary area south of the Basement. The majority of these waters show deuterium excesses between 11.6 - 15.6 i.e. above the WML. Short residence times underground are hinted at by tritium contents in the range of that of current precipitation. "Deeper storage" is associated either with fault systems, which are responsible for elevated spring-water temperature (37°C at Ikogosi Warm Spring) or karst features (exceptionally high dissolved $CaHCO_3$. Two C-14 analyses of water which contains less than 4 T.U. yielded 78.2 - 83.2 p.m.c. This means the water is approximately 50 - 100 years and is thus the oldest water so far traced in the Basement Complex.

Some dug well waters follow an evaporation line: $\delta D + 3.7\delta^{18}O + 1.25$.

Recharge is currently occurring in some of the deeper Quaternary and Cretaceous strata since boreholes tapping these aquifers yield waters with tritium. On the other hand, other deep aquifers have waters which are tritium-free. These aquifers are therefore not being recharged.

REFERENCES

ANDERSON, H.R. and OGILBEE, W., 1973. Aquifers in the Sokoto Basin, With a Description of the General Hydrogeology of the Region. U.S. G.S. Water-Supply Paper 1757-L, 1-79.

BARBER, W. and JONES, D.K., 1960. The geology and hydrology of Maiduguri, Bornu Province. Nigeria Geol.Survey Recs. 1958, 1-20.

BUCHANAN, K.M. and PUGH, J.C., 1976. Land and People in Nigeria. Hodder and Stroughton, 1-252.

DANSGAARD, W., 1964. Stable isotopes in precipitation. Tellus, 16 (4), 436-468.

IAEA, 1969 - 1979. Environmental Isotope Data No. 1 - 6: World Survey of Isotope Concentration in Precipitation (1953-1975). Technical Reports Series No. 96, 117, 129, 147, 165, 192.

MILLER, R.E, JOHNSTON, R.H., OLOWU, J.A.I. and UZOMA, J.U., 1968. Ground-Water Hydrology of the Chad Basin in Bornu and Kikwa Emirates, Northeastern Nigeria, with Special Emphasis on the Flow Life of the Artesian System. U.S. G.S. Water-Supply Paper 1757-I, 1-48.

SONNTAG, C., KLITZSCH, E., LOEHNERT, E.P. EL-SHAZLY, MUNNICH, K.O., JUNGHANS, C., THORWEIHE, U., WEISTROFFER, K, and SWAILEM, F.M., 1979. Paleoclimatic information from deuterium and oxygen-18 in C-14 dated north Saharan groundwaters; groundwater formation in the past. Isotope Hydrology 1978, IAEA, Vienna.

UNESCO, 1972. Groundwater studies. An international guide for research and practice. Chapter 10: Nuclear techniques in groundwater hydrology.

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MOHAMMED AKRAM GILL

DEVELOPMENT OF WATER RESOURCES IN THE SOKOTO STATE

INTRODUCTION

The Sokoto state is situated approximately between 10°N 14°N latitudes and 4°E and 8°E longitudes. The total area of the state is about 64,000 sq. km. The state is traversed by a number of streams which are tributaries of the Sokoto- Rima system. Sokoto (pop. 141,000) is the seat of state government and Gusau and Birnin - Kebbi are the next two biggest towns. During a period of last ten years, the Sokoto state in general and Sokoto town in particular have experienced a phenomenally rapid development in terms of urban facilities e.g. water supply, roads, housing, etc. Development of water resources in the Sokoto state for water supply and irrigation is briefly described herein.

CLIMATE

The climate varies from hot and dry in the northern part to hot and humid in the southern part of the state. The maximum air temperature usually occurs in the month of April and the minimum in the months of December/ January due to harmattan (ref. 1). The rainy season generally starts in late May or beginning of June in the northern part. The rains end usually towards the end of September. The wettest months are generally August and September. Space distribution of rainfall is shown in the isohyetal map of Fig. 1, (ref. 2). There is only one rainy season with the result that rivers cease to flow soon after the cessation of rains except in the lower sedimentary region of the catchment where rivers receive some base flow from the ground water storage. Some data of pan evaporation at Kwarre is plotted in Fig. 2 and are compared with total water losses (evapotranspiration, seepage, and percolation) from the Wurno reservoir (ref. 1). On the average some 150 - 180 cm depth of water may be lost in evaporation annually from an open lake in Sokoto region.

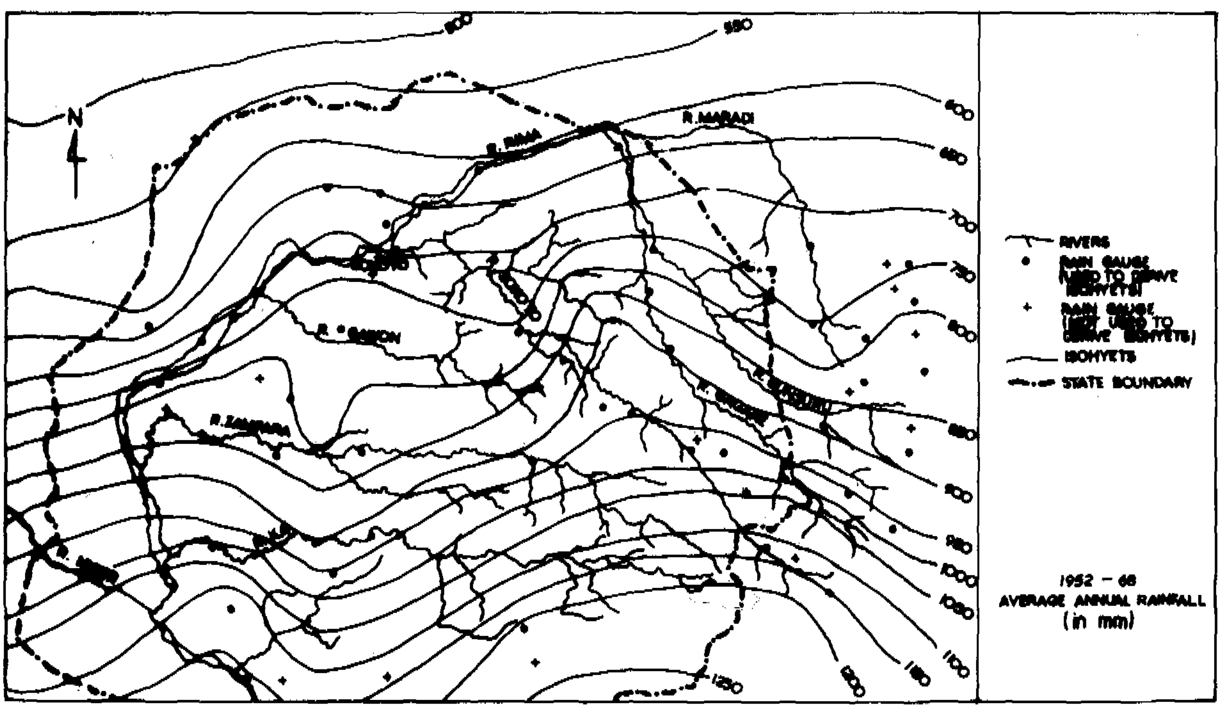

FIG. 1.- Isohyetal map based on average annual rainfall for the period 1952 - 68, after MRT (ref. 2).

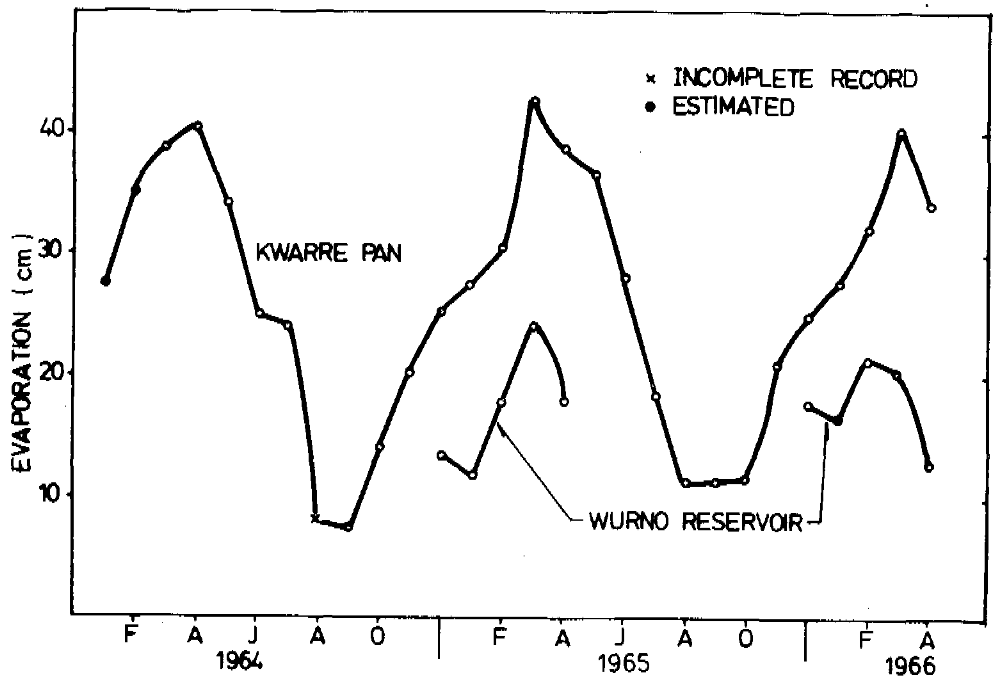

FIG. 2.- Pan evaporation at Kwarre compared with total water losses at Wurno reservoir.

WATER SUPPLY DEVELOPMENT

Geologically the state is divided into two parts by a line running from the north east to south west, Fig. 3 (refs. 1,3). The area to the right of the divide line is underlain by the basement complex which consists of gneisses, granites, phyllites, and quartzite. These rocks are covered by weathered lateritic rocks which usually store some water which is tapped by boreholes for water supply. The yield is uncertain and fluctuates during the year. More dependable source of water supply is the surface storage such as the reservoirs at Kaura Namoda, Gusau, Zuru, etc.

The area (about 40,000 sq. km.) to the left of the divide line is composed of thick sedimentary deposits and is capable of holding large quantity of water. Although the actual quantity of ground water in the sedimentary region is still undetermined, it is sufficient to provide for the water supply of urban and rural areas at many places.

Before 1970, urban water supply schemes existed only at Sokoto, Gusau, Birnin Kebbi, and Yelwa. A treatment plant of about 16.0 million litres/day capacity was built only in 1968 at Sokoto; well points in the river bed were used as source of water supply before 1968. A reservoir across the Koram Wanke stream was built around 1970 in Gusau and a treatment plant of 6.8 million litres/day in 1972. The water supply in Birnin Kebbi was based on five artesian boreholes capable of producing 900,000 litres/day. The water required no treatment and was the only water supply system which was of good quality in the Sokoto state before 1965. A primitive treatment plant without any filters of 22,700 litres/hour capacity existed in Yelwa. The network is now extended to twelve other towns, Fig. 3. Only a few schemes which could be described as semi- urban existed before 1970. A vast network has now been developed in the state which includes 45 semi- urban schemes in addition to 16 urban water supply schemes, Fig. 3. Many more (around 100) boreholes have been drilled in rural areas where water is available at stand pipes. At other places, dug wells provide water for domestic use. Some small surface storage schemes also exist at some places which were developed primarily for the use livestock but nonetheless provide raw water for domestic use as well. Table 1 gives the capacities of the urban water supply schemes in the state.

TABLE 1.- Capacities of urban water supply schemes in million litres /day.

Station	Capacity	Station	Capacity
Sokoto	32	Argungu	1
Birnin Kebbi	14	Yelwa	5
Gusau	14	Zuru	5.2
K- Namoda	2.5	Koko	1.2
Gwadabawa	1.2	Shinkafe	1.2
Jega	1.2	Kamba	1.2
Tambawal	1.2	Anka	1.2
Talata-mafara	1.2	Gummi	1.2

The average yield of boreholes is 9,000 - 11,000 litres/ hour, the maximum being upto 16,000 litres/ hour. Most of the boreholes are drilled upto a depth of 35 m or so. One of the boreholes in Sokoto town was drilled upto a depth of 120 m with an exceptionally high yield of 45,000 litre per hour. The borehole was abandoned because it contained a heavy content of iron requiring additonal facility for oxidation. The demand is

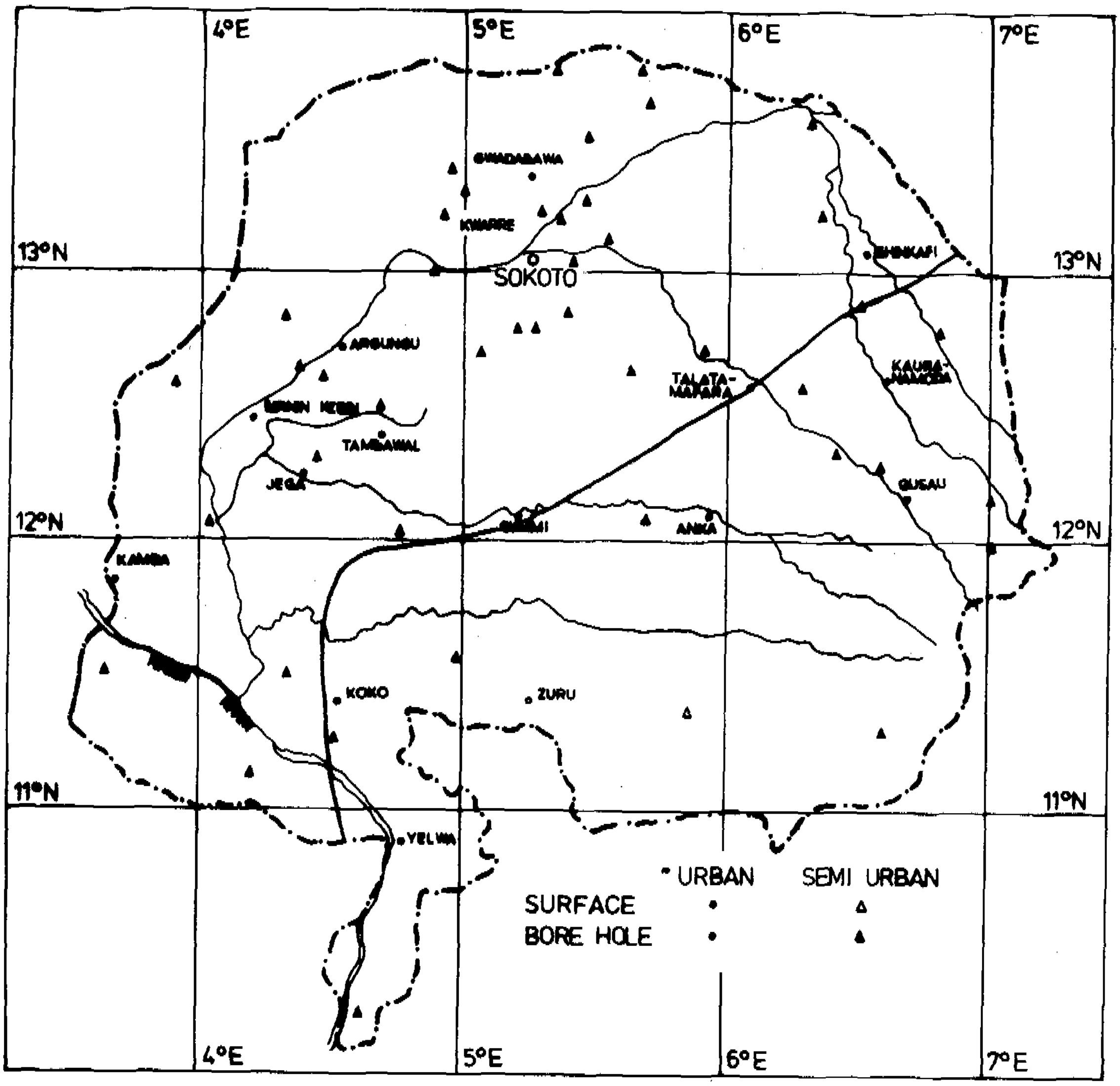

FIG. 3.- Location of urban and semi- urban water supply schemes.

easily met by other shallow boreholes where quality of water is good. The quality of borehole water in general is good excepting the Argungu borehole where iron content is in the range of 4 - 5 ppm. A facility for oxidation is provided there in order to reduce the iron content. Treatment plants are provided where the source of water is natural rivers and streams.

IRRIGATION DEVELOPMENT

Before 1970, a number of minor irrigation schemes were developed in the state, ranging only from 2.5 hectares to 250 hectares. Some of these schemes were pump lift while others were based on gravity flow principle. One of the largest of such schemes was at Wurno where a reservoir was created by building earthen dikes along a natural ridge in the fadama. The total area suitable for irrigated agriculture was around 250 hectares of which nearly half was developed around 1970.

In order to develop large scale irrigation schemes in the state, a basin wide survey of soil and water resources was undertaken by the regional Government of Northern Nigeria around 1961 in colloboration with the Food and Agricultural Organisation (FAO) of the United Nations. A comprehensive report was compiled by the FAO which located a number of prospective dam sites and identified suitable areas for irrigated agriculture. Based on the recommendations of the FAO, the Bakolori dam has now been constructed across the Sokoto river, Fig. 4, near Talatamafara. A number of irrigation canals and structures has been built for the application of irrigation water on the farm land in the development area. A total area of nearly 12,000 hectares is envisaged to be developed by irrigated agriculture. All the different types of soils e.g. heavy clayey soils in the fadama and the open textured soils in the upland, will be developed using gravity and sprinkler systems of irrigation. Lift irrigation will also be developed where required. The Bakolori scheme will not only enhance the national agricultural production but will also provide the much needed training in irrigation practices. This will prove immensely useful for developing future irrigation schemes.

Work is about to start on the construction of Goronyo (Kachera) dam across the Rima river,

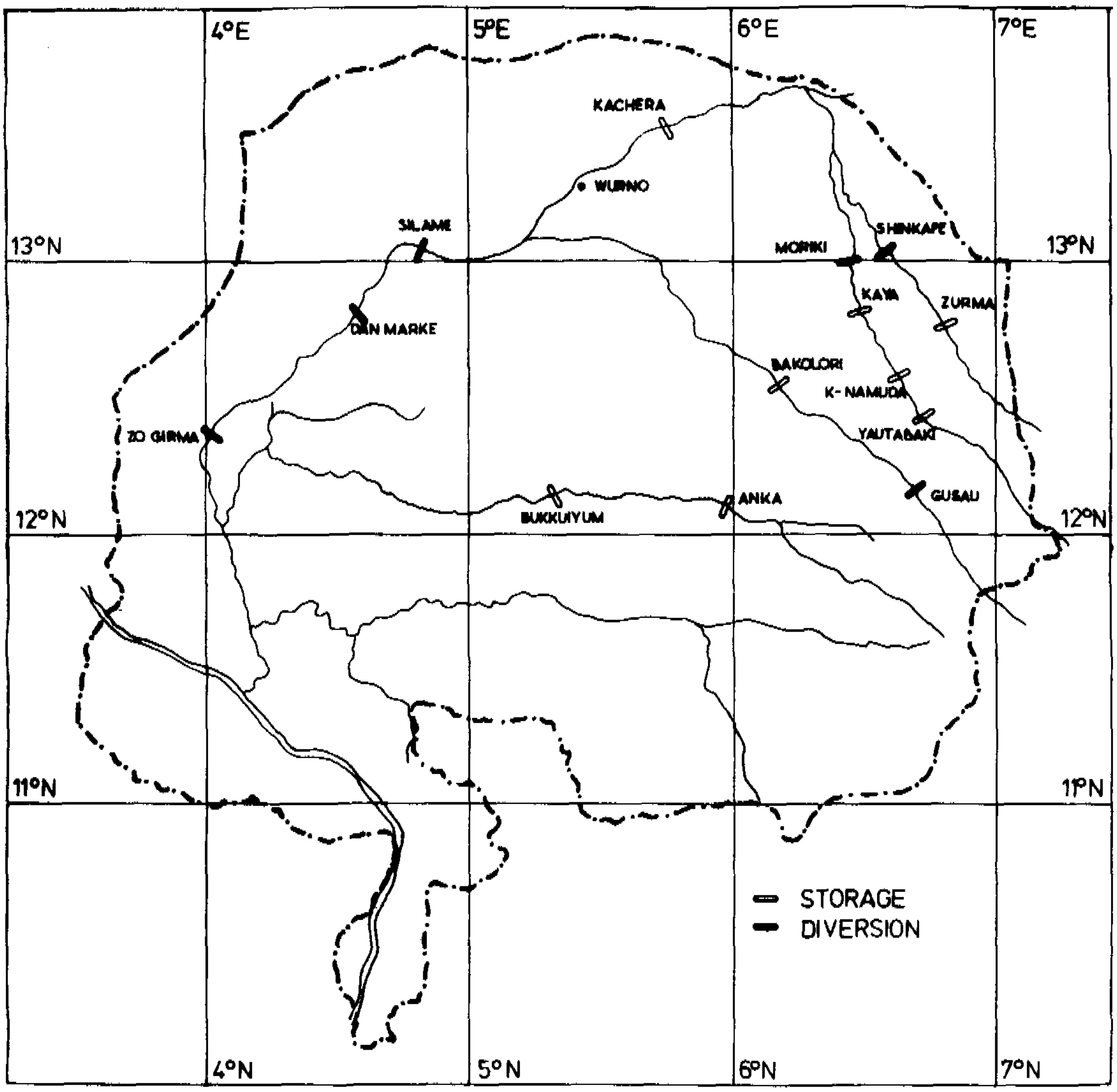

FIG. 4.- Proposed locations of storage and diversion dam sites, after FAO (ref. 4). Open rectangles denote storage dams and the black ones the diversion dams

Fig. 4. The various sites for storage and diversion dams proposed by the FAO are shown in Fig. 4 and their reservoir capacities are given in Table 2.

TABLE 2.- Proposed dam sites and reservoir capacities in the Sokoto- Rima Valley.

Site	River	Capacity m^3
Zobe@	Gagere	37,300
Zurmi	Gagere	8,500
Yautabaki	Bunsuru	35,300
Kaura- Namoda	Bunsuru	27,300
Kaya	Bunsuru	21,000
Kachera	Rima	57,000
Gusau	Sokoto	14,800
Bakolori	Sokoto	42,000
Anka	Zamfara	9,900
Bukkuyium	Zamfara	24,700

@ In Kaduna state.

There may be modifications in the FAO proposals at the time of actual execution of these projects. In due time, the agricultural production of the state will be greatly enhanced when the proposed projects are implemented.

ACKNOWLEDGMENT

The water supply section of the paper is based on several discussions held with Mr S.M.M. Hassan, Director, and Mr J. Eapen and Mr B.A. Qureshi, Deputy Chief Engineers, Ministry of Water Resources and Electricity Supply, Sokoto State, Sokoto.

REFERENCES

1. Gill, M.A. Hydrological characteristics of the Sokoto- Rima basin, Savanna, Vol. 3, No. 1, June, 1974, 61- 76.
2. Sokoto water supply extension, (report), MRT Consulting Engineers Ltd., May, 1979, Fig. 6.1.
3. Jone, B. The sedimentary rocks of Sokoto province, Geological Survey of Nigeria, No. 18, 1948.
4. Soil and water resources survey of the Sokoto valley, Nigeria, Final Report, FAO, Vol. 1, 1969.

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RICHARD FAULKNER and GEOFF MORTIMER

THE EFFECT OF CATCHMENT DATA ON PROJECT EVALUATION

THE IMPORTANCE OF RUNOFF RECORDS

In the assessment of a surface water source (including irrigation), the relationship between the reliability of supply from the source, the storage (if any) associated with the supply from the source, and the source yield is of great importance. The main factor governing this relationship is the variability of the surface flow. To take an extreme example, if all the riverflow occurred during 10 days and the rest of the year the river was dry, then storage would have to be provided to maintain the supply through the remaining 355 days. Conversely, if the riverflow remained constant throughout the year then theoretically no storage would be required.

The reliability of a source is partly related to the year to year variation of flows. Again taking a simple example, if the distribution of runoff between wet and dry seasons did not vary from year to year then the source would never fail and hence have 100% reliability.

Variability of river/stream is of great importance therefore and the only accurate way to estimate the effect of these variations is to analyse a long runoff record.

What constitutes a long record? This depends on a number of factors which include the variability of flow and the reliability of the supply.

In many situations 25 years of data would be considered adequate, however in very many countries including those of Africa this amount of data is rarely available.

METHODS WHERE DATA ARE SCARCE

Where the runoff record is short or non-existent, then attempts should be made to use other data available. A procedure for this is shown in Figure 1 and the rainfall/runoff model types mentioned in this figure are shown in Tables 1 and 2. It should be mentioned here that before the procedure in Figure 1 is followed the data used should be checked for errors. It is a difficult and sometimes expensive task to measure and collect hydrological data and in many cases the quality of this data is poor both in developing and developed countries. The most effective way of checking data is to visit the gauge on site if possible and then carry out checks with other data in the area if it exists (ref 1).

The list of rainfall/runoff methods given in tables 1 and 2 are by no means comprehensive but serve only to indicate the range of methods available. Many have been developed for specific areas and so are not strictly applicable to other catchments.

In order to high-light the problems of data when assessing surface water sources, two aspects are considered in further detail.

INFILLING DATA

In assessing meteorological data for hydrological purposes the situation is often encountered where a small number of stations have a comparatively long period of records, say thirty years, whilst there are many other stations in the same catchment or area with short term records. Additionally, many of such records are often found to be incomplete. The problem is to make the best use of such data. Consider say that annual rainfall is the parameter being utilised, then it would be possible to simply adjust the short record averages against the norms established by the long term records. However, this implies that the fluctuations of the long records are representative of the fluctuations in the short records, which may not be true. In cases where only a few, maybe incomplete, long records exist in the data the following method is a more reasonable way of establishing the average annual rainfall.

The stations are first grouped on say a geographical basis and the cross correlations of the available annual rainfalls computed. The bivariate correlations are examined and stations that are well correlated would be used for data infilling for those stations. No attempt is made here to define 'well correlated', but stations with say ten years common data that show a correlation coefficient greater than 0.8 would certainly be in this category.

Data infilling is then carried out by the normal ratio method. For each missing value in the particular record being infilled, the corresponding value in each of the other (well correlated) records is reduced to its ratio to the norm for the common period of record. The missing value is then obtained by multiplying the norm for the incomplete data by the average ratio to the norm obtained from the complete records. In this way all incomplete records may be infilled, providing of course that at least one recorded value exists for each data point within each group of well correlated stations.

The following table shows the cross-correlation between a number of rainfall stations in the same country:

Station	1	2	3	4	5	6	7	8	9	10
1	1.00	0.81	0.87	0.59	0.52	0.78	0.70	0.23	0.17	0.12
2	0.81	1.00	0.72	0.56	0.49	0.79	0.68	0.36	0.27	0.29
3	0.87	0.72	1.00	0.60	0.80	0.80	0.87	0.49	0.07	0.17
4	0.59	0.56	0.60	1.00	0.21	0.74	0.85	0.39	0.04	0.18
5	0.52	0.49	0.80	0.21	1.00	0.56	0.63	0.42	0.37	0.38
6	0.78	0.79	0.80	0.74	0.56	1.00	0.87	0.37	0.40	0.26
7	0.70	0.68	0.87	0.85	0.63	0.87	1.00	0.34	0.33	0.17
8	0.23	0.36	0.49	0.39	0.42	0.37	0.34	1.00	0.88	0.82
9	0.17	0.27	0.07	0.04	0.37	0.40	0.33	0.88	1.00	0.91
10	0.12	0.29	0.17	0.18	0.38	0.26	0.17	0.82	0.91	1.00

In this case stations 3, 4 and 9 had thirty years of data and the remainder of the stations ten years. The grouping of well correlated stations for infilling data was selected as shown below:

Station	Stations used for infilling
1	2, 3, 6
2	1, 3, 6
3	records complete
4	records complete
5	3
6	7, 3, 2
7	4, 6
8	10, 9
9	8, 10
10	8, 9

Note that station 3 was not used to infill station 7 (r = 0.87) because the two are geographically separated and clearly in different catchments.

Consider as an example the following common data for four well correlated stations:

Taking the average ratio of rainfall to norm for the stations with records the infilled values for stations with missing values are hence:

1974 value = 361 x 0.77 = 278 mm
1976 value = 349 x 1.07 = 373 mm
1978 value = 331 x 0.90 = 298 mm.

For extending the records of the stations with only ten years data to the full thirty years, the procedure is as above except of course that each station is only compared to one other (ie with full 30 yrs record).

Year	rainfall (mm)			
1970	273	302	320	230
1971	382	367	387	335
1972	356	373	385	367
1973	417	432	440	402
1974	missing	288	285	228
1975	313	300	321	307
1976	398	missing	382	353
1977	481	452	484	475
1978	327	334	350	missing
1979	301	293	315	278
norm	361	349	367	331
1974/norm	-	0.83	0.78	0.69
1976/norm	1.10	-	1.04	1.07
1978/norm	0.91	0.84	0.95	-

RUNOFF WITH NO STREAMFLOW RECORDS

The United States Department of Agriculture soil conservation service have developed a method of predicting peak runoff from comparatively small rural catchments, where no runoff records exist. Sufficient rainfall records are required to decide on the design 24 hr rainfall. This rainfall is then applied to suitable profile, for frontal or convective rainfall standard profiles are used or alternatively any particular locally determined profile can be utilised. The original SCS method may easily be modified to yield the runoff hydrograph for the design storm. (16)

The method takes into account land use practice, soil type and ground condition in estimating runoff and hydrograph dimensions. Where appropriate allowance is made for channel losses and snowmelt base-flow. The following input parameters are necessary:

(i) Design 24 hr rainfall and profile
(ii) Surface runoff number C, derived from
  (a) antecedent rainfall conditions
  (b) crop cover and land preparation
  (c) hydrologic soil group
(iii) Catchment parameters
  (a) length of longest watercourse
  (b) area of catchment
  (c) gradient

The hydrologic soil group under section (ii) (c) is divided into the following categories:

Group A - high infiltration even when wet
Group B - moderate infiltration when thoroughly wet
Group C - slow infiltration when thoroughly wet
Group D - very slow infiltration when thoroughly wet.

Then depending on the crop cover and land preparation eg straight row crops, fallow, meadow etc, the curve number C (from 0-100) is found on a table (for average antecedent moisture conditions). This value is then modified if necessary for dry or wet antecedent conditions. The basic formula is:

$$Q = \frac{(P-I)^2}{(P-I)+S}$$

where Q = run-off
P = precipitation
I = initial losses
S = potential maximum retention.

If it is assumed that I = 0.2S,

then $$Q = \frac{(P-0.2S)^2}{P+0.8S}$$ in imperial units

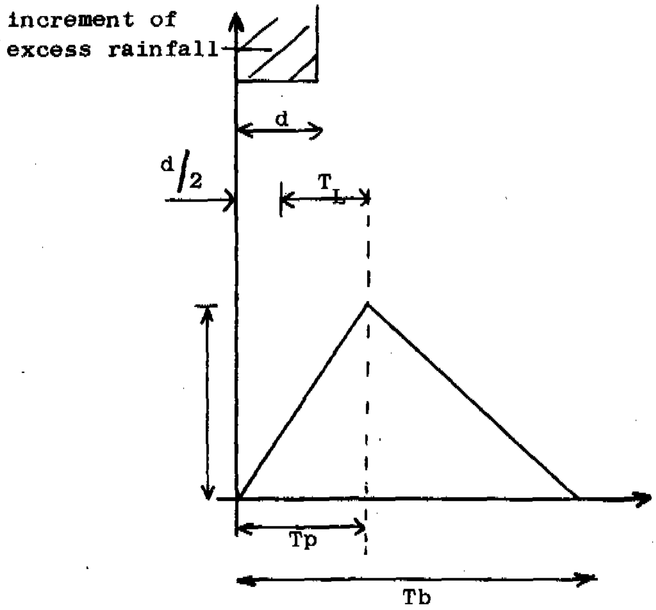
or $$Q = \frac{(P-5.08S)^2}{(P+20.32S)}$$ in metric units

The S parameter depends partly on the initial infiltration and surface storage but mainly on the infiltration after runoff has commenced. S is related to the curve number by the following relationship:

$$S = \frac{1000}{C} - 10$$

Thus knowing C, S can be determined.

A simple triangular hydrograph shape is assumed, the geometry of which is shown below.



$$q = \frac{A \times Q}{4.806 Tp}$$

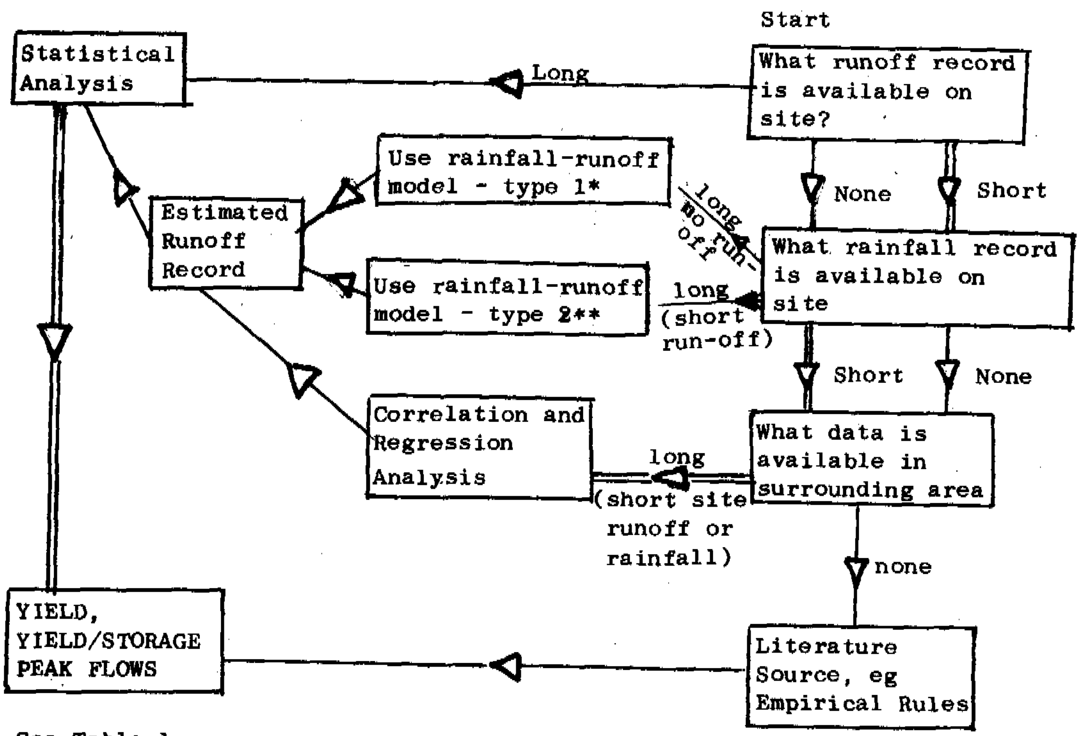
where q = hydrograph peak in m^3/s
Q = runoff in mm from storm increment d hours
A = catchment area in sq km
$Tp = d/2 + L$
$Tb = 2.67\ Tp$
T_L = lag time in hours

$$T_L = \frac{(3281\ L)^{0.8} \times (S + 1)^{1.67}}{9000\ Y^{0.5}}$$

L = mainstream length in km
Y = slope of mainstream per cent.

The methodology is now to calculate the parameters of the unit hydrograph (ie 10 mm effective rainfall) for a suitable time increment. This unit hydrograph is then applied to the increments of effective rainfall for the corresponding time increment from 0 to 24 hurs. The resulting hydrographs are then convoluted to give the final runoff hydrograph.

Although originally developed for small agricultural catchments, the method has been found effective for ungauged catchments in excess of 10 km^2, but care is required in the assessment of the C number.



* See Table 1
** See Table 2

Fig 1

Table 1 - Rainfall-runoff methods
Type 1 - Long rainfall record, no runoff record

Flow type		
Low	Semi Empirical Methods eg Turcs rule (ref 2) Basin Climate Index (ref 3)	Application to Limpopo River (ref 15) Application to Limpopo River (Ref 15)
	Runoff Coefficients (see notes) (from lit sources) eg Zambezi (ref 4) Nile (ref 4) Kafue (ref 5) Sokoto (ref 6)	) and other rivers)
High	Storm Runoff Coefficients (ref 7)	
	Synthetic Unit Hydrographs Nigeria (ref 8)) GB and used in other countries) (ref 9))	- derived from catchment characteristics
	Soil conservation service method	See later
	Richard's method (ref 10)	

Note 1. The catchment under consideration may not be found within the major catchments listed but it may be possible to use the runoff coefficients if the areas are hydrologically similar.

Table 2 - Rainfall-Runoff Methods
Type 2 - Long rainfall record, short runoff record

Flow type	Method	Remarks
Low	Water balance methods	(ref 12) Evaporation data required
	Regression analysis	
	'soil moisture reservoir' methods	eg applied in Botswana (ref 11)
	Black box methods	(ref 7) Mathematically based
	Comprehensive models Stanford Watershed model SAAR methods	(Ref 13) Will predice range of hydrological parameters. Computer required
High	Regression analysis	
	Unit hydrograph	(ref 8) Commonly used method
	Soil moisture reservoir	
	Black box and many others	(ref 14)

FINAL COMMENT

Assessment of surface water sources will never produce the 'right answer' to the yield/storage/reliability relationship or peak flow even with 100 years of data or more, since future flow variations cannot be predicted. All that can be expected is an estimate with an error which is related to the amount of data and the techniques used. Where much data are available many methods are available for solving the problem but where data are scarce the techniques available for estimation are equally scarce.

REFERENCES

1. Nemec J. Engineering Hydrology. McGraw-Hill 1972

2. Turc L. Paper presented to 3rd Hydrological Engineering Congress. Societe Aidrologique de France, Argel 1954.

3. Smith RL. Utilising climatic data to appraise potential water yields. Proc of Development of Water Resources Projects with Inadequate Data. Vol 2, Madrid 1974. UNESCO

4. Balek J. Hydrology and Water Resources in Tropical African Developments in Water Science No 8. Elservier 1977.

5. Balek J. An application of the inadequate hydrological data of the African Tropical regions in engineering design. Proc Symp Decisions with inadequate hydrological data. Fast Collins USA 1972.

6. Gill M A. Hydrological characteristics of the Sokoto-Rima.Basin Savanna Vol 3 No 1 61-75 June 1974

7. Chow V T. Handbook of Applied Hydrology. McGraw-Hill. P 25-2 to 25-8. 1964

8. Duru J O. Runoff hydrographs from Northern Nigeria watersheds with stream flow records. Paper to WEDC Conf, Zaria, Nigeria 1980

9. Nash M A. A Unit Hydrograph study with particular reference to British Catchments. Proc ICE.vol 17.249-282.1960.

10. Richards B D. 'Flood estimation and control'. Chapman Hall, London 1957

11. Chidley T R E & Goodwill I M. 'A compact watershed model system'. J of Hydrol 24. 155-169. 1975

12. Sokolov A A (ED) Methods for Water Balance Computations. The UNESCO Press. Paris 1974

13. Lansley R K & Crawford N M. 'Computations of a synthetic streamflow record on a digital computer. Int Assoc Sci Hydrol. Pub 63, 573-587

14. Pawdy D R & Kalnin G P. Mathematical modelling in hydrology. Report of mid-decade conference of Int Hyd Decade 1970. Bull of Assoc Hydrol XV (1)

15. D'Oliveira, Mertens E E & Loureiro J J M. Application of Coutagnes and Turc Formula to the Southern Mozambique Rivers. Proc of Dev' of Water Resources with inadequate data. 123-140 Madrid 1974 UNESCO

16. Hydrology, Supplement A to Section 4 in 'Engineering Handbook', US Department of Agriculture, Soil Conservation Service, Washington DC. 1957

6th WEDC Conference: March 1980: Water and Waste Engineering in Africa

J OBIUKWU DURU

RUNOFF HYDROGRAPHS FROM NORTHERN NIGERIA WATERSHEDS WITHOUT STREAMFLOW RECORDS

BACKGROUND

Despite occasional criticism directed primarly at the principle of time invariance embodied in the unit hydrograph theory, the unit hydrograph has been well accepted and extensively used by hydrologists. Its appeal stems primarly from its simplicity and versatility, in the sense that it will allow the reconstruction of runoff from any storms however complex.

The derivation of the unit hydrograph as proposed by the Sherman (Ref. 1) does, however, require that the stream for which a unit hydrograph is required by gauged. But relatively few streams are gauged. Moreover, the gauging station may not be located at the point of interest for a particular application. As a result, the need was identified for methods of synthesizing a unit hydrograph.

SYNTHETIC UNIT HYDROGRAPH

All methods of synthesizing unit hydrographs aim at expressing unit hydrograph parameters - mainly peak run off rate, peak time, and total base time - as simple functions of the physical characteristics of the watershed. The unit hydrograph parameters are related to watershed geometry by empirical coefficients which have been found to be regionally sensitive. Thus, establishing a synthetic unit hydrograph for a region amounts to quantifying these empirical coefficients for that particular region. And since an exceeding few of Nigerian streams are gauged, it was felt that the synthetic unit hydrograph provides the best and, perhaps as of now, the only avenue to any useful information about the hydrology of Northern Nigeria watersheds.

USDA - SCS Synthetic Unit Hydrograph

Although many methods have been proposed for synthesizing unit hydrographs (Refs. 2,3,4) the triangular method proposed by the United States Department of Agriculture (USDA). Soil Conservation Service (SCS), (Ref. 4) was elected for this study. The better known Synder synthetic hydrograph was bypassed because it calls for a minimum base time of three days, thus making it unsuitable for basins with short runoff periods. Considering the extremely short rainfall and runoff records available, this additional constraint would have made the study totally impossible.

For a unit hydrograph, the volume of runoff (V) is given by :

$$V = (1 \text{ unit of rainfall}) (\text{watershed area})$$

From the geometry of a triangular hydrograph the volume is also given by :

$$V = \tfrac{1}{2} q_p T$$

so that

q_p = peak runoff rate

T = base time

From extensive studies by the SCS, empirical relationships

$$T = (1 + H)\, t_p$$

and

$$t_p = t_c + 0.5\, t_r$$

have been established.

In equations (4) and (5) t_p is the peak time, t_c is the time of concentration, and t_r is the duration of effective rain fall. Both and H are coefficients which need to be determined.

STUDY PROCEDURE

Records of streamflow and recording rain gauges for three drainage basins in the

Kano State were studied, and storms that reasonably satisfy the assumptions of the unit hydrograph theory were selected. Unit hydrographs for discharges corresponding to these storms were reduced to the same duration - 2 hours - via the S - curve procedure. Graphs of equations (4) and (5) were plotted on regular graph paper. The 'best' straight line for each case was fitted by eye and values of and H were determined. The values of and H were found to be 0.55 and 1.41 respectively.

Verification of the Coefficients

The coefficients and H were used to synthesize direct runoff hydrographs from one of the three basins. Similated and observed hydrographs are compared in Fig. 1.

Integrated Urban - Rural Hydrograph

Al the three basins used in the study are basically rural in character. While signs of transition to urban character are in evidence, each basin presently has less than 10 per cent surface imperviousness and the Unit Area Hydrograph (UAH) method for computing the urban runoff component of the composite hydrograph does not predict a hydrograph reliably when imperviousness drops under the 20 per cent level (Ref. 5).

Thus, the basins were all treated as rural. The direct runoff hydrograph synthesized with a unit hydrograph was considered to represent the entire basin.

DISCUSSION AND CONCLUSION

The objective of, and need for, this study should attract no arguments. However, the data base is so narrow that the conclusions should not be generalised to apply to all Northern Nigeria as the title of the paper may lead one to do. Caution should be exercised in generalising the conclusion to all of Kano State as the three basins studied are not evenly distributed in the State to reflect any regional peculiarities. The scope of the study is so narrow because there are only six recording rainfall gaging stations, in addition to the National Airport, in Kano. All the six are located in the same region which is less than half of the state, and all have only been operating since 1977. And, even then, some of the six stations are considered inaccessible by the operators and no data could be obtained from them.

The coefficients and H were found to have numerical values of .55 and 1.41. For USA conditions the same coefficients have values of 0.60 and 1.67 respectively. The hydro-

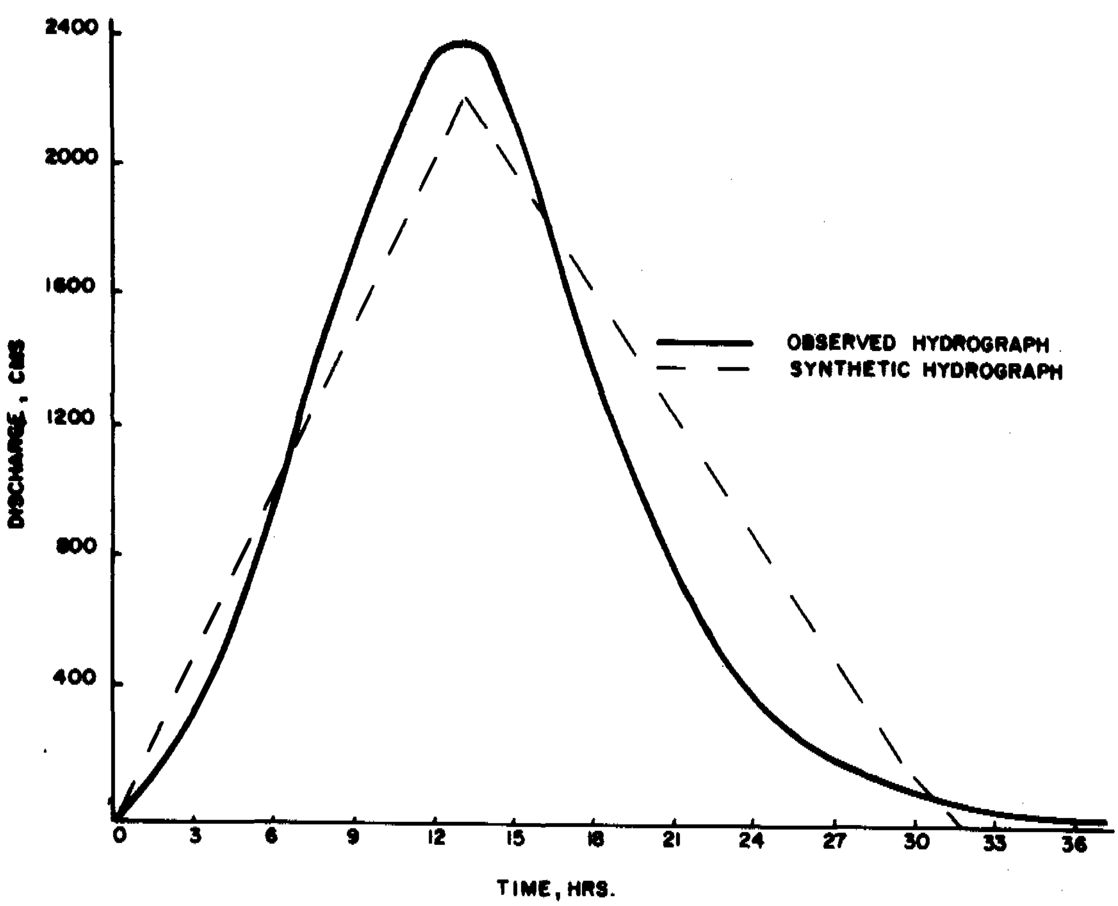


FIG. 1. OBSERVED AND SYNTHETIC HYDROGRAPHS FOR RIVER KAMANDA, AT KYARANA, JUNE 22-24, 1978

graph synthesized with = .55 and H = 1.41 (Fig. 1) does not match the observed hydrographs perfectly, though the simulation is considered reasonably good for hydrologic work. It is difficult to say at this time wether the differences between synthetic and observed hydrographs may be attributed to imperfection in the values of and H. There is another possible source of error. There is only one rain gauge near each of the watersheds studied. The lone gauge in one case is located at one corner of the basin, and in two of the three cases totally outside the basin, so that the readings may not be representative. This makes relating rainfall to runoff rather uncertain.

Perhaps a real value of this work which is as important as the findings lies in its leading the way in an important area of research, highlighting difficulties that are real, especially non-existences or inadequacy of data, and clearly exposing the need for co-operation among all persons in the water resources field. This co-operation is needed to intensify data collection effort and to insure that any data collected are relevant and in usable form. While the values of and H as determined in the study appear reasonable judging from the synthetic hydraograph the result should be considered tentative. The research base should be expanded by including many more drainage basins and using many more events from each basin. This expanded study should reaffirm the finding of this study and thus strengthen confidence in the established coefficieints or point toward a modification to achieve the desired objectives.

ACKNOWLEDGMENT

The author is grateful to the staff of the Hydrology Section of the Water Resources Engineering and Construction Agency, Kano, for making their records available and assisting the author through the work.

REFERENCES

1. Sherman L.K. Streamflow from rainfall by the unit-graph method. Engineering News Record, Vol. 108 April 7, 1932.

2. Snyder F.F. Synthetic unit graph (Trans. Am. Geophs. Union, Vol. 19 1938.

3. McCarthy G.T. The unit hydrograph and flood routing. Referenced from V.T. Chow (ed), Handbook of Applied Hydrology, McGraw-Hill Book Co. P.14-22 1964.

4. Hjelmfelt A.T. and Cassidy J.J. Hydrology for Engineers and Planners, Iowa State University Press, pp. 109 - 113 1975.

5. Duru, J.O. A Unit hydrograph concept for predicting flood hydrographs from suburban subdivisions. Proceedings, International Symposium on Urban Storm Water Management, University of Kentucky Lexington Ky - July 24 - 27 1978.

Session 4: SURFACE WATER SOURCES

Discussion

A M Abdullahi

Engineering Measures for the Development of Surface Water Resources in Kano State

Mr ABDULLAHI described the geographical position of Kano, on the fringes of the semi-arid zone of West Africa; therefore water supply was a serious problem for the region. Before the State was created in 1968, there was a serious water shortage in both rural and urban areas, but after 1968, the Government made water supply and agriculture a priority, so the problem was eased. The geological formations of Kano State dictated the types of water supply associated with each, with special emphasis on dam building. Surface water sources were the most expensive to utilise, but dams cost more to build than boreholes, so in areas where surface water was available, more investment was needed.

2. Mr C E EGBORGE pointed out that it was wrong to compare the cost of boreholes for water supply only to that of dams which were normally built for multi-purpose usage. He wondered if the poor yield from the Basement Complex could not be attributed to insufficient depth of the wells.

3. Mr ABDULLAHI answered that the advantages of ground water over dams were mainly commercial. From personal experience in Kano where about twenty dams were constructed, it was found to take a minimum of 1 million Naira per dam, and often more. But to drill a borehole, only a good drilling rig was needed which cost 150000 to 500000 Naira of investment. Also, for a small rural water supply it would be silly to spend a lot of money on a dam when a borehole would be quite adequate. With reference to the basement complex, the observations made were based on the type of drilling rig used, which was not a suitable one for drilling in this type of material. New rigs were being bought which would be more suitable, so more information would be available in the future.

Dr E P Loehnert

Aspects of Isotope Hydrology in Nigeria

Dr LOEHNERT gave a definition of isotopes as elements having the same number of protons but a different number of neutrons. He also described the types of environmental isotopes. The variation in the abundance of these isotopes was useful for hydrological studies to assess the history or future of the water.

5. Although radio-active isotopes occurred in nature, the most important ones for hydrologists were the man-made ones, produced by such things as nuclear tests. All shallow groundwater was found to have traces of these.

Professor M A Gill

Development of Water Resources in Sokoto State

6. Professor GILL explained that water resources could be divided into two types: small scale schemes and irrigation. Where dams were needed for large reservoirs, hydrological data was needed. The collection of this data involved setting up hydrological and meteorological stations, and the data thus provided formed the basis for the formulation of large scale construction schemes.

7. Figure 4 in the paper showed the main rivers and storage sites, based on the data collected in the early 1960's. Much data was collected on the sedimentation aspect and so estimates could be made of the sedimentation and transport rates etc, allowing estimates then to be made of the useful life of a reservoir. In all cases this was more than fifty years. The collection of data for small water supply schemes started when very few had begun. There was no treated water, and in the rainy season the water quality was very poor. In the last twenty years many new schemes had been built. Now the situation was looking much healthier and more schemes were planned for the future.

8. Mr G H READ said that plans to build reservoirs must be based on economic considerations. He expressed surprise at only a fifty year half-life for a reservoir due to sedimentation. This figure seemed low. He wondered whether there were any plans for afforestation and protection areas etc.

9. Mr GILL replied that the economics of dams was based on the availability of materials and most dams were large when irrigation was needed. It was true that the figures were not very good, but they were only approximate. For some dams it was much longer than this, up to 150 years in some places. The problem had been the lack of data. River gauge data

was available from one station from 1948, but most stations had data for only a few years. However, something needed to be done urgently in this area, so the schemes had to go ahead with the available data.

10. Mr G H MORTIMER said that if the length of the data record=return period, then there was no need to do a statistical analysis. It had been found that 150 years' records were needed to forecast a 100 year flood with 90% confidence limits, so that even to estimate a once-in-fifty-year event a long record was needed. Professor GILL said that the most difficult thing was extrapolation to calculate the average return period. Often it was necessary to extrapolate 50 to 100 times and this was a most dangerous situation.

11. Mr R R BANNERMAN wanted to know whether yields from the wells drilled in the basement complex were unsatisfactory. He thought that sound geophysical and hydrological investigations should be carried out for this area. Professor GILL said that careful geological surveys were done before drilling was started to make sure that it was worth drilling.

R Faulkner and G H Mortimer

The Effect of Catchment Data on Project Evaluation

12. Mr MORTIMER explained that the paper was about data and how to use it in water resource projects. He described the types of data available and the relations between them. Money must be available to protect against the possibility of failure of a supply. The cost of failure might be small in a rural area where only a few people depended on the water supply, but the costs could be huge where industry was involved.

13. For data to be really useful, a long site record was needed, and a 100-year period would not be too long for this. However this sort of record was unlikely. The amount of data needed was usually calculated by the return period divided by two, but for a good estimate the length of data should be equal to the return period. For any estimate at all, a minimum of five years data was needed. So the need was for planning to begin early so that data could be collected for many years before a project was due to start. The importance of accuracy was stressed, especially where little data was available. The best thing would be to plan hydrological networks for our children's children; by giving them 60 years of data they would then be able to get good estimates of water resources.

14. Dr O C IGWE commented that the talk had highlighted the problems, but what was the conclusion or advice given? Mr MORTIMER should have said "plan and run" hydrological data collection for future generations. Expensive equipment is not needed, just simple readings.

15. Mr R I OZOEKWE commented that the problem in developing countries when it came to data collection, was one of co-ordination. In Nigeria there are records going back to 1945.

16. Dr B ALMASS'Y commented that in 1968 there were fourteen hydrological stations collecting data in the country, and now there are about sixty. The lengths of observations were not long, but they were accurate and reliable, and it was hoped that in the future the situation would get better.

J O Duru

Runoff Hydrographs from Northern Nigeria Watersheds without Streamflow Records

17. Mr DURU said that the groundwork for the information in his paper had been laid by Mr Mortimer when he pointed out the inadequacies of available data. We should be planning for the future, but we should not fold our arms and leave all the work for our great grandchildren. In studying watersheds for dams, irrigation etc, we need the rainfall:runoff relationship and so it was possible to use a synthetic unit hydrograph in place of a long data record. Using examples from Kano State Mr Duru showed how the synthetic unit hydrograph could be used in studying watersheds where there was no record available, or a very inaccurate or biased record.

18. Mr R R BANNERMAN asked whether there was any data available from the basement complex area of SW Nigeria. Mr DURU said that there was some data available, on springs, rainfall, rivers and groundwater. It was intended to use this experience to assess the development of these waters in the hydrological cycle. One result had been that it was found that there was very little rainfall recharge in the area.

19. Dr O C IGWE asked what were the objectives of this method? The uncertainties and shortcomings of the synthetic unit hydrograph had been outlined, but by next year, would there be an improvement in the situation in Kano State? Mr DURU said that he did not give details of field work. Schools and Colleges had records, and were willing to collect information and data. The problem was a lack of personnel and funds.

20. Dr IGWE said that in the keynote address, the practical need for data, especially in Africa had been mentioned. But he wondered how to go about this. Practical solutions were needed instead of just highlighting the problems. Was the synthetic unit hydrograph a long-term solution to the problems of lack of data? Or should we just give up and say we could not cope with the problems? Mr DURU said that it was not a long-term solution, but it could work. The ideal solution to present problems was co-operation for collecting data in a useful form.

M S ABID

KADUNA WATER SUPPLY EXTENSIONS - BARNAWA DAM PROJECT

INTRODUCTION

Kaduna, the capital of Kaduna State of Nigeria is situated between 10^0 26' N and $10^0$37' N latitudes and $7^0$24' E and $7^0$29' E longitudes. The Kaduna river flows through the city, dividing it into Kaduna North and Kaduna South. The total area of Kaduna is 115 sq km, with an estimated population of about 550000. Kaduna has enjoyed treated water supply since 1929. Although measures for increasing Kaduna water supply have been

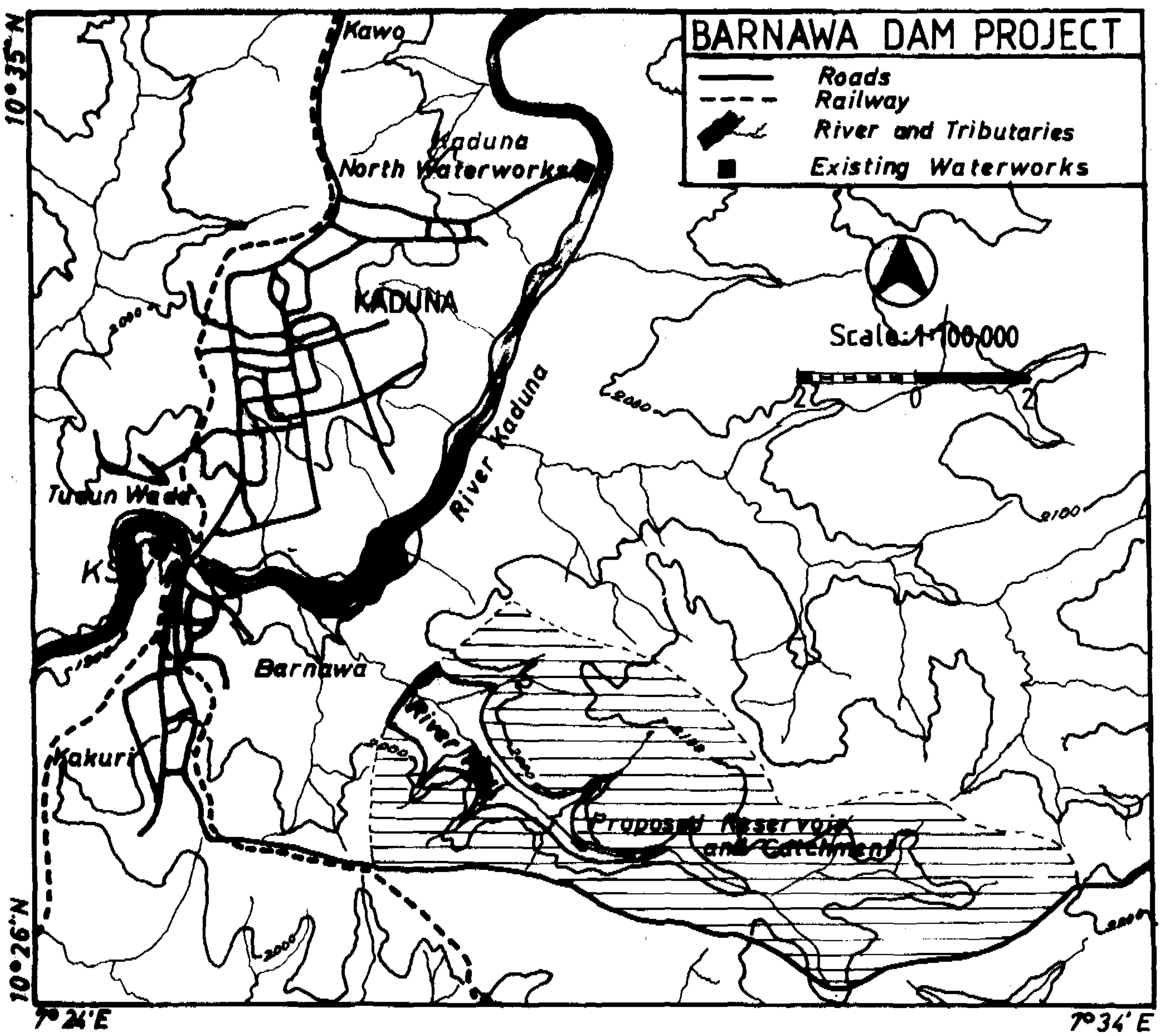


Fig:1 Map showing Kaduna city, the existing Waterworks and the proposed Dam.

taken from time to time, they proved inadequate for the soaring population and growing industry. Kaduna State Water Board engaged the services of Ward Ashcroft and Parkman (Nigeria) as consultants, who recommended extension at Kaduna North Water Works only, and phasing out of Kaduna South Water Works (Reference 1). This proposal is for a dam on Kuyi river, a tributary of Kaduna river, which will ensure about 136mld when fully developed, enough for the needs of Kaduna South until the end of the century. As the tributary is downstream of the North Water Works, the project will not affect any development there. The project is not only economical, but can also be further developed into a recreation centre, (Figure 1).

CONSULTANTS' REPORT

The Consultants made two alternative studies of the project, ie a) Extensions at the North Water Works only and ultimate phasing out of the South Water Works, and b) Extensions at both North and South Water Works to serve Kaduna North and Kaduna South seperately. Tables 1 and 2 show the development proposed by these studies.
The Consultants recommended the first proposal that all new treatment plants be sited close to the existing North Water Works and phasing out of South Water Works, although it would involve higher costs. The Consultants recommendations are based on pollution of Kaduna river at Kaduna South due to discharge of effluent from populous Tudun Wada, Tudun Nupawa and Sabon Gari, upstream of the South Water Works, which contaminates the raw water to a great degree. This view is supported by another Consultant, Louis Berger Incorporated Nigeria, engaged by the Water Board for a pollution study of Kaduna river.

THE PROPOSAL OF BARNAWA DAM

The proposal is to make an earth dam on Kuyi river, a tributary of Kaduna river with a catchment of over 39 sq km. Although the tributary is seasonal, yet some springs upstream in the catchment keep it flowing throughout the year with a minimum average discharge of 2 cusecs during the dry season.

To check feasibility, however, flow discharge studies and subsurface investigation along the axis and abutments will be necessary. If this proposal is implemented, there may be no need to shift the entire Works to Kaduna North as suggested by the Consultants. River pollution problems faced at Kaduna South will also be overcome since the Barnawa reservoir will not have any major source of pollution.

This project will not only be much more

Table 1. Scheme A
Schedule of Water Works

Water Works	Proposed Phased Development in mld			
	# 1980	Stage I 1983	StageII 1989	Stage III 1995
Existing North Water Works	89	89	89	89
New North Water Works	-	115	160	205
Existing South Water Works	27	##	-	-
Total	116	204	249	294

Table 2. Scheme B
Schedule of Water Works

Water Works	Proposed Phased Development in mld			
	# 1980	StageI 1983	StageII 1989	StageIII 1995
Existing North Water Works	89	89	89	89
New North Water Works	-	-	40	40
Existing South Water Works	27	27	27	##
New South Water Works	-	110	110	165
Total	116	226	266	294

\# Capacity after Emergency Extensions which will add 445 mld.
\## Existing South Works taken out of commission.

economical as far as capital expenditure is concerned, thus reducing the foreign exchange component, but it will also have much less operational expenditure compared with any other proposal on Kaduna Water Supply Extensions.

HYDROLOGY

Discharge studies of Kuyi river are only available for one year, but calculations based on average annual rainfall, (Figure 2), and catchment area suggest that an 18m high and 1 kilometer long earth dam will be able to

Fig 2 Average annual Rainfall in Kaduna south *Ref. 3*

store over 27 million cubic meters, (Figure 3). This storage will be sufficient to provide approximately 136 mld of raw water for the consumption of Kaduna South after accounting for evaporation and seepage losses, (figure 4)

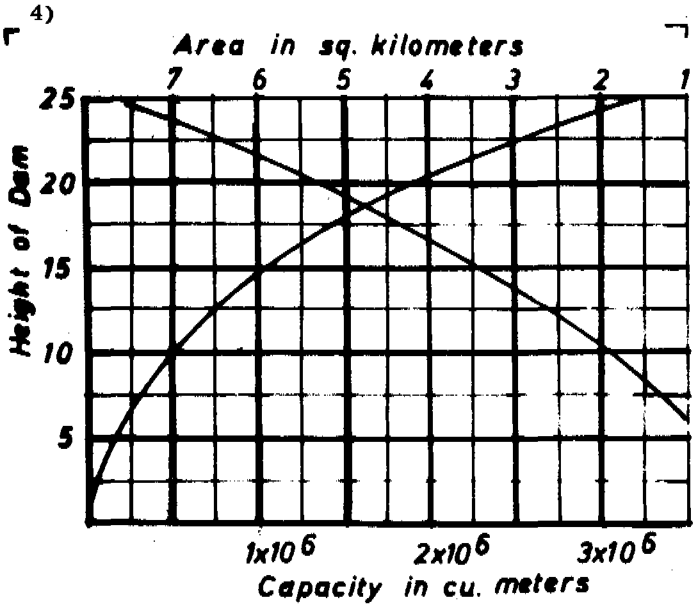


Fig:3 Area Capacity Curve

The reservoir capacity will be 405 hectares.

CIVIL WORKS

As per preliminary studies, the earth dam at Kuyi river will have a reinforced concrete

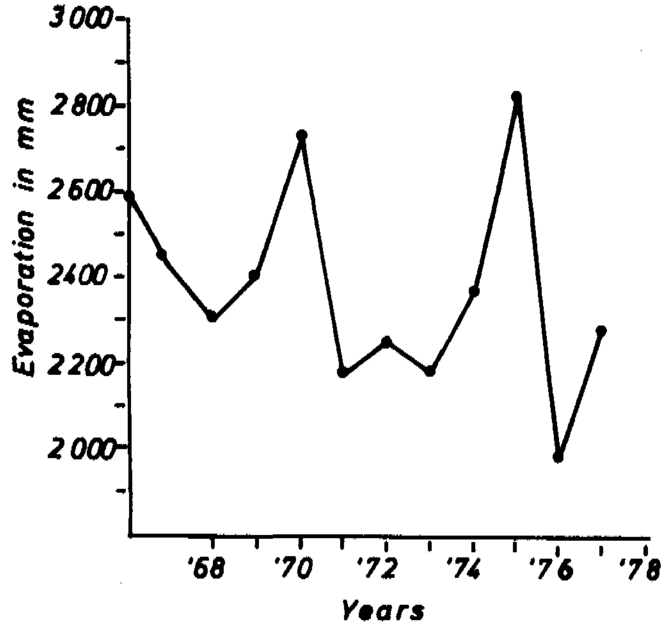


Fig: 4 Pan Evaporation at Kaduna south. *Ref. 3*

spillway and an emergency spillway. The construction of these hydraulic structures will take about 9 months.

Besides for water treatment, a complete water works comprising an intake, sedimentation tanks, clarifier, rapid gravity filters and treatment works are also proposed to be built at Barnawa near the dam and the reservoir. The whole project can be completed within two years. Any suitable equipment can be transferred to the proposed new works at Barnawa to keep it centralised and save expenditure on operation and maintenance. Another advantage of building water works and service reservoir at Tudun Wada village is its high contour which will ensure gravity distribution thus further reducing maintenance costs.

An aternative will be to make an intake at Barnawa and pump raw water to the existing South Works for treatmrnt and distribution. The capacity of the South Works can be increased by increasing the capacity of the treatment works.

The whole scheme is expected to cost not more than 5 million naira at current prices.

RECREATION

Apart from water storage for supply to Kaduna South, the Barnawa Dam reservoir will attract hotels and other related industries. Artificial beaches, gardens, childrens park, sports centres, gymnasia and recreation centres can be developed near the reservoir which will not only add greatly to the beauty of Kaduna city, but will also be financially beneficial to Kaduna State Water Board in particular and Kaduna State in general.

CLIMATE

The location of a large lake close to Kaduna will result in more vegetation, which will have good effects on weather and general climate. The dry weather will be reduced, nurturing better health conditions for the residents of Kaduna and its suburbs.

RECOMMENDATIONS

A guage was installed on the stream in 1979. It will be worthwhile to install a 'V' notch weir also to accurately determine the stream discharge.

Subsurface investigations by core drilling along the dam axis will be important to determine the foundation conditions.

CHEMICAL STUDIES

Raw water samples from different points in the stream should be collected for chemical, bacteriological and pathological examination, to assess the quality of raw water and the treatment needed.

CONCLUSION

This proposal is expected to save at least 10 million naira on the overall cost of the Kaduna Water Supply Extensions proposed by the consultants.

Also this project will be relatively simpler and quicker to construct, for which technical expertise and manpower is comparatively more available within the country. It will also help in less dependence on Kaduna river flows which fluctuate greatly. Under the circumstances the Barnawa dam proposal shall be an interesting study for early implementation.

ACKNOWLEDGEMENT

This paper is being presented with the approval of Alhaji Junaidu Mamuda, Chairman, Kaduna State Water Board. Dr M A Gill, Professor, Civil Engineering Department, Ahmadu Bello University, Zaria, provided all the necessary guidance. Mr Chandra Prakash and Mr A M Villavarayan of Kaduna State Water Board helped in preparing all the figures and tables.

REFERENCES

Kaduna Water Supply Extensions (Report), by M/s Ward Ashcroft and Parkman (Nigeria), March 1978.
The Analysis of the Kaduna Water Supply Distribution System and the Kaduna River Pollution Study (Report), by Louis Berger Incorporated Nigeria, December 1978.
Kaduna State Water Board Hydro-Meteorological Year Book 1972-1977.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

E A ANYAHURU

PIPE–BORNE WATER SUPPLY IN A TRADITIONAL SOCIETY – NIGERIAN CONDITION

INTRODUCTION

Pipe borne water supply in rural areas has received more publicity than the attention it deserves in most parts of Nigeria. In the urban centres, the story is not very different. A false impression is created that everybody in the society including those in government appreciates the role of clean water in a healthy society. Funds for executing water projects are lacking when the figures are put forward. Projects started for Enugu, Nsukka, Abakaliki and Aba in Anambra and Imo States have virtually grinded to a halt due to lack of funds.

Several problems militate against the formulation of working and workable government policies on the distribution (allocation) of this essential commodity, water, under a stringent financial constraint. The practice of communities raising funds to build their own water system may not be economical in the long run. It is believed that the most economical use of water resources is that which is based on a regional distribution: small community projects may not fit into the regional network.

1. Administration: There are three levels of government in Nigeria - Federal, States and the Local Governments. It is the responsibility of the state governments to provide potable water to both urban and rural communities in the country. In the most recent development in government, states have created Ministries of Utilities which, in some states have limited scopes - Water Supply and Rural Electrification. In addition to this new ministry, there are state owned Corporation/ Boards charged with the Authority to ensure that government policies on Water Supply are implemented, or in some cases, evolve policies on Water Supply in the states. There are provisions for Advisory Water Committees in the local areas to act as links "between the Water Corporation and the locality served by the committee" (Edict, 1976).

2. Government Policy on Water Supply: It has not been easy for many state governments to define working and workable guides for sighting a pipe-borne water project in the state. Should a water project be sited according to need knowing that potable water is an absolute and natural necessity? Should the most depressed and neglected section of a state be compensated with a water project? Should a community be required to deposit a fixed sum of money per capita to enable the government mount a water project for the community? If so, what percentage of the project must the community contribute before government approves the project: How effective should personality cults be in the location of water projects?

The above questions highlight some of the problems of the distribution of this limited resource. If funds were limitless, there would be pipe borne water in every village, hamlet and household.

3. Components of a Water Project: There are communities whose underground formations contain "underground rivers". If a hole is dug on such places to the depth of these formations, water collects within the hole. A suitable device installed into the hole facilitates the abstraction of the water for domestic and other uses. In Imo State, Local Government Areas like Ukwa, Obioma Ngwa, Isiala Ngwa, Owerri, Aboh, Egbema/Ohaji/Oguta, and most parts of Ahiazu and Oru are enriched with abundant ground water. The chemical and bacteriological qualities of the water are very satisfactory, requiring no serious treatment. It is quite soft with low pH averaging 5.0 in samples from over ten isolated boreholes. The following components are required to draw such an underground water up to the surface and down into a standing public tap or domestic plumbing fixtures:

3.1 (a) Development of source through wells or boreholes. In our present practices two boreholes is a minimum in a station. This unit may take up to 20% of the total cost of a project;

(b) An electric generating set and a building to house the set where central electric power is absent. This unit takes up to 6% of the project cost;

(c) A storage, normally able to take about half-a-day's consumption, or a whole day's consumption. This can be a ground level tank or an elevated tower, depending on the general topography of the area. It could be constructed in pressed steel or in reinforced concrete. The unit consumes up to 32% of the project in relatively flat terrains;

(d) Pumps and accessories at estimated cost of 6% of the total cost of project;

(e) A network of pressure pipe lines to connect the source (a), the storage (c), and the location of the standing public taps. Depending on the scope of area to be served, this unit may consume over 36% of the total project cost.

On the other hand there are communities which have to be supplied with adequate potable pipe borne water from surface water sources such as rivers, streams, lakes, brooks and springs. Ohaozara, Afikpo, Okigwe/Isuikwuator, Arochukwu/Ohafia and parts of Umuahia/Ikwuano, in Imo State are some Local Government Areas that have this singular handicap with their water supply. This is a handicap because there may be a collection of communities that do not have perennial streams for a stretch of over 10km. Pipe-borne water can only get to such areas through extensive pipe network. Although industrial pollution is not a major problem yet in the rural areas, the water from most of the streams have to be treated to remove colour, turbidity and silt in the rainy season. This means extra running cost for a water scheme. The following components may be required to draw the water out of the stream and make it potable at the standing public tap:

3.2 (a) Development of source through embarkments, impoundment, dams, weirs etc. Depending on the location of the source and its pollutional load, the water may undergo a full or partial chemical/bacteriological treatment to make it potable. The cost of this unit may run as high as 30% of the total cost of the project;

(b) A generating set or generating sets and accessories. Though the cost of this unit may be similar to those in item e.1 (b), it may constitute less than 5% of the project;

(c) Pumps (high and low lifts) with accessories may consume less than 5% of the project cost also;

(d) A storage as at item 3.1 (c), may consume about 30% of the project;

(e) A network of pressure pipes as at item 3.1 (e) may take up to 30% of the project cost.

4. <u>Cost of a Water Project</u>: Pipe borne water project may take one of the forms described in item 3 above. Table 1 shows a cost breakdown of a water project for a community of 10,000 people (including women and children). Cost details will vary with local conditions, but figures in Table 1 are taken from present-day market prices for on-going water projects in Imo State (Table 1). The figures in this unit give a unit cost of ₦39.30k per consumer. For a project which is financed entirely by the community, a farmer with eight children should contribute ₦ 393.00 towards the water project. Only very few rural communities in a Nigerian society can fund this project and execute it in a logical sequence without suggesting the purchase of a generating set first because it is the cheapest item of the lot. Communities volunteer to undertake the trenching for the pipeline, but this item comes up in the last phase of the project.

Pipe extensions in 100mm and 75mm to remote villages or villages outside the path of the main pipe line are additional costs which will have to be borne entirely by the local councils or the villages.

5. <u>Economy and Sophistication</u>: In the thirties and early forties, the colonial government in parts of southern Nigeria dug a number of 1 200mm (4'.0") shaft open wells to provide "clean" water to villages where it was technically feasible to do so. Women and children drew water with ropes and buckets in a very unhygenic manner. Buckets from various homes and contaminated well surroundings converged in the wells. The level of economy reflected in this crude method of water supply was distinctly different from the pipe-borne water supply system enjoyed by the Europeans and other township dwellers. In the townships, potable water was piped into homes at the European Quarters. A few standing public taps were located at some road junctions for other township dwellers. With independence in 1960, experimental boreholes were drilled in parts of the former Eastern Region with electric or diesel powered pumps to pump the borehole water into reservoirs and towers in small pilot rural pipe-borne water schemes built by the governments. From the generally simple standardized cylindrical reinforced concrete water tanks a network of pipes radiated to parts of some communities. Communities near the scheme collected money for pipe extensions to convey the water to their village centres. The per capita daily

Table 1: Cost Breakdown of a Rural Water Project From Borehole Source

S/No.	Description	No./Unit	Rate	Cost
1	200mm boreholes	2 Nos.	40 000.00	80 000.00
2	Generator House	1 No.	15 000.00	15 000.00
3	Generating Set	1 No.	10 000.00	10 000.00
4	Pumps Complete	2 Nos.	12 000.00	24 000.00
5	450 cubic metre steel tower	1 No.	120 000.00	120 000.00
6	150mm pipes	8,000m	18.00	144 000.00
	Total	-	-	393 000.00

water consumption was of the order of 23 litres (5 gallons). This was the beginning of the sophistication in community water supply which, less than twenty years later has become the standard method of pipe-borne water in our rural centres. Today, boreholes have tragically become synonymous with rural water supply especially to the uninformed public. Only very few of the water schemes were constructed because government could not fund many of them at the time.

Following the bitter experiences of 1966 and the subsequent civil war, there is now a general tendency for people in the Eastern States of Nigeria to develop estates and modern residential homes in their villages. Such estates are hardly complete without modern water closet toilet systems which depend on a reliable public water supply. There is therefore a demand to provide pipe-borne water in the villages, not simply to satisfy the requirements of the traditional village dwellers, but to meet the demands of the few elites who are used to such sophistications in the urban centres. Though the level of economy can ill afford the luxury of the duplication of modern pipe-borne water system - in the villages and urban centres - and though the elites are few in number, enjoying village facilities at the weekends and during annual vacations, Water Authorities are made to provide them even at the risk of inefficient and irregular operations in the main urban centres. There are no studies to justify the slogan that rural water supplies will directly stop or even minimise the general drift into the urban centres where many other opportunities exist for young people.

6. Contributions for Water Projects: Some communities initiate development projects to attract government grants. Most of the projects which have been successfully executed by communities through this combined effort of the people and the various levels of government include construction of school blocks, short span bridges, earth-roads and market stalls. Cash contributions of up to ₦ 20,000.00 invariably go a long way towards the completion of the unit, or it might make a significant impact on the structure to the extent of attracting the attention of outsiders including the various levels of governments. In Water Supply project, the matter is not so simple as illustrated in Table 1 for a simple rural water project.

7. Practical Designs: The design of any public utility services in a developing economy is beset with a multiplicity of problems. Nothing is certain or definite in the design parameters which are required for effective sizing of the components of the services. Initial population figures, population dynamics, per capita demand, and the probable life of the utility are unknown parameters in this country. There are no maps. Wherever it is possible, design figures and safety factors are lifted from British, American or German literatures depending on the designer's educational background. There are no Nigerian national codes for Water Works practices. These imported standards may not tie with local conditions, and the resulting designs may not be economic. Some engineers even tend to consider the application of a rigid engineering principle in water supply practices as a mere academic exercise. This is very unfortunate.

Amidst these problems of under-development is the politics associated with the distribution of a scarce commodity. Water supply is a political issue. The location of a water project may be based on a political consideration with little or no bearing to the direct cost of the project or even the technical feasibility of the venture. It is not uncommon to drill a borehole drilling team into a village or group of villages sitting on top of shales to give water to the people. The result is money wasted on abortive or dry boreholes. There are instances where communities have volunteered to have their own separate water project in preference to water from a nearby unfriendly community. These underlying and in-built social and political difficulties militate against the application of engineering principles to design economic projects. However, the following detail design

Procedures have been found to yield a measure of economy in some of the state-owned Water Corporations and Boards:-

(i) A Request for a Project - A request or proposal for a community water project is initiated by community leaders. There should be an arm of government responsible for the welfare and general development of the rural communities in a state where water supply services have been programmed and phased out for execution. The proposal for a project is accompanied with a list of all the villages and establishments to benefit from the proposed water project;

(ii) Preliminary Investigations: Maps showing the locations of the villages, where available, and in the appropriate scales with contour lines, are assembled. It will be easy to determine whether the villages can be supplied through pipe extension from existing water schemes or to locate a possible source and nature of treatment if any. Available maps may have to be blown up (manually) in the Drawing Office. Some natural features may be lost in such a map necessitating site visits by the engineer to locate some of the essential features. Where no maps exist, the surveyor goes to prepare plans of the main roads and paths with spot levels. Villages and village centres are located on the plan.

(iii) Preliminary Design: In this country, the only official population figures are those of 1953 and 1963. These figures can be collected from the Community Development Divisions of Local Government Councils. This two point graph is a basis for population estimation, generally based on a geometric rate of growth. Per capita daily water consumption of 50 litres is considered a reasonable rate for the initial development of the source (for ground water sources). A maximum rate of 90 litres per capita per day in 20 years when habits on water usage in the village should have become stabilized assists in sizing the trunk mains. Storage should cater for a day's demand. Where a standby pump or borehole is provided for only ten hours demand - a 450 cubic meter pressed steel tower on 10m piers could be made a standard storage for communities of up to 10 000 people in relatively flat areas.

Quite often there is a need to provide standard boreholes in a state to minimize maintenance problems in a country where all components of a pump are imported. This may lead to unnecessary wastage in resource allocation where a small isolated community of less than 5 000 people may be supplied with water from 300mm boreholes each yielding over 50 litres per second (40 000 gallons per hour). It may be uneconomical to extend water from such an isolated community to the others. A balance has to be struck between designing a large central project for groups of villages or communities, even inter-local government areas and isolated small schemes for individual locations. The former is preferred for ease of maintenance. Based on the demographic distribution of villages in the coastal plains of Imo State, it is observed that when trunk mains get beyond 250mm, it may be more economical to consider the location of another water project in the area. Designs of this size cover 6 to 10km radius in these rural areas.

At this stage the Water Authority's detailed report will contain a reliable cost estimate to enable the financier decide on the stages for executing the particular project. The financier, usually the government, can decide to complete the project in phases, stretched over a number of years.

7. Execution: The project can be executed according to the following four year schedule:

(i) First year - Prepare the design including the costing of the project;

(ii) 2nd year - Drill the boreholes or develop the intake and indent for the pumps and other electromechanical equipment. Build the storage tank;

(iii) 3rd year - Complete the storage tank. Install the pumps, generators etc. and connect up the pumps and tanks. Provide public standing tap so that communities along the trunk mains already laid, and those situated in the vicinity of the storage tank can begin to draw potable water from the public taps;

(iv) 4th year - Laying of all the remaining large diameter pipes, namely 250mm, 200mm and 150mm to the centre of the design areas.

After laying the 150mm pipes, the government can hand over the completed water project for operation and maintenance. Further pipe extensions in 100mm and 75mm pipes which can still take the water up to 2-4km from the trunk mains depending on the topography and demand, can be continued by the communities through community efforts and contributions.

CONCLUSION

State governments have set up the machinery for the control of water supply services. There are, however, numerous socio-political forces which militate against equitable distribution of these services. Pipe-borne water schemes are very expensive projects to be left to communities to finance without government support. By applying basic principles in engineering design however, a community water project can be phased out through a period of four years (ideal for the present political set-up in the country). In this way, a pipe-borne water project initiated by a regime on assumption of office will be duly completed before the next election. Those not completed are to be taken over from well defined stages which make for easy completion.

The essential components of a pipe-borne water scheme, namely - (a) Source development, (b) power supply, (c) water treatment where it is necessary, (d) storage, (e) provision and laying of pipe trunk mains, 150mm and upwards should be a government responsibility. Pipe extensions in 100mm and smaller diameters can be undertaken by communities with government technical advice.

ACKNOWLEDGEMENTS

The author wishes to thank the Imo State Water Authorities for permission to publish this paper. The views expressed in this paper are those of the author and are necessarily not those of the Imo State Water Corporation, nor those of the Ministry of Water and Electricity.

REFERENCES

1. Edict 1976: Edict No.5 of 1976. Supplement to Imo State of Nigeria. Gazette No.9, Vol.1 (pages A13-30); 3rd June, 1976 - Official Government publication.

2. Anyahuru, E A. Financing a Water Project - Cast Study. Engineering Challenges In Nigeria in the 80's. Proceedings of the National Engineering Conference. Nigerian Society of Engineers' publication. Page 126 - 133, December 1977.

3. CAMPBELL, M.D. & LEHR, J.H. Rural Systems Planning and Engineering Guides. A United States Commission on Rural Water publication, Washington D.C. 1973.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

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COST COMPARISON IN WATER SUPPLY ALTERNATIVES IN SAUDI ARABIA

INTRODUCTION

Fresh water resources in Saudi Arabia are very limited and exhibit a potential problem for planners at the national and local levels. Most water supplies in the Kingdom come from shallow ground water aquifers that have limited areal extents and supplies. The most extensively developed aquifer systems are located in the eastern and north-eastern regions of the Kingdom where extensive sedimentary layers have been deposited along the flanks of the pre cambrian Arabian shield complex. Localized shallow alluvial aquifers predominate in the western and south-western regions where extensive wadi systems have been developed during the quaternary period.

Rainfall in the Kingdom is very sparse and whatever of it reaches the soil surface, evaporates fast and therefore little or no recharge of these aquifers takes place. The amount of available water in these aquifers is therefore limited and the water levels have been declining sharply for the past few years. More and more water is being needed to keep up with rising use in agriculture, industry and municipal supplies. The affluence from the income of oil production, thus brought with it large development schemes that need yet larger and larger quantities of water, in which case the available sources could never meet. The attention of the planners have thus shifted to alternative sources of water supplies to satisfy these future needs. One of the first alternatives that have been utilized extensively is the desalination of sea water from the Red Sea in the west and the Arabian Gulf in the east. The first major desalination plant became operational in 1970, and produced 5 mgd to augment the increasing municipal demands of the city of Jeddah. This was followed by another plant in 1974 at Al-Khobar on the Arabian Gulf, and produced 7.5 mgd to supply the population of Al-Khobar, Dammam, and Qatif. Since then more plans for major desalination projects have mushroomed and the planned daily production capabilities have exceeded thousand million gallons. A major pipeline is under construction to transport desalinated water from Jubail at the Arabian Gulf to feed the capital city of Riyadh some 460 kilometers towards the interior.

Besides desalination other conventional and unconventional sources of water supplies have been also contemplated. Amongst these, the most controversial was the transport of icebergs from Antarctica to the Red Sea coast. Research on this project is still going on by private investors who may one day see the feasibility of such projects and find it more economical to undertake. Amongst the more conventional sources of fresh water that has not been talked about much yet is the import of surface water via canals or pipes from the lower reaches of the Tigris and Uphratis rivers in Iraq. Although it may be more economically feasible to import water from such sources, yet the political atmosphere in the area is probably the most recognized stumbling block against the realization of such a project. The import of water via incoming oil tankers is yet another scheme that could be thought of and implemented if some sort of encouragement is considered. By declaring certain lucrative discounts to tanker owners who buy their oil supplies from Saudi Arabia, many shippers will begin to seriously think of such discounts especially with the current staggering rises of fuel prices and the negligible cost of renovating the tankers to accomodate for shipping fresh water.

No economic studies have so far been conducted on the cost comparison of such water supply alternatives for Saudi Arabia. Due to lack of data in importing water via tankers and canals or pipes, the present study will, therefore, be limited to desalination processes and potential use of iceberg utilisation.

The major objectives of this study are: to develop a cost model relating water cost with the system capacity and efficiency of removal of hardness and total dissolved solid (TDS); to establish cost-capacity relationships for various desalination processes; and to evaluate the use of icebergs as potential fresh water resource.

COST EVALUATION OF WATER SUPPLY SYSTEMS

Water supply system can be grouped into collection, purification and distribution subsystems. Collection subsystem is used to supply the source water in adequate quantities on intermittent or continuous basis to the purification subsystem. It is then treated to an acceptable quality and conveyed to the consumers through transmission and distribution subsystems. The cost of water thus collected, purified and supplied to the consumers depends on the capital cost of the whole system as well as the operations and the maintenance costs of the various components of the system. The cost of water supply is also related to the capacity of the system which is expressed as:

$$C = a(Q)^{b} \qquad (1)$$

where

C is the cost of water supply system,

a is constant which decides the cost of unit capacity,

Q is the capacity of water supply system,

and b is the economies of scale.

The constant 'b' is usually less than one. It means that the total cost increases with the capacity of the water supply system but at a decreasing rate. If variable, 'C' represents unit water cost and coefficient 'b' is negative, the cost per unit volume of water dereases with the increase in the capacity of water supply system.

Waters in arid regions like Saudi Arabia are usually hard and contain high concentration of TDS. The removal of these constituents below a maximum permissible level is, therefore, a necessity. In addition to the capacity of water supply system, the unit water cost will also be affected by the extent of removal of the these constituents.

A model, determining the unit water supply cost should include hardness and TDS as additional parameters. Such an attempt is made by using multiple regression analysis and is expressed as:

$$C_u = a(Q)^{b} (HARDEFF)^{c} (TDSEFF)^{d} \qquad (2)$$

where

C_u is the unit water cost,

Q is the water supply capacity,

HARDEFF is the efficiency of hardness removal in percent,

TDSEFF is the efficiency of TDS removal percent.

a,b,c, and d are regression coefficients.

The regression coefficients for the reverse osmosis desalination process are estimated using the data listed by Miller (Ref. 18). This relationship is as follows:

$$C_u = 0.790(Q)^{-.073}(HARDEFF)^{-.722}(TDSEFF)^{1.944} \qquad (3)$$

The correlation coefficient for the above model was highly significant ($\underline{r}^2 = .969$).

In Eq.(3), C_u is expressed in cents/cum and Q in 1000 cubic meter per day. HARDEFF and TDSEFF are defined in Eq.(2).

Similar relationships can be developed for other water supply systems.

COST-CAPACITY RELATIONSHIPS FOR DESALINATION PROCESSES

Commercially important desalination processes are multistage flash (MSF), reverse osmosis (RO) and electrodialysis (ED). Among these, MSF and RO are commonly used in Saudi Arabia. Multistage flash is used for treating seawater (high salinity water), whereas RO is mainly used for treating brackish water. Since RO and MSF are commonly used in the Kingdom, therefore, cost-capacity relationships of these processes will only be established.

Total cost as well as unit cost models based on 1979 United States index (Ref. 16), are developed for the above mentioned desalination processes. Total cost models are categorised into direct capital, total capital and annual operations and maintenance models.

Cost-capacity relationships (Eq. 1) for both total cost and unit cost models can be generallised as follows:

$$C = a X^b$$

The variables and coefficients in this model have earlier been defined. The cost-capacity relationships are established using the data listed by Larson and Leitner (Ref. 16).

The variable 'C' in the case of total costs is expressed in million dollars and, in the case of unit cost models, it is defined as the cost in dollars per cum. The capacity X is in thousand cubic meter (CUM) per day. The regression coefficients thus obtained are listed in Tables 1 and 2.

Table 1 Regression coefficients for cost-capacity models (MSF: Seawater)

Items	Regression Coefficients a	b	Correlation Coefficient γ^2
1. Total cost			
a) Direct Capital Cost	1.842	0.773	0.99
b) Total Capital Cost	2.934	0.792	0.99
c) Annual Cost without Energy	0.565	0.787	0.99
2. Unit Cost of Water			
a) Oil fired boiler	1.983	-0.168	0.98
b) High Sulfur coal boiler	2.015	-0.176	0.97
c) Low Sulfur coal boiler	1.964	-0.170	0.98
d) Dual purpose	1.955	-0.171	0.97

Table 2 Regression coefficients for cost-capacity models (RO Process)

Items	Regression Coeff-icients a	b	Correlation Coefficient γ^2
Seawater Desalting			
1. Total Cost			
a) Direct Capital	1.316	0.862	0.99
b) Total Capital	1.664	0.868	0.99
c) Total Annual	0.204	0.889	0.99
2. Unit Cost	1.546	-0.122	0.97
Brackish Water Desalting			
1. Total Cost			
a) Direct Capital	0.388	0.802	0.99
b) Total Capital	0.473	0.817	0.99
c) O&M Cost	0.248	0.634	0.89
2. Unit Cost	0.405	-0.114	0.90

EVALUATION OF UNIT WATER COST FOR SAUDI ARABIA

The following assumptions were made in analysing the unit cost of water using various desalination processes in Saudi Arabia.

1. Plant life = 30 years
2. Amortization factor = $0.0641/year based on 30 years plant life and interest rate 4.875% (Ref. 1)
3. Plant capacity factor = 66%
4. Plant availability factor = 92%
5. Load factor = 90%
6. In case of MSF desalination system, a credit of $500 per KWH of electrical capacity is assumed in the analysis.
7. In cases, where data on O&M are not given, the annual operation and maintenance cost is computed as a percentage of known capital cost data (Ref.16). These values are as follows.

   MSF seawater desalting = 24.23%
   RO seawater desalting = 9.81%
   RO brackish water desalting = 20.32%

Based on the above assumptions, the unit water cost for desalination processes were computed. The result of these computations are listed in Table 3.

Table 3 Cost evaluation of desalination process operating/proposed in Jeddah.

Location	Approx. operating yr.	No. of units	Power (MW)	Water (mgd)	Process	Contract (10^6\$)	Cost (\$/1000 gal.)	Cost (\$/m^3)
Jeddah I	1970	2	--	5	MSF	19	5.84	1.54
Jeddah II*	1977	4	80	10	MSF	182	14.69	3.88
Jeddah Seawater	1978	9	--	3.2	RO	30	7.36	1.94
Jeddah III*	1980	4	200	20	MSF	428	16.97	4.48
Jeddah IV*	1983	10	500	50	MSF	718	9.68	2.56

* In Jeddah II, III and IV desalination plants the contract value included the capital costs as well as operations and maintenance costs for a period of two years.

ICEBERGS

The utilisation of icebergs, as freshwater supply alternative for Saudi Arabia, is very attractive. It is believed that the transport of icebergs is economically and technically feasible and will not pose a potential hazard to marine environment (Ref. 17 and 20). The Kingdom of Saudi Arabia has seriously considered the implications of the icebergs on terrestrial environment (Ref. 6).

The major factors, in transporting an iceberg, are ocean currents, towing technology, and shape, hardness and size of the iceberg. It is suggested that transporting icebergs from the South Pole is relatively economical and feasible because of the favourable ocean currents in towing Antarctic icebergs. Moreover, Antarctic icebergs are more regular in shapes (Ref. 18). During transport, the icebergs can be wrapped into insulating material, like polyurethene to minimize evaporation and melting losses (Ref. 15).

The shallowness of the Arabian Gulf will restrict the use of icebergs only to the Western Coast of Saudi Arabia. The Red Sea near Jeddah is also shallow and icebergs must be sliced, probably near Aden, prior to towing to Jeddah or other coastal cities of Saudi Arabia.

The energy required to move the icebergs, the velocity at which it will travel, the density and shape of icebergs are deciding factors in determining the cost of water obtainable from them. The cost of iceberg utilisation, computed by various theorists, is listed in Table 4.

Table 4 The cost of iceberg utilization as water supply alternative

Iceberg Theorists	Ice Moved tons/Newton	Velocity (m/s)	Yield (km^3)	Cost in (¢/cum)
ISAACS	640	0.5	1.1	3.3
Weeks-Campbell	425	0.5	10.3	4.7
Halt Ostrander	144	0.5	10.3	24.0
CICERO	14	0.8	1.9	202.0

It may be noted in Table 4 that assumptions, like energy requirements and water yield, made by different theorists vary significantly and reflect on the necessity of further research in the area. The cost of icebergs utilization in Saudi Arabia is compared with other sources of freshwater in Table 5.

Table 5 The cost of freshwater obtained from different sources in Saudi Arabia

Sources	Cost (U.S.\$/m^3)
Reverse Osmosis	1.94
MSF Desalination	1.54 - 4.5
Icebergs	0.03 - 2.02

DISCUSSIONS AND CONCLUSIONS

Any definite conclusion on cost-capacity relationships can not be drawn for Saudi Arabia unless sufficient cost data are obtained and analysed. The reulsts listed in Tables 1 and 2 can be modified to establish cost-capacity models for Saudi Arabian desalination process provided a reliable statistical mean value of the unit water cost for RO and MSF is evaluated.

By comparing unit water cost models for seawater reverse osmosis and MSF process (Tables 1 and 2), it is concluded that for relatively small capacity RO is more economical than MSF.

As shown in Table 5, the most economical alternative is the iceberg utilisation. Further research and analysis are needed. It is also evidenced from Table 5 that the unit water cost to treat seawater in Jeddah using RO is usually lower than MSF alternative.

REFERENCES

1. Abdul-Fattah, A.F., Husseiny, A.A., and Sabri, Z.A. Nuclear desalination for Saudi Arabia: an appraisal. Desalination, 25, 1978, 163-185.

2. Abdul Fattah, A.F., Husseiny A.A., and Sabri, Z.A. Desalting in Saudi Arabia - demand, production, management, associated power generation and future plans. Desalination 25, 1978, 9-44.

3. Agarwal, A. Will Saudi Arabia drink Icebergs? New Scientist, July 7, 1977, 11-13.

4. Al-Gholaigah, A., El-Ramily, N., Jamjoom, I. and Seaton, R. The World's first large seawater reverse osmosis desalination plant at Jeddah, Kingdom of Saudi Arabia. Desalination 27, 1978, 215-231.

5. Al-Gholaigah, A., and Ericson, B. Riyadh's reverse osmosis water treatment plants - The largest demineralization complex in the world. Proc. Int. Congress on Desalination and Water Re-use, Nice, France, Oct. 1979, 301-315.

6. Al-Faisal, Muhammad, H.R.H.M. Water supply and weather modification through the use of transported icebergs from Antarctic. Proc. the First Desal. Cong. Am. Continent, Mexico, Oct. 24-29, 1976.

7. Aswad, M. and El-Hares, H. Cost comparison of effectively produced desalted water by different processes in a developing country. Desalination, 23, 1977, 285-290.

8. Basmaci, Y., and Jamjoom, M.O. Delivery of icebergs to Saudi Arabia. Proc. the First Int. Conf. on Icebergs Utilisation, Ames, Iowa, 1977, 556-576.

9. Bushnak, A.A., Abdul-Fattah, A.F., Husseiny, A.A., and El-Nashar, A.M. Selection of desalination technology, a decision analysis approach and a case study. Proc. Int. Congress on Desalination and Re-use, Nice, France, Oct. 1979, 483-498.

10. Day, J.M. Icebergs used in theory and suggestions for the future. Desalination, 29, 1979, 25-40.

11. Doelle, R.R. Reverse osmosis pre-treatment techniques in Saudi Arabia. Proc. Int. Congress on Desalination and Water Re-use, Nice, France, Oct. 1979, 316.

12. Floyd, F.X. A water treatment and re-use program in Riyadh, Saudi Arabia. Proc. Int. Congress on Desalination and Water Re-use, Nice, France, Oct. 1979, 321.

13. Hult, J.L. Icebergs for reservoirs, freshwater, and cooling. Desalination, 29, 1979, 41-60.

14. Hult, J.L. and Octrander, N.C. Antarctic icebergs as a global freshwater resource. R 1255-NSF, Oct. 1973.

15. Hussain, S.N. Iceberg protection by foamed insulation. Proc. the First Int. Conf. on Iceberg Utilisation, Ames, Iowa 1977, 423-472.

16. Larson, T.J. and Leitner G. Desalting seawater and brackish water: A cost update. Proc. Int. Cong. on Desalination and Water Re-use, Nice, France, Oct. 1979, 525-539.

17. Lundquist, T.R. The Iceberg commeth: international relating to Antarctic iceberg exploitation. Natural Resources Journal, Vol. 17, No.1 January 1977, 1-41.

18. Miller, E.F. Demineralization of brackish municipal water supplies - comparative costs. Journal of the American Water Works Association, 69, 1977, 348-351.

19. Victor, P.E. Will Deserts drink icebergs? UNESCO COURIER, Feb. 1978, 17-22.

20. Victor, P.E. Water supply and weather modifications from transferred icebergs from Antarctica to countries of the world's thirst belt. Desalination, 29, 1979, 7-15.

21. Weeks, W.F., and Campbell, W.J. Icebergs as a freshwater source: an appraisal. Symp. on Hydrology of Glaciers, Camb., England, Sep. 1969.

L G HUTTON and W J LEWIS

NITRATE POLLUTION OF GROUNDWATER IN BOTSWANA

INTRODUCTION

During a review of water records and analytical methods at the Botswana Geological Survey in 1973 it became apparent that chemical analyses of some groundwater samples showed a cation-anion imbalance with an anion deficiency. When these samples were analysed for nitrate the balance was restored.

Nitrate analyses had not been made previously because information about an easy, reliable method was not available. However, after evaluating the various analytical methods, it was decided to use the colorimetric salicylate method (1) for nitrate determination on a regular basis.

Between 5-10% of all water samples analysed in the laboratory were subsequently found to have nitrate levels greatly in excess of WHO (2) recommendations as set out in Table 1.

The results were reported to government and concern was expressed at the highest level. Therefore the GS10 Groundwater Resources Evaluation Project team (3) was asked to investigate the causes of the pollution. Preliminary surveys (4,5,6,7) in 1976 had shown the extent of the pollution in major villages in eastern Botswana relying on groundwater supplies.

Table 1
WHO recommendations for nitrate levels in water (2)

	mg/l NO_3^-	category
general population	under 50	acceptable
	over 50 and under 100	borderline
	over 100	unacceptable
infants under 6 months	over 50	unacceptable

Table 2
Major villages with high levels of nitrate in their groundwater supplies

Village map reference	Name	Population actual (1971)	Dwellings	No of Boreholes with $NO_3^- > 20$ mg/l	Highest NO_3^- mg/l
1	Mochudi	6945	1578	9	603
2	Molepolole	9448	1763	18	422
3	Serowe	15364	2593	17	663
4	Kanye	10664	1884	2	251
5	Francistown	18613	3618	9	189
6	Palapye	5218	873	6	580
7	Mahalapye	11377	1876	4	227
8	Ramotswa	7991	1316	4	170

20 other villages (population less than 5000) were surveyed and nitrate values above 20 mg/l were detected in all of them.

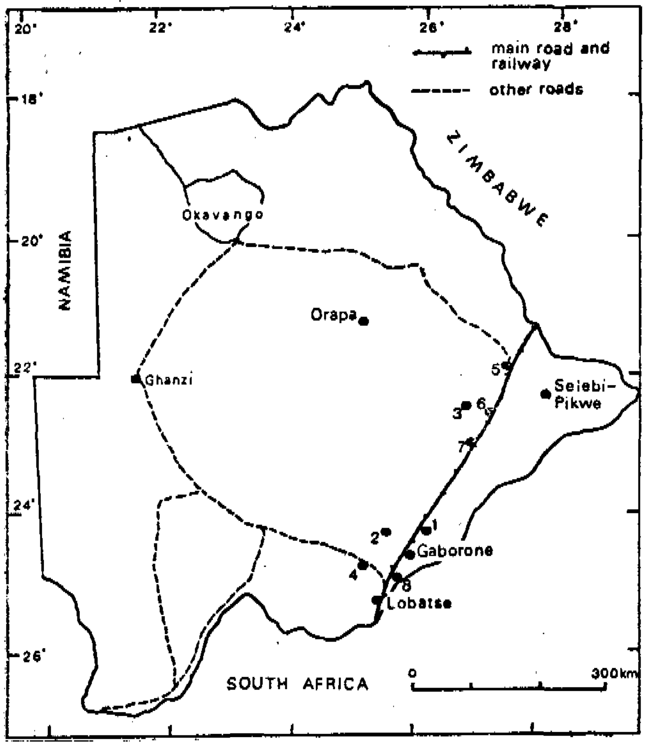


Figure 1

Location of major villages with high levels of nitrate in their groundwater supplies.

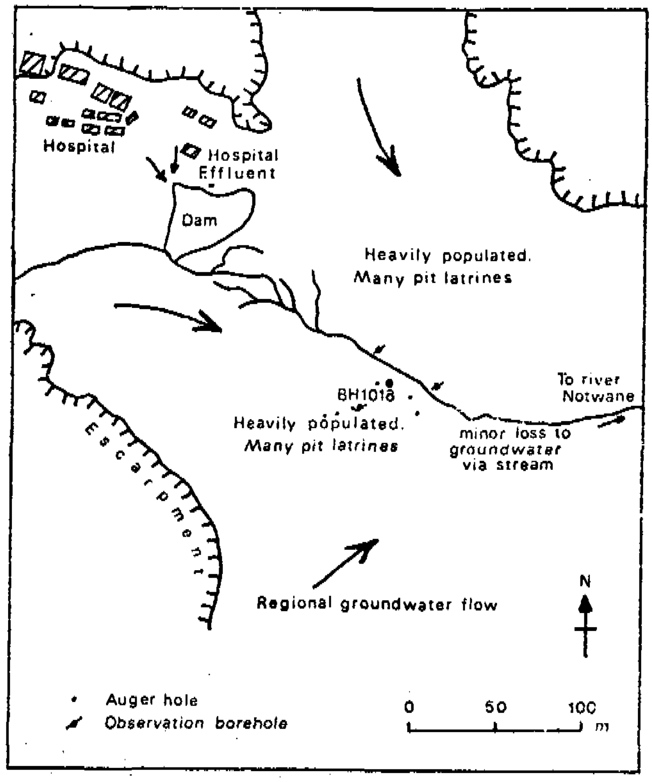


Figure 2

Mochudi Village and site plan of investigation area.

SIGNIFICANCE OF NITRATES IN THE GROUNDWATERS

Nitrate is an end-product of the decay of nitrogeneous material. This material could be fertilisers or animal and human excreta. Since the surveys showed that the nitrate contamination was generally confined to heavily used boreholes within village boundaries and that fertiliser is hardly used in Botswana, it was concluded that the nitrate was being derived from pit latrines. It is also common practice to defecate in secluded places.

There is a strong association between groundwater pollution and population density, but the major towns, Gaborone, Orapa, Selebi-Pikwe and Lobatse, which are served mainly by surface water, are unaffected.

CASE STUDY - MOCHUDI VILLAGE

A research study was funded through the GS10 project at Mochudi village (see Fig 1) during 1978 to confirm the source of the pollution.

Mochudi lies at the foot of a Waterberg sandstone escarpment resting on Basement Complex granites and gneisses. The specific study area was situated in a densely populated embayment in the escarpment underlain by Waterberg talus and weathered Basement Complex rocks. The soil cover is dark, clayey, fairly thin, grading downward within 2-3 m into weathered rock. Groundwater is extracted from quite shallow depths in the weathered rock and overburden.

Rainfall in Mochudi averages 500 mm with 35% seasonal variability. It was assumed that recharge occurred during the study period since there was heavy rainfall.

Three observation boreholes were drilled around a public supply borehole and a 72 hour pump test carried out to determine the aquifer characteristics. Chemical and bacteriological analyses were made on soil and water samples from the unsaturated and saturated zones and a tracer study was used to determine the rate at which pollution travelled.

RESULTS

Pump test data indicated that the weathered granitic material forming the aquifer zone around Bh 1018 had a low transmissivity of 14-20 m^2/day. This implies that open fractures are few, the majority being filled by clayey weathering products. The drawdown after 21 hours pumping at the rate of 1 litre/sec was 9m (static water level 6 m).

Lithium chloride tracer injected into a pit latrine was detected in the supply borehole 25 m away after only 235 minutes. The steep hydraulic gradient between latrine and borehole was thought to have induced this rapid movement with flow occurring in open fissures.

Analyses of augered soil samples collected near the pit latrine showed high concentrations of nitrate (1-200 mg/100g) and chloride (1-40 mg/100 g) with highest values from the layer directly above the bedrock. Control samples from auger holes 40 m away showed only background concentrations (0,2 mg/100 g nitrate and 0,4 mg/100 g chloride). The zone of contaminated soil extend for at least 15 m either side of the pit latrine. This represents a massive quantity of potentially leachable nitrate and confirms the conclusion of the earlier studies that excreta disposal represents a major source of contamination to shallow groundwater supplies.

The bacteriological tests confirmed the presence of faecal coliforms in the supply borehole (10 coliforms/100 ml) and gross contamination (350 faecal coliforms/100 ml) in the observation borehole adjacent to the pit latrine.

RELATIONSHIP BETWEEN NITRATE CONTENT AND BACTERIAL POLLUTION

An attempt was made to determine the relationship between nitrate contents of groundwaters and bacterial population. However, no clear picture emerged; wells with little or no nitrate contamination were found with and without bacterial contamination. Similarly, wells with nitrate contamination were also found either with or without bacterial populations. It was concluded that the relationship between bacterial contamination and nitrate was not statistically significant (8). Similar findings were reported by Brookes and Cech (9) in their work on rural water supplies in Texas. However, these authors infer that there may be a complex non-linear relationship probably involving factors not presently well understood.

DANGERS OF NITRATE POLLUTION OF DRINKING WATER

The dangers of high nitrate concentrations in drinking water are well documented (10). Essentially, these are methaemoglobinaemia and carcinogenesis.

Methaemoglobinaemia

Nitrate can be reduced to nitrite by entero-bacteria in the stomach. The nitrite is absorbed into the blood stream where it reacts with haemoglobin, the oxygen-carrying part of blood, to form methaemoglobin. Methaemoblobin cannot carry oxygen, so, if untreated, the condition leads to oxygen starvation of the tissues and possibly death for infants under the age of 3 months and cattle. Burden (11) reported cattle deaths from drinking water with high nitrate concentrations (70-870 mg/l nitrate) in Sudan. Studies by Shuval and Greuner (12) indicate that the oxygen deficient condition of methaemoglobinaemia can be transmitted from a mother across the placenta to her unborn child.

According to Berwick (13) methaemoglobinaemia can act synergistically with other diseases such as diarrhoea and anaemia which means, for example, that if a child has methaemoglobinaemia and then gets diarrhoea the health risks are much more serious.

Many factors are involved in human susceptibility to nitrates but in general young infants are the most vulnerable group for the following reasons:

1. infants have a lower stomach acidity than older children or adults. This allows the growth of certain microbes that contain enzymes capable of reducing nitrates to nitrites

2. foetal haemoglobin in the infant may be particularly more susceptible to conversion to methaemoglobin by the action of nitrites

3. the enzymes which can reduce methaemoglobin to haemoglobin are deficient in the young infant

4. the fluid intake of the young infant is higher than that of the adult in relation to body weight which means that more nitrate is consumed in relation to body weight.

Carcinogenesis

Nitrites, derived from nitrates, can react with amines and amides in the stomach to form nitrosamines. N-nitroso compounds can cause cancer in a wide range of animals and most are mutagenic. However, there is not enough data on either cancer-inducing dosages of nitrate/nitrite nor on the complex inter-relationships of environmental and biological mechanisms of carcinogenesis to draw definite conclusions.

IMPLICATIONS OF NITRATE IN WATER SUPPLIES

These studies clearly establishes the serious groundwater pollution hazard represented by pit latrines in hydrogeological environments such as those widely encountered in eastern Botswana. There may be a major build-up of nitrogeneous effluent in the soil and weathered bedrock surrounding pit latrines from which high quantities of nitrate are leached.

If pit latrines are close to water supply boreholes and pumping results in rapid flow from latrine to borehole, potentially grave risks to public health arise. Bottle fed infants are at particularly high risk if nitrate contaminated waters are used in preparing feeds. Boiling water will concentrate, not remove, nitrate.

The government of Botswana is well aware of the dangers of groundwater pollution and have ordered that the polluted wells be closed and alternative groundwater supplies provided for many of the listed villages (Table 2).

THE SIGNIFICANCE OF NITRATE TO WATER ENGINEERS

The importance of nitrate values for the water supply engineer is as an indicator that pollution has taken place. With this knowledge steps can be taken to locate the possible sources of pollution, stop it at source, or, failing this, protect the water supplies from further pollution. At the moment there are no economic methods of removing nitrate from polluted water supplies.

The engineer should remember that nitrate values of any particular water source can fluctuate seasonally depending on the period of recharge. Once a source has been found to have a nitrate value greater than 20 mg/l it should be tested regularly to determine whether there may be higher nitrate values at different times of the year.

Simple field methods of nitrate analysis are available and these can greatly assist field engineers in routine monitoring of water quality (Appendix 1).

APPENDIX 1

Field methods of testing for Nitrates and Nitrites

Dip stick tests for Nitrate and Nitrite have been developed recently by Merck. These give a semi quantitative determination of Nitrate in steps of 10, 30, 100, 250 and 500 mg/l of Nitrate and 1, 5, 10, 25, 50 mg/l of nitrite. The test strip is dipped into the water, removed and if nitrate is present a red-violet colour is produced on the sensitised part of the strip within 2 minutes. After this time the colour developed is compared to a colour scale printed on the side of the container and the amount of nitrate present read off.

The test strips enable simple and rapid semi-quantitative determination on site and can be used by relatively untrained staff. An on-site assessment of the likely sources of pollution can be made immediately and demonstrated visually to local officials and health workers. The use of test strips allows the field worker to screen water samples and indicates whether special samples need to be taken for more accurate laboratory analysis. The approximate cost is £5 for 100 strips, contained in an aluminium can 10 cm long and 3 cm diameter. At 5p per determination the cost is negligible compared to the field worker's transportation costs. The strips have a field life of about 1 year.

Other field test kits available for nitrate determinations are produced by Lovibond (UK) and Hach (USA). The kits use disc colour comparators and addition of chemicals to the sample contained in glass tubes to produce colours. The Hach kit uses encapsulated reagents which are opened using nail clippers. The reagents are stable in hot climates for about 6 months. The cost is about £28 for the kit and £8 for reagents sufficient for 100 tests. The kits are packed in carrying cases 20 x 15 x 15 cm.

The values obtained are obviously not as accurate as those which could be measured using sophisticated laboratory methods but the field engineer may not require accuracy and is unlikely to have the support of sophisticated laboratories and staff.

REFERENCES

1. MULLER R and WIDERMAN O. 1955 "Bestimmung das Nitrat-ions in Wasser" Vom Wasser, 22, p 247
2. World Health Organisation 1977 "Report of Working Group on Health Hazards from Drinking Water" London 1977. WHO Regional Office for Europe, Copenhagen, 1978.
3. Lewis W J, Farr J L and Foster S S D. 1980 A detailed evaluation of the pollution hazard to village water supply boreholes in Eastern Botswana. *Proc Inst Civ Eng.* Part 2 (in print).
4. Hutton L G, Lewis W J & Skinner A C. 1976 A Report on Nitrate Contamination of Groundwaters in some Populated areas of Botswana. Geol Surv unpub rep BGSD/8/76
5. Hutton L G. 1976 Geol Surv Botswana unpub report BGSD/9/76
6. Lewis W J. 1976 Geol Surv Botswana unpub report BGSD/14/76
7. Hutton L G & Loehnert E P. 1977 Hydrochemical surveys of selected Karroo areas in Botswana. Vol XII Proc IAH Conf, Birmingham, UK
8. Lewis W J. 1978 Geol Surv Botswana unpub report BGSD/3/78
9. Brooks D and Cech I. 1979 Nitrates and Bacterial Distributions in Rural Domestic Water Supplies. Water Research, 13, 33-41
10. World Health Organisation. 1978 Environmental Health Criteria No 5 Nitrates, Nitrites and N-Nitroso compounds. WHO, Geneva 1978
11. Burden E H W J. 1961 Analyst, 86, No 1024, 429-433
12. Shuval H I and Gruener N. 1972 Am J Public Health 62, 1045-1052
13. Berwick M. 1978 ProgWat Tech. Vol 11, No 12 pp 117-120

ROBERT TRIETSCH

EXPERIENCE WITH SHALLOW WELLS IN TANZANIA

Background

Well before international conferences such as "Habitat" in Canada (1976) and the "Water Conference" in Argentina (1977) set new policies and targets that strongly backed rural water supply programmes, in fact as far back as 1971, the Tanzanian government embarked on an ambitious programme to provide water for everyone by 1991.
Whereas the original target was to
- provide a source of clean and dependable water within reasonable distance of each village by 1981
- provide a piped water supply to the rural areas by 1991 so that all people would have "ease of access" (less than 400 metres) to a public water point, the sheer magnitude of this task in combination with financial limitations forced the government to reassess the programme and to focus attention on attaining the 1991 goal. Furthermore the emphasis shifted from piped supply to shallow wells with hand pumps (ref. 1,2).

Comparison of water supply systems

There were several supply possibilities to choose from, for instance surface water or groundwater supplies, pumped supplies or gravity supplies, etc.
With few exceptions surface water is bacteriologically unsafe, may contain high sediment loads seasonally, and as a matter of standard practice will require more or less complicated treatment, thus resulting in high investment and operating costs.
Next to springs, which are mainly found in hilly or mountainous areas and even then in limited numbers, shallow wells and boreholes constitute the most reliable groundwater sources.
The construction of boreholes, relatively narrow-diameter wells of greater depth (more than 30 to 50 metres), requires machine-powered equipment. Even for the simplest type of drilling equipment, the percussion rig, high initial expenditure and skilled personnel are required, while its operation remains entirely dependent on the availability of fuel and spare parts.
Shallow wells do not have these disadvantages, as their construction requires a minimum of skill and no mechanized equipment. Furthermore, manually operated pumps are generally sufficient for their exploitation.
In boreholes the water table is often so deep that manually operated pumps cannot be used. Unless pumps can be powered by wind energy (requiring a very stable and constant wind pattern and/or huge water storage capacities) or solar energy (as yet requiring high capital outlays, though a solar pump is at present under test at the Morogoro compound) a conventional pump, generally diesel-driven, will have to be used. Although such pumps can be very reliable, their continued use presupposes the availability of skilled pump operators, skilled maintenance technicians and adequate fuel and spare parts.
As a rule not all these requirements will be met, especially in rural areas of developing countries.
A comparison of development and recurrent

Table 1. Cost estimates of alternative water supply systems (in TShs)(ref.1)

	Development cost per person	Operating cost per person
Well without hand pump	65	3
Well with hand pump	100	3
Borehole; diesel pumped; 90 m	276	8
Borehole; diesel pumped; 70 m	254	8
Surface water supply; gravity; short transmission main	162	8
Surface water supply; gravity; long transmission main	320	8
Surface water supply; diesel pumped	365	12
Dam; diesel pumped	504	14

Note: 1 TSh = £ 0.06 = US$ 0.12

Table 2. Cost estimate for rural water supply programme 1979-1991

Type of supply	Percentage of population supplied	Population supplied (millions)	Unit cost per person (TShs)	Total development costs (millions of TShs)
Gravity supply	15%	3.0	900	2700
Surface water (pumped)	23%	4.6	700	3220
Boreholes	12%	2.4	700	1680
Shallow wells	50%	10.0	80	800
total	100%	20.0	-	8400

costs for the various water supply options (table 1) shows the attractiveness of shallow wells from an economic point of view. Experience in Tanzania shows that the actual development costs for shallow wells and boreholes or surface water supplies are even farther apart, with shallow well schemes costing about one-tenth of the alternative options.
Using these updated cost figures and the division of supply expected to be found in Tanzania by the year 1991, table 2 shows the expenditures up to that year.
It is assumed that, due to the population growth and the need to rehabilitate or replace existing water supply systems, a total of 20 million people will have to be provided with water supply facilities within this period.
In order to realize this ambitious programme, annual development funds of approximately TShs 700 million should be available. With the total donor contributions at present amounting to approx. TShs 300 million annually (for the rural water supply sector) it is clear that it will be extremely difficult to attain the goals. It is also clear that shallow wells are by far the most attractive solution, economically, since half the rural population would be supplied with water for less than ten percent of the total costs. The most recent government policy has thus been to encourage the construction of shallow wells wherever feasible. Other water supply options should only be tried when the construction of shallow wells is unfeasible due to water quality, subsoil conditions, etc.

Shallow-well programmes under execution

At present several projects that aim at constructing shallow wells in larger numbers are under way.
Two such projects form part of the Netherlands-Tanzanian bilateral assistance programme: the Shinyanga Shallow Wells Project and the Morogoro Wells Construction Project. The first was executed from end-1974 to mid-1978 and the second was carried out consecutively, employing a large part of the first project's expatriate staff.
In the course of the Shinyanga project a wells construction organization was set up, capable of siting and constructing an average of 20 shallow wells per month, i.e. the production capacity that is required per Region in order to attain the 1991-goals.
Well construction methods were developed in Shinyanga, special equipment was designed, and the local staff was trained to the extent that the project could be continued as a fully Tanzanian operation from July 1978 onward.
The success of this project may be illustrated by the fact that, with a total production of some 750 wells up to July 1978, the Tanzanian staff succeeded in adding another 169 wells within one year, despite the severe constraints imposed by the hostilities between Tanzania and the former Ugandan regime.
In Morogoro a wells construction organization is now operating which again has an output of 20 to 25 wells per month, but with greater emphasis on the training of staff and the supply of equipment. Personnel from other Regions in Tanzania is trained, mainly at Morogoro, but also at Shinyanga, and the Morogoro workshop provides hand-drilling equipment, Kangaroo pumps and miscellaneous items to these Regions upon request.

Finding a suitable well site

The first step in the construction of a shallow well is to find a suitable site. Obviously a geohydrologic survey would give the best results, but the cost and the time available render anything but the quickest and simplest methods impracticable.
Geoelectrical surveys were carried out at the beginning of the Shinyanga project, but the results were of hardly any value and the surveys were discontinued in favour of large-scale test drilling with small-diameter drilling equipment.
Initially, light machine drills (approx. £ 6000 apiece) and trailer-mounted machine-drills (£ 25 000) were used, but the first were abandoned in favour of hand-drilling equipment. The trailer-mounted machine-drills are reserved for the cases where hand-drilling cannot be used.
A typical hand-drilling set consists of Edelmann and riverside bits of 7 and 10 cm diameter, a screw auger, bailer and extension rods and handles, and costs approx. TShs 41 500 (ex-Morogoro), including 15 metres of casing pipe and a test pump.
The final adoption of a well site is based on the results of a simple pumping test with a hand pump. Experience in Shinyanga shows that a test yield of 200 litres per hour is the minimum requirement for a large-diameter well

(1.25 m dia.), whereas for a drilled well of 0.15 m dia. the negligible storage capacity requires a minimum test yield of 500 l/h.

Well construction methods

The traditional way to make a shallow well is to dig it by hand, which is simple, requires very little investment and only unskilled labour.
Programmes that require a large number of wells to be finished within a fixed period impose their own restrictions, however.
When laterite layers are encountered, as is the case in the Shinyanga and Morogoro Regions, the time-consuming method of using hammer and chisel may be technically possible, but still requires so much construction time that it hampers the progress of the entire project. Jackhammers may then be used. Petrol-driven jackhammers produce exhaust gases that are hazardous for the well sinkers, pneumatic jackhammers require huge capital outlays and electrically-driven jackhammers require generators, with the ensuing fuel supply and maintenance problems. The latter type has been used in Shinyanga but eventually the project resorted to the hammer-and-chisel method or percussion drilling.
Especially when the aquifer recharge is large, digging a well to the required depth may be impossible because of the inflowing water. Then two different methods can be followed: either the pit has to be dewatered during construction, or digging is continued as far as possible, after which the well is completed, to be deepened in the dry season, if necessary.
The first option requires the use of pumps during construction.
Suction pumps are simplest, but can be used only for water tables down to 7 m; for deeper wells lift pumps are required. Especially with larger inflows, machine-driven pumps are required, preferably electrical pumps, whereby great attention should be given to avoiding all risk of electrocution of the well diggers.
The problems encountered with the supply of spare parts and of fuel have resulted in a re-assessment of the dug well concept.
In a number of cases dewatering of the pit during construction resulted in washing out the sandy aquifer material from between horizontal clay layers; these subsequently collapsed and sealed off the aquifers. Therefore a method which did not require dewatering of the well was reverted to: hand- or percussion drilling. The Morogoro project uses hand-drilling almost exclusively.

Dug wells

In Shinyanga most wells were hand-dug (fig. 1a; ref. 4), with a lining of unreinforced concrete rings. These rings (1.25m int.dia.; 1 m height) were of no-fines concrete at aquifer level and of plain concrete at other levels. The well rings were manufactured centrally, at a cost of approx. TShs 300 apiece, and trucked to the site. There the well was dug manually as deep as possible without lining. Then rings were lowered into the well, using a simple tripod and winch, and digging continued as a caissoning process. In the initial stages of the project mechanical well digging with a hammer grab was tried out, but failed to give satisfactory results. When the wells had been dug to the required depth and the concrete rings put into their final position, the space between the rings and the undisturbed soil was backfilled with coarse sand or gravel and a concrete or clay seal employed just above the aquifer level, in order to block seepage. On top of this seal the original soil material was backfilled up to the ground level, the well opening itself was covered with a concrete cover-cum-pump-stand and the area around it with a concrete apron, cast in situ.
For wells with deep-lying aquifers the diameter of the concrete rings above groundwater level was sometimes reduced to save on cement and transport (fig. 1b).

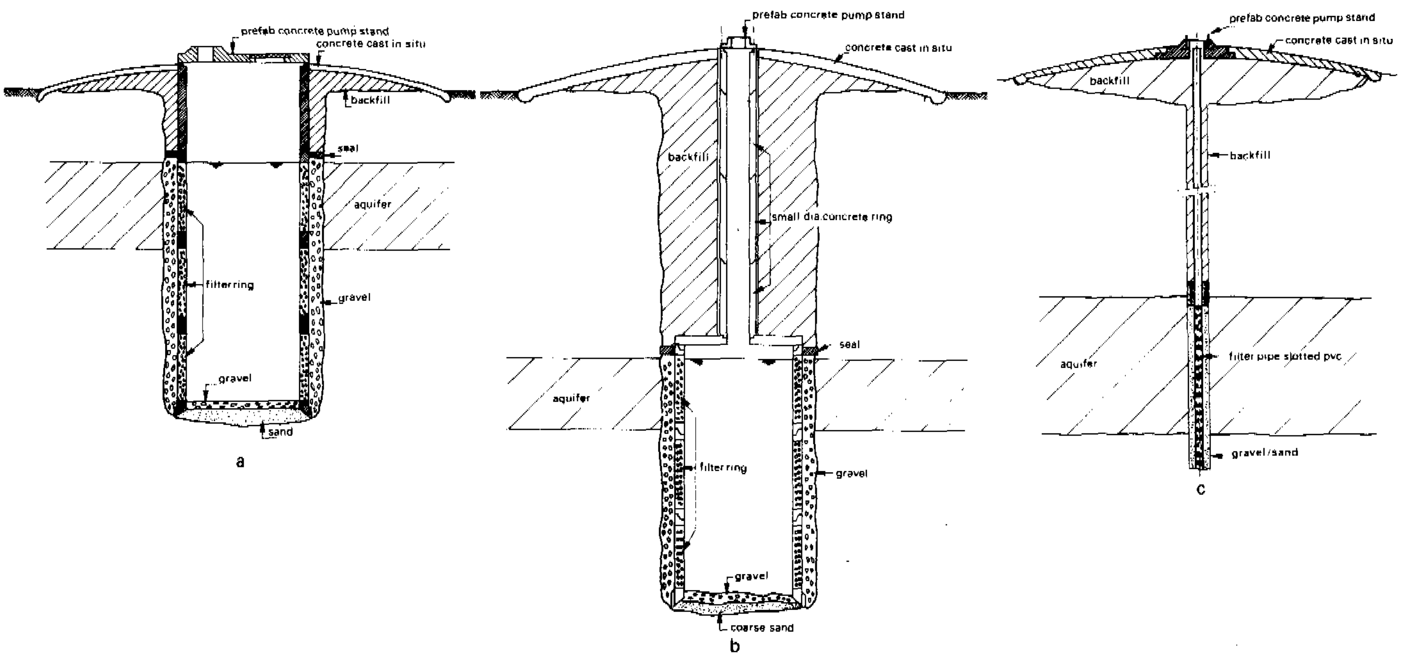


Fig. 1 Shallow well types

Hand-drilled wells

As already mentioned, dewatering the dug wells sometimes caused severe problems and by the end of the Shinyanga project hand-drilling had gained a solid foot-hold.
Because generators and pumps were no longer required, initial expenditure could be brought down and also overall costs per well turned out to be lower than for dug wells. The requirement of higher aquifer transmissivity (yield during test pumping: 500 l/h rather than 200 l/h as for dug wells) was met at the vast majority of the well sites. Thus for the Morogoro project the emphasis has been on hand-drilled wells (fig 1c) from the start.
Hand-drilling equipment consists essentially of a continuous-flight auger with various bits of 30 and 23 cm dia. (the latter to be used inside a casing), a cross piece with four handles for turning the drill, bailers, casing pipe, etc. (fig. 2).
It costs approx. TShs 105 000 per set (ex-Morogoro).
At the beginning of the drilling operation the cross piece with handles, a continuous-flight auger and a bit are connected and hung from a cable that runs through a pulley block in top of a tripod. A crew of 4 to 6 people, most of whom are employed on a semi-self-help basis, screw the drill down for approx. half a metre. The drilling assembly is then lifted, soil is removed from the auger, the assembly is lowered again, and this process continues, with or without a casing, until the required depth has been reached. Depending on the soil type a regular auger bit, conical auger bit, riverside bit or bailer is used. When the hole is at the required depth a slotted pvc pipe is lowered into it, a gravel pack is put around the pipe, and the well is finished in essentially the same way as a dug well. The slotted pvc pipe is imported or manufactured locally from plain pvc pipe (cost ex-Morogoro: TShs 450 per length of 3 m).

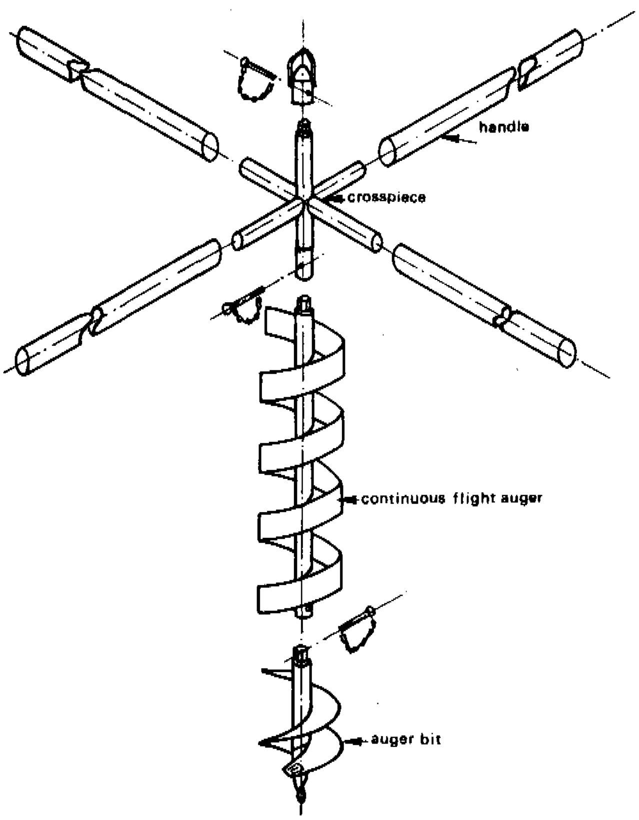


Fig. 2 Heavy hand-drill

Hand pumps

Traditionally, bucket and rope are often used for drawing water in larger-diameter wells. Not only is contamination of the ground water almost certain in these cases, but for smaller-diameter (drilled) wells the use of buckets is impossible.
From the beginning of the Shinyanga Shallow Wells Project it has been intended to use hand pumps on the shallow wells.
For a long time the "Shinyanga" pump was the only type used in this project.
It is a modified version of the "Uganda" or "Unicef" pump used in East Africa and consisted as far as possible of standard pipe fittings, so that construction and maintenance could be easily carried out locally.
The cylinder assembly is completely different from the orignal versions, however, having a pvc or ABS cylinder, a commercially available manchet-type piston and brass piston and foot valves. In the course of time the assembly has undergone repeated modifications, aimed at improving the reliability and -especially - reducing the maintenance requirements of the pump. The same train of thought has led to the replacement of the Shinyanga pump by the Kangaroo pump, at least for the Morogoro project.
A number of considerations, one of these being that centralized maintenance of pumps and wells in an area as sparsely populated as rural Tanzania is extremely costly, have led to a shift in policy. The most important criterion is no longer that pumps should be built up from locally available materials, but that they should require as little maintenance for as long a period as possible. By constructing a pump head that acts in the same way as a pogo stick, the vertical movement of the pump piston is transferred directly to the pump head, without any levers or hinges that require lubrication (fig. 3).
Elimination of the wooden parts of the superstructure, which might be stolen for firewood, adds to the life expectancy of the pump.
At present the costs of the Shinyanga and Kangaroo pump heads are TShs 1500 and TShs 2200 respectively; the cost of a 3" cylinder assembly is TShs 1250.

Maintenance

As mentioned before, in rural Tanzania centralized maintenance of shallow wells would be extremely expensive, possibly costing more than the entire water supply budget. With many piped supplies already out of order due to unavailability of spare parts or fuel, and lack of funds, reduction of the maintenance costs has become of utmost importance, even when implying increased investment costs. In the Shinyanga and Morogoro projects the problem has been approached in two ways: by decreasing the maintenance requirements (e.g. by using Kangaroo pumps) and by decreasing maintenance costs by decentralization of the organization and shifting the first maintenance responsibility to the villages. In this way maintenance costs per head could be reduced to TShs 2 per annum.

Costs

Table 3. Cost of shallow wells

Depreciation of equipment, buildings, vehicles	TShs	5 000
Surveying	TShs	1 500
Materials, tools	TShs	2 000
Hand pump	TShs	4 000
Salaries, labour	TShs	2 000
Transport	TShs	4 000
Overhead	TShs	1 500
Total (hand-drilled well)	TShs	20 000
Total (hand-dug well)	TShs	25 000
Total (machine-drilled well)	TShs	30 000

Thus overall costs per well range from TShs 80 per head (hand-drilled) to TShs 1200 per head (machine-drilled), with hand-dug wells between the two.

Training

With a total of 20 million people to be supplied with water before 1991, at least half of whom may obtain water from shallow wells, the total number of shallow wells to be constructed is between 40 000 and 60 000, or: approximately 250 wells per year for each of Tanzania's 20 Regions. In order to realise this objective, personnel from other Regions is trained at Morogoro. The equipment required, and with which the personnel has been trained to work, can also be obtained at the Morogoro workshop.

Generally speaking the training takes about 2 to 3 months. An average of one well siting/construction crew of 3 people per District (average of 4 Districts per Region) is sufficient to realise the annual target of some 250 wells per Region.

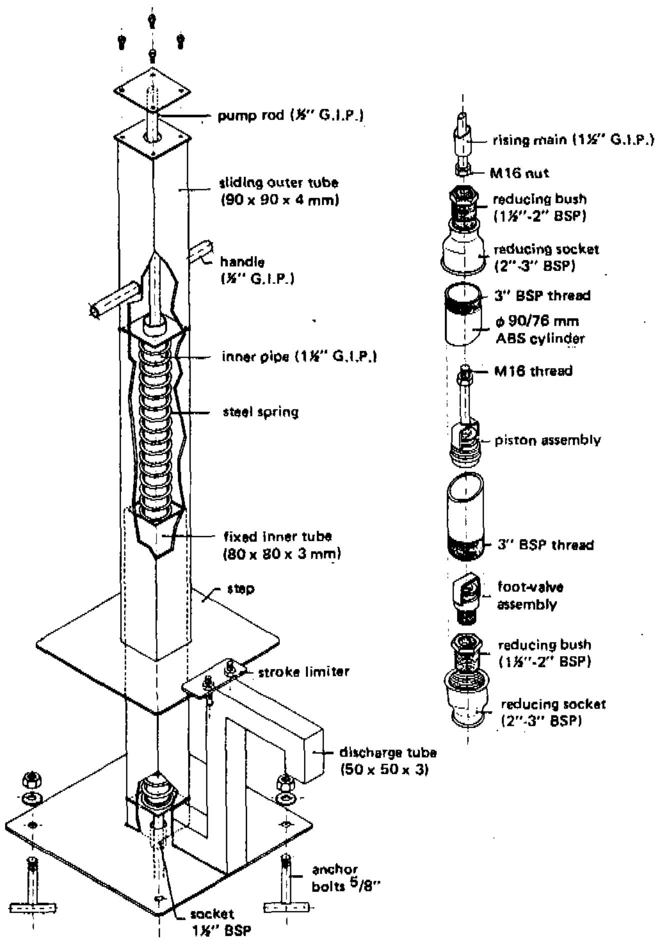


Fig. 3 Kangaroo pump

Acknowledgement

The author wishes to thank the International Technical Assistance Department of the Netherlands Ministry of Foreign Affairs for enabling him to present this paper. The invaluable contribution of the project personnel in Tanzania should also be acknowledged. Without this contribution, whether is was from the Tanzanian staff, the consultant staff or members of the Organization of Netherlands Volunteers, the project would never have been so successful.

REFERENCES

1. DWORKIN Daniel, et al. Tanzania: rural water supplies. A review of current activities and guidelines for possible AID-sponsored projects. July 20, 1979
2. ANONYMOUS. Tanzania rural water supply development programme 1979-1991. A feasibility study. Tanzania, 1979.
3. KASHORO Y.N. Taarifa ya utekelezaji wa visima vidogo mwaka 1978-79. Shinyanga Shallow Wells, P.O. Box 147, Shinyanga, Tanzania. August 1979.
4. DHV CONSULTING ENGINEERS. Shallow Wells, 2nd edition. December 1979.

Dr B ALMA'SSY

GREATER KANO WATER SUPPLY

Kano, the largest city in Northern Nigeria, has enjoyed a dominant position as a commercial centre throughout the centuries. This important role was strengthened further with the creation of the States and with the improved road links to other parts of the Federation. The infrastructural development in the last twelve years has had a great impact on the industrial growth. However, although beneficial it has been, it has had its undesirable effects as well. The population growth rate seems to be far above the average and is further increased by migration from the rural areas to Kano, which is the only real urban and industrial centre in the State. Beside the actual spatial expansion of the town, the population density has also greatly increased in certain parts of Kano township and a seasonal fluctuation of the population can also be observed.

The first waterworks in Kano was built between 1928-31, with a capacity of 2 MGD (o.1 m^3/sec). This plant generally known as the "Old Waterworks", was later extended to a maximum capacity of 4 MGD (o.2 m^3/sec), and is still kept in servicable condition.

The first phase of the new waterworks was completed in 1968, with a design capacity of 5 MGD (o.25 m^3/sec); its extension to the present capacity of 2o MGD (1 m^3/sec) followed the commissioning of the first phase almost immediately and was put into operation in 1974.

This far-sighted planning secured an exceptional position for Kano, where no major water shortage has occured in the last 12-15 years. From the early 197o's up to the present, the reserve capacity and almost uninterrupted supply, together with

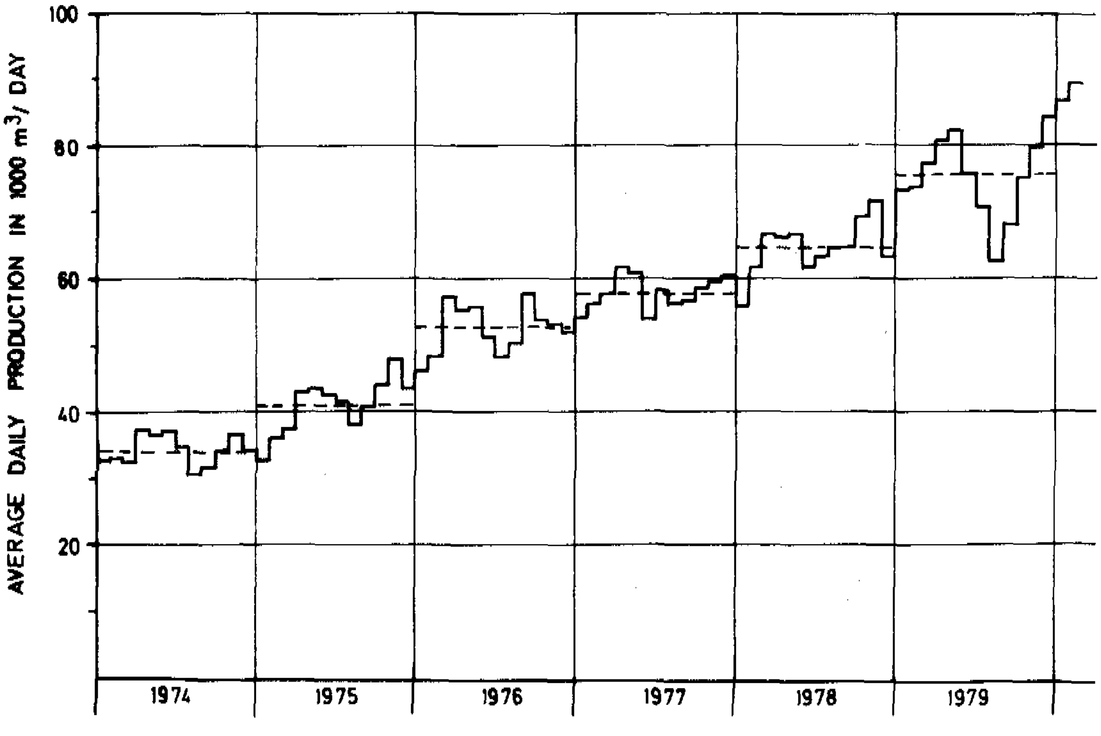


Fig. 1. Average daily production between 1974-1979

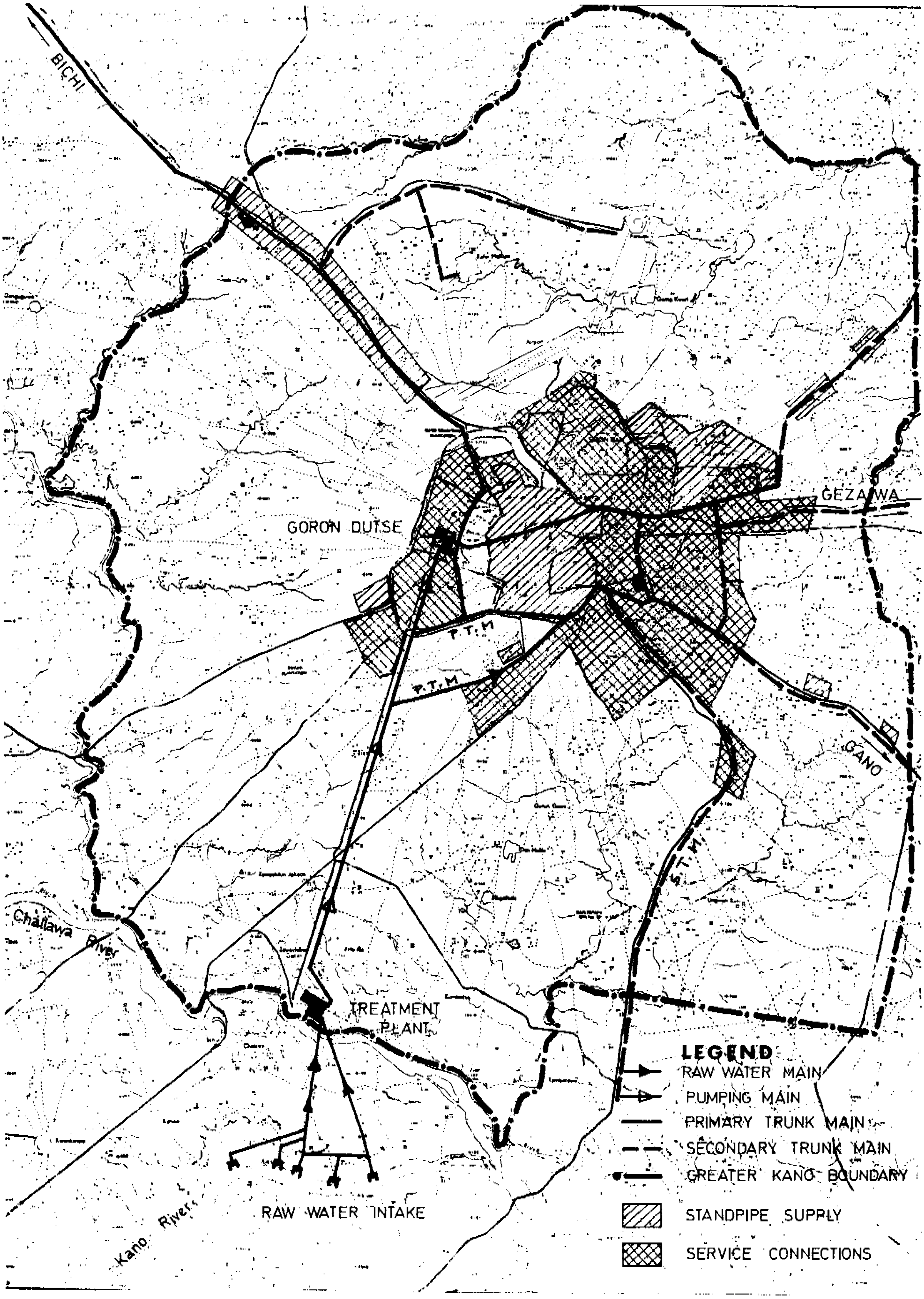


Fig. 2. General layout of the present water supply scheme of Kano. (Scale approximately 1:125ooo)

the other infrastructural development, attracted a rapid influx of industry.

With the production of water secured, in the late seventies more weight was given to the extension of the distribution network, the total length of which exceeds now 1ooo km and half of this was laid between 1975 and 198o. The diagram on Fig.1. shows the average daily production in the last six years.

Fig. 2. shows the simplified layout of the water supply system in Kano, indicating also the level of services in the areas supplied. The quality of the water has been maintained to the requirements of International Standards.

The raw water supply to the Old Waterworks was based originally on the Challawa river, while the intake of the new waterworks was situated on the River Kano. In the early stages the intake consisted of wells and tube-wells sunk into the alluvial river deposits. The specific yield of the intake was limited in the Challawa river, due to the fine, silty deposits. The much coarser sand in the Kano river ensured better specific yields. Extensive investigations and studies were carried out in the mid 196o's which proved that the seasonal recharge of the Kano river sand would not provide sufficient source for the new waterworks extension. The recognition of this led to the construction of the first major impounding reservoir, the Bagauda dam, built on a tributary of the Kano river. The carefully monitored release of water from this reservoir, providing a perennial flow between the outlet works and the waterworks'intake, ensured the necessary recharge of the river-bed deposits, with an approximate 15% loss along the river stretch. The same reservoir served as the source of water for the Kadawa Pilot Irrigation Scheme. In the future a small regional scheme can be based on this source.

With the construction of the Tiga Dam, impounded in 1974, the Kano-Hadejia-Yobe rivers have been transformed into a perennial river system which provides a virtually unlimited raw source for the Kano water supply system.

This solid base for the improvement and extension of the water supply services in Kano and the fact that the production has almost approached the design capacity of the plant made it imperative to find quick and economic solution for future expansion. The work was begun with the study of population and demand growth. This included the survey and study of

a/ present population densities in the various areas and districts;

b/ population growth in the specified areas;

c/ the spatial development of the town (planned and forecast - controlled and uncontrolled);

d/ extension of the distribution network to areas still without services;

e/ present and future levels of supply.

The discussion here is focused an Greater Kano, but planners and designers obviously face the same or similar problems elsewhere.

The national census undertaken in 1963 revealed a population of 467,5oo in the total Kano metropolitan area and 294,45o in the actual urban area. Present population estimates can be based either on the hypothetical figures of national growth factors, (2.5 percent as an average and 8 to 9 percent in the high density urban areas). Another approach is to carry out a physical population survey on selected sampling areas.

Such a survey was carried out within the scope of the Kano sewerage and drainage project by the Consultants G. HOLFELDER LTD., sponsored by the UNDP and the Kano State Government.

14 sample areas were selected where the population densities and sanitary conditions were recorded. The data, used together with the plans showing the present and projected (planned) future land use were compared with previous studies (Trevallian report, 1963; Chr. Becker, 1967; Traffic Analysis, 1973) and the actual population increases within given areas were evaluated. These results already include the migration factor.

The figures thus obtained show a population of 892,ooo for the total metropolitan area and 643,ooo for the urban area, and an average growth factor of approximately 5%.

Based on the Urban Development Plan, the most probable population density figures and the future land use maps, combined with the desirable level of services were used to prepare the water demand growth curve (Fig. 3.). The demand curve based on the UNDP report has been slightly modified taking two more factors into account:

a/ The rapidly growing, partially uncontrolled, ribbon type development along an approximately N-S axis, while the controlled development shows a more definite trend along an E-W axis;

b/ The water demands in other major settlements outside the metropolitan area but supplied from the Greater Kano Water Supply scheme. These settlements were not part of the sewerage and Drainage Project's study.

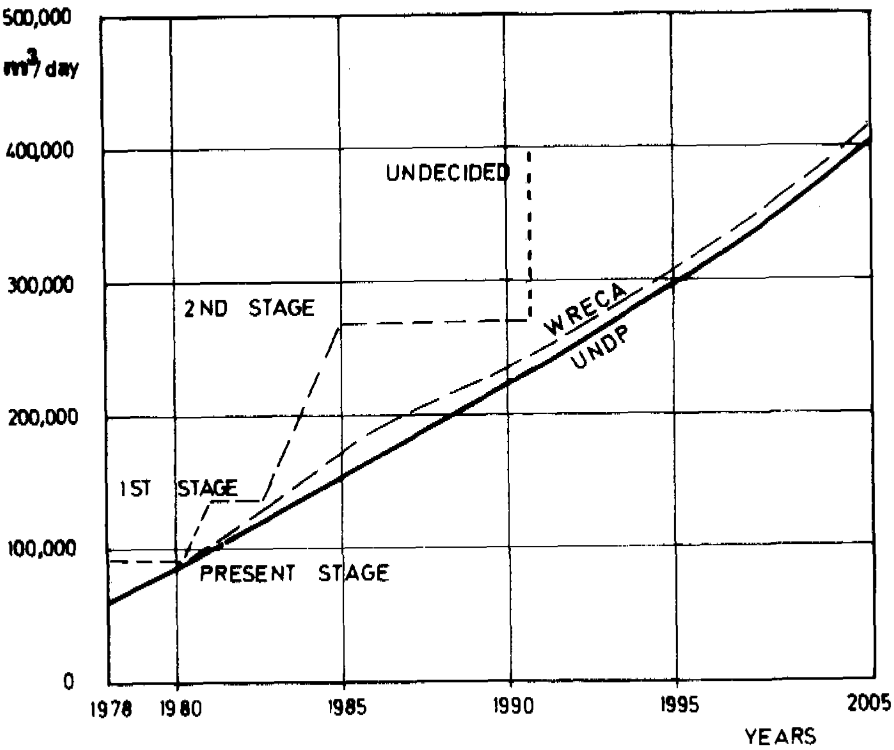


Fig. 3. Estimated water demand growth (net).

The per capita consumption in low density housing areas was suspected to be too high. Measurements were carried out in a sample area and it was found that consumption went beyond the 1ooo l/capita/day figure. This is obviously unacceptable both at present and for future planning and specific measures will have to be taken to improve the metering, tariff-system and revenue collection in order to reduce the exorbitant consumption rates.

The present design capacity of the treatment plant, according to our analysis, can be uprated with minor modifications, almost to 3o MGD (1.5 m^3/sec) which is also the upper limit of the available pumping plant and transmission mains (including the new 1ooo mm diameter main presently under construction).

The treatment plant is a traditional Paterson-Candy design, consisting of 24 No. hopper-bottom type vertical flow sedimentation tanks (clarifiers), 16 No. rapid gravity filters, 1 million gallon (45oo m) capacity clear water storage and adjoining pumping plant. The first stage of uprating will include the introduction of flocculant aids and the more proper admixing of chemicals (aluminium-sulphate and lime) to the raw water.

In the second uprating stage we intend to improve the flocculation process simultaneously with the clarification. To this end, one of the settling tanks will be modified and used as a 1:1 scale model.

Laboratory test results show that the use of coagulant aid (nonionic polymer) will greatly improve the settling properties of the floc, but adequate slow mixing and detention time is needed to improve the flocculation process. This is, naturally, in accordance with the findings and results of extensive research work and worldwide experience in this field.

The simple sludge blanket upflow clarifiers, though widely accepted and incorporated in a number of new treatment plants in Nigeria and elsewhere, are nonetheless considered in many quarters to be oldfashioned. Their advantage is that they are not too sensitive to fluctuations in flow (below their design capacity) and raw water quality. Thus, their operation is simple and does not require highly qualified staff.

With this statement we arrive at a very interesting and important question: what degree of sophistication is advisable and acceptable in the developing countries and specifically in Nigeria? Conditions may vary from place to place, but in author's opinion, the young generation of Nigerian engineers provides now a good and rapidly improving base to allow the application of new and more sensitive technologies. On the other hand, high degree of automation of plants for automation sake must be viewed circumspectly. It is not the more complicated or sensitive process, but the more complicated equipment that should be regarded with caution. The inflow of spare-parts and expertise needed for this equipment may cause more problems than a treatment technology more sensitive to fluctuating factors, but less dependent on automated processes would do.

The aim of this conference is not just to discuss treatment technologies in detail. However, it is well known that in the last one and a half decades a rapid development has taken place in the clarification process technology. Two basic concepts seem to compete: the ballasted flocs settling basins and the lamellar settling basins. Without discussing the advantages of these methods in this forum, I should like to call attention to the possibility of the wider application of the lamellar settlers - both in new plants and in the uprating of existing treatment works.

In the not very distant past, the meagre operational records and the difficulty of obtaining physical and chemical analyses did not provide sufficient base for the designer to choose the more efficient technology; the lack of local experience and the almost sole use of foreign designer consultants equally contributed to the "safe design" principle - resulting in indisputably well functioning, but very costly plants, as the investment cost to capacity ratio and construction time are concerned.

This is exactly the situation in the Kano waterworks. The rapidly growing demand must be met; the available time and funds are limited; the present treatment plant is of a rather conservative design.

Experience has shown that many plants can be uprated by the use of more advanced engineering technology. With carefully designed modifications, plant output can be increased manifold at minimum cost and with minimum disruption of the continuous operation.

In order to increase capacity the plant first must be hydraulically capable of handling a greater throughput. The relevant study, carried out by UMARU ABDULAZIZ, has shown that the conveyance capacity of the raw- and settled-water channels must be increased; the necessary modification is at present in the design stage, but - as anticipated - this creates actually more difficulties than the alterations in the treatment process itself.

The uprating of the rapid gravity filters is likewise possible, though it also means some changes in the piping system. Filter backwash at the present rate of flow takes place in 18-24 hours, based on the increased headloss in the filter media. Deterioration of the filtrate quality has not occured so far. The conservative filtration rate can easily be increased even threefold, especially if the planned improvement of the settling-clarification process ensures that there would not be high floc "carryover" to the filters.

Extension of the treated water balancing tanks and new pumping plant cannot be avoided, but a gradual increase of the treatment capacity will be of great help to meet the growing demands within the limited time and funds available.

Last, but not least, the extension and reconstruction of the trunk-main and distribution systems including the storage capacity should be mentioned.

Fig. 4. shows the average daily fluctuation in the consumption. This curve was arrived at using actual flow measurements data at the treatment plant, below Goron-Dutse reservoir and at the only direct cross-connection from the high pressure pumping main to the system, supplemented with the water level fluctuation data in the storage tanks.

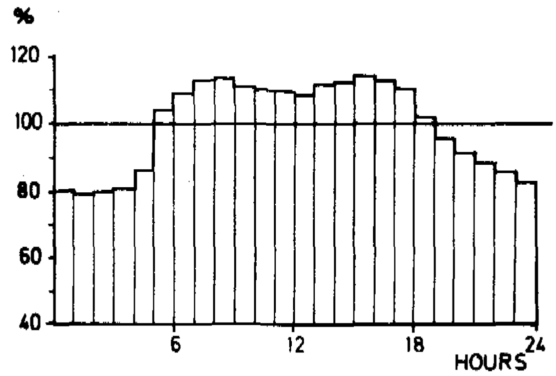


Fig. 4. Average daily fluctuation of consumption

This curve shows a remarkable character: the level of consumption was shown to be far more even than anticipated. Consequently, less than 40% of the storage capacity has been utilized, except on a few occasions when pumping was interrupted due to the failure of power supply. The pump operators can follow the demand fluctuations very closely, based on the telemetric recordings of prevailing water levels in the storage tanks.

The total storage capacity in the distribution system is 10 MG (45000 m³); i.e. cca. 50% of the daily total production. This capacity at present can be regarded as more than sufficient, but the question is, what should be the total daily consumption/ storage ratio in the future.

The topographycal situation does not allow the further extension of the high level Goron-Dutse tank. The previous planning made allowance for a large low level tank at the bottom of Goron-Dutse and another pumping station to lift the total amount of water to the hilltop tanks, from where the whole system was supposed to be gravity fed. Detailed network study was completed for this concept, demanding very large diameter ring and radial maine in the network, in order to maintain the required pressure in the entire system.

Another study is under way now, in which the reliability of the power supply versus total storage is going to be looked into, as the basic question. With the present and future pumping stations at the waterworks, the demand fluctuation can be closely followed. The more reliable the power supply from the national grid, the less total storage and standby capacity is required. The previous concept would require two standby stations - at the waterwork and at Goron-Dutse. Changing the philosophy of the supply, /1/ pumping directly into the system at 2 or more points, /2/ using the existing storage facilities entirely as balancing tank, /3/ one standby generating station at the waterwork and /4/ the possible reduction of the ringmains diameter seem to result in less capital costs, even with the construction of more elevated water tanks at strategic points in the distribution system.

The surprisingly even consumption pattern in 24 hours may be contributed to two causes (high losses [waste] in the distribution network and a large total capacity of storage facilities in the industrial and domestic consumer sector). The provision of extra storage in the industrial sector should be further encouraged, thus reducing the requirement of storage in system, the usual domestic tanks on the other hand, can always be a source of pollution at the consumers' taps and should be avoided as much as possible from the public health point of view.

The greater Kano water supply system will ultimately cover an area of 3o km radius and additional other towns and villages even beyond this distance. It should be regarded as a sizeable regional water supply scheme, providing water to a large suburban and rural area as well. In a long-term programme this system can be connected to neighbouring water schemes based on other sources, like the new dam-reservoirs along the GWARZO Rd, the WATARI Dam near Bagwai and Bichi and a wholly integrated system can be developed. However, individual, smaller water supply schemes can be built in the north-eastern part of Kano State, based on the aquifers of the Lake Chad formation.

6th WEDC Conference: March 1980: Water and Waste Engineering in Africa

A M SABARI

OPERATION AND MAINTENANCE OF SEMI-URBAN WATER SUPPLY STATIONS IN KANO STATE

In Kano State the term Semi Urban water supply station means all water supply systems, except Kano City where machinery is used to lift water to the consumer.

The scope of this paper is limited to the experience in the Chad Basin, where water is supplied from a system of boreholes rather than the basement complex, where the water mostly comes from impounded sources. (See Map 1.)

The paper is not meant to be the solution to water problems in similar areas but simply serves to illustrate a method of approach to analysis and solution of the problem. By detailed observation and rational planning.

At present there are over sixty water supply stations successfully operating - reliably, which when referred to water supply stems nothing less than 100% availability is envisaged.

The following is a brief summary of how the system developed.

Before 1970 the number of boreholes were limited and the pumps used were diesel driven. This requires an engine and an operator at each borehole, also the cost of standby capacity, essential for reliability was enormous.

To minimise operational, maintenance and standby capacity costs in 1970 it was decided to go over to electric submersible pumps and generating sets. This enables two or more pumps to be run by one engine and operator. Hence every water supply system was run from one central station cutting down running cost and also standby generating set.

But however at this stage the importance of certain factors e.g. cooling air circulation for generating sets, standardisation of equipment to minimise stock of spares and inclusion of measuring and matering equipment to facilitate trouble shooting were not fully realised.

So in 1974 a comprehensive survey was carried out, by the then Chief Water Engineer Mr. C.J. Cox, to determine the causes of water shortages in places where there are water supply systems.

The following guidelines were adopted for the survey :

1. Ease and speed of erection and expansion.
2. Ease of maintenance.
3. Minimising stock of spares and running costs.
4. Full utilisation of equipment and personnel.

The survey carried out established the following reasons as the main causes of water shortages.

1. Lack of boreholes.
2. Silting of existing boreholes.
3. Inadequate distribution system.
4. Inadequate storage leading to partial shortages during peak periods.
5. Frequent breakdown of generating sets.
6. Frequent breakdown of pumps.
7. Inaccessibility of stations due to lack of motorable roads and vehicles.

Causes 1 &2 can only be cured by drilling more boreholes using correct sizes of screen and selecting correct size of pump for each borehole. Or alternatively, if geologically feasible, obtain water from dams and rivers, which entails extra treatment and pumping long distances.

Causes 3 and 4 can only be cured by proper design of distribution networks having correct size of pipes and adequate storage capacity of cover the peaks.

It should be appreciated that these first four problems are comparatively easier to cure but can take a long time and cost a large amount of money.

Cause 5 on further analysis was found to be mainly due to :

a. Overheating of sets due to inadequate ventilation of generator houses.

b. Inadequate and badly executed repairs and overhauls.

c. Inadequate maintenance.

d. Lack of trained personnel.

The classic vicious circle situation has been reached. The generators were breaking down due to inadequate maintenance, because the staff who should be doing the maintenance were fully occupied in carrying out repairs.

Cause 6 was found to be due to the following :

a. Voltage at the pumps was found to be below the acceptable minimum.

b. Sand in the boreholes.

c. Unnoticed single phasing of the motors.

d. Prolonged running in the wrong direction.

As discussed Causes 5 - 7 are the most crucial as they have to be checked from day to day.

On the basis of this survey and analysis of each factor (Mr. Cox recommended) the following solution which was adopted.

1. ORGANISATION

The whole set up to be divided into three separate sections namely

a. Reinforcement of the drilling section who will drill boreholes and occasionally clean them out.

b. Reinforcement of the Semi Urban Water Supply section who will design and construct the riser main, distribution network and storage tanks. They will also run the pumps and generators but do no maintenance on them apart from checking engine oil.

c. Establishment of the Challawa Workshop Section, who will do all the electro-mechanical installation and maintenance and should have a base workshop.

2. EQUIPMENT

The following steps were taken to facilitate ease of erection and maintenance, minimise running costs and stock of spares and make possible trouble shooting.

a. All machinery and equipment were standardised e.g. direction of rotation of generators, phase sequence, switchgear and starters of pumps, riser main, borehole head work etc.

This allows for the exchange of any unit with a new or reconditioned part from the base workshop.

b. A generator house was designed which provides adequate ventilation. This generator house takes any two of the standard generating sets in use i.e. Lister HR 2, 3, 4 and 6 with only minor changes in the exhaust assembly.

An 800 gallon fuel tank was incorporated outside the generator house and in areas of limited accessability two or more.

A separate fuel pipe runs from the tank to the engine fuel filter eliminating the use of drums, dirty cans, etc. likely to introduce dirt in the engine fuel system.

Fuel meter and water separator were also included.

c. Inclusion of measuring and metering equipment.

3. PERSONNEL TRAINING

Instructors from the manufacturers were brought in to train the staff which proved cheaper than sending the staff abroad.

4. SCHEDULE OF MAINTENANCE FOR EFFECTIVE REPAIR AND MAINTENANCE

1. A group of travelling gangs in Land Rovers were formed and they visit every station fortnightly to carry out routine maintenance, i.e. roughly to change oil and filter also adjust tappets.

2. Monthly a gang of electricians to visit every station, roughly they blow out the generators and check for loose contacts.

3. If anything more is required the whole set is changed and the old one returned to the base workshop where the repairs will be carried out with proper tools and under good supervision and then tested and load.

This unit exchange system enables a small number of fully trained staff to oversee repair and overhaul of the equipments.

5. FUTURE DEVELOPMENT

To make possible continued rational planning a monitoring system in the form of weekly reports was introduced (Fig. 2)

In this are recorded quantity of water supplied by each pump, quantity of diesel used, power generated by each set and number of hours run by each equipment.

From these data the efficiency, rate of growth of demand and deterioration of equipment are determined.

Session 5: WATER SUPPLY AND GROUNDWATER

Discussion

M S Abid

Kaduna Water Supply Extensions - Barnawa Dam Project

Mr ABID gave an illustrated talk on the scheme to build an earth dam on the tributary of the Kaduna river downstream of the existing North waterworks, so that development of the existing facilities would not be hindered in the future. By 1990-1995 it was expected that the new works planned on the reservoir would be producing 150 million l/d.

2. Summing up, Mr ABID made the point that when designing schemes for developing countries designers should give consideration not only to economics, but also to maximising the use of local resources and improving the surrounding area.

Dr E A Anyahuru

Pipe Borne Water Supply in a Traditional Society - Nigerian Condition

3. Dr ANYAHURU said that the methods used to solve water supply problems differed from place to place as the density of population differed. Piped water supplies became the most rational solution in most places, although they were expensive to build. In Nigeria, central Government had nothing to do with water supply. It was considered to be the responsibility of the State Governments, and this had prevented many well-designed projects from going ahead through lack of funds, even in urban areas. The answer to this was that self-help projects were being encouraged.

4. Dr T O EGUNJOBI pointed out that the cost of a rural water supply project, as shown in the figures given , might be too high for a community. The analysis should have included the cost of operation to give a true picture. The wrong impression was given, that once a water supply project had been completed, provision of water to the people was guaranteed which was indeed not true. Maintenance was very important, and many of the problems relating to water supply were due to inadequate maintenance.

5. Dr ANYAHURU agreed with this. Maintenance costs should have been included. But they were left out in order to emphasise that the initial costs were high, and the poplulation could not go ahead with the project without Government aid. The Government had now agreed on a flat rate, and this should be enough to cover maintenance costs.

T Husain, M Ukayli and M Sadiq

Cost Comparison in Water Supply Alternatives in Saudi Arabia

6. Dr M UKAYLI described how studies and research on the evaluation of the existing water resources and forecasting the future demands is being carried out in order to make better use of them. He discussed conventional and unconventional water sources. When asked if icebergs were a feasible source of water he said that if it were feasible to send a man to the moon, then certainly it was feasible to tow an iceberg from Antarctica to Saudi Arabia, California or Australia. An illustrated description was given of the four alternative sources in Saudi Arabia.

7. Desalination was now the most practical, and cheap electricity could be produced from the steam or hot water used in the process. By 1983 a total capacity of 577.3 million gal/d would be produced by desalination, and this would be combined with 5745 megawatts of electricity, more than would be required.

L G Hutton and W J Lewis

Nitrate Pollution of Groundwater in Botswana

8. Mr HUTTON said that the results of the study showed that 10% of water supply boreholes were polluted by nitrates. When this was reported to the Government it produced rapid action, and money was made available to extend an existing project to look at groundwater pollution from nitrates. Tests were made on the passage of polluted water from pit latrines to boreholes. Some bacteriological tests were done, but these were limited due to lack of money. These tests were usually too expensive for use in most developing countries. However it was possible to use the presence of nitrates to indicate past or present bacterial pollution, and nitrates were easy to test for. The study required close co-operation from everyone

involved, from geologists and water engineers to the owner of the pit latrine, and this co-operation was given willingly.

9. Dr E P LOEHNERT asked how borehole 1018 at Mochudi village was constructed, ie did it have a casing or screen? Also the low transmissivity figure in the paper seems to contradict the fast travel time of the pollutants. In this context did water quality change along with nitrates, ie did hardness and chloride content increase?.

10. Mr HUTTON said that there was a correlation between hardness and nitrates as in other parts of Botswana. This was related to reactions within the soil zone there. Chemical tests were made which would be published in the Proceedings of the Institution of Civil Engineers. The well had a casing which protruded over the top of the concrete base, so that the conditions were almost sanitary. There was only the slightest leakage down the casing.

11. Dr K Y BALIGA said that dry pit latrines could only transmit ions and bacteria when the water level was high in the ground. The appearance of lithium chloride in the borehole seemed to suggest the lack of proper protection in the borehole. Further appearance of ions did not necessarily indicate that bacteria or organic material was also moving. Nitrates could also come from fertilisers.

12. Mr HUTTON repeated that the borehole was well protected. There was very little fertiliser used in Botswana, so this could be discounted as a source of nitrates. It was possible to use nitrogen isotopes to check whether the nitrates were of human faecal origin or fertiliser origin, but as no fertiliser was used in the area, it could be assumed that the nitrates were of human and cattle origin. Cattle produced high nitrogenous waste, and some watering boreholes for cattle had been found to be polluted.

13. Some bacteria might be killed off, held back or absorbed by the soil, but the soil was very poor in this area. For a 15m radius around the pit, the soil was found to be saturated with nitrates and chloride, at up to 200 ppm per 100g soil material. So this must be human pollution. Faecal coliforms were found in the borehole water samples, but it was not possible to say definately that they came from the pit latrine. However it probably did. Faecal coliforms could not be dated, ie it could not be said that faeces deposited yesterday in the pit were reappearing in the borehole later, but they were in the pits and the boreholes.

14. Dr K O IWUGO said that he believed nitrates were usually considered to be major anions in ion balancing for water analysis. He also asked for information on the levels of nitrates observed in Botswana water supplies, and whether there was any indication of an increase in concentration over time.

Mr HUTTON answered that nitrates could only be used in ion balancing if good facilities were available in the form of analytical methods or chemicals. He said that there was not yet enough information on nitrate levels, and seasonal variations occurred which could mask on-going results. In Botswana the studies were continuing.

15. Dr IWUGO then asked what analytical methods were used for estimating nitrate levels in groundwater supplies, commenting that perhaps future work should search for more accurate methods. Mr HUTTON replied that the method used in the laboratory, based on the yellow colour produced by Salycyclic acid, was described in Reference 1 mentioned in the paper. Also, NO_3 specific ion electrode was tried, but there was difficulty with failure of the membrane. The tests advocated for field officers should be used for screening samples, and would not be suitable for laboratory use. All AWWA standard methods were tentative. The method used for this investigation was one used extensively in France and Germany and was known to be relatively accurate.

R Trietsch

Experience with Shallow Wells in Tanzania

16 Mr TRIETSCH said that the great problem with boreholes was the cost of construction. Shallow wells were much cheaper, so that the tendency was to use these in order to try to reach the 1990 target. Using slides of hand dug and drilled wells, he went on to describe the advantages and disadvantages of each type as outlined in the paper.

17. Problems had been encountered with pumps. Originally, Uganda type pumps were used, but it was found that the wooden handles were stolen and used as fuel for cooking. Also, this type of pump needs costly maintenance, so now the Kangaroo pump was used.

18. Mr BANNERMAN said that the Tanzanian experience confirmed that the best way of developing a hand pump for a particular programme was first to purchase any good type or make of pump "off-the-shelf", to give it thorough field trials and then to modify and redesign it based on the field experience. He asked how deep the shallow wells were and how the annual changes in groundwater level were overcome. Also were the shallow wells meant to be permanent supplies?

19. Mr TRIETSCH answered that they were to be permanent supplies until the country could afford better. The policy was to give easy access to clean water in both urban and rural areas, so for the time being, no other system was possible. Piped supplies tended to break down, and spare parts were not available. The shallow wells were 4-7m deep. At the start of the project the wells were dug in the easier places where the ground water was high. As

the project progressed, more difficult areas were opened up, and the depth had to be increased to 7-10m, and up to 15-20m in some places. Ideally, all wells would be dug in the dry season, to be sure of the right depth, but this was not possible in practice. If possible drilling was continued right through the aquifer, and in some cases caisson rings were used.

20. Mr M S ALHASSAN wanted to know how the crew got down into the hole when digging a well by hand. Mr TRIETSCH answered that the workers used to descend by rope ladder, but now most wells were drilled rather than hand dug.

21. Mr R I OZOEKWE commented that in the paper the emphasis was on the cost and the percentage of the population served. In Table 1, the lowest overall cost was wells in general. As the problems of hand dug wells could largely be overcome, by using blasting to get through hard layers and suction pumps to keep the water table down, should the programme not be restricted to hand dug wells from an economic point of view?

22. Mr TRIETSCH did not agree with this. He said that the switch was made to drilled wells because of the large numbers of wells needed to serve the population. Blasting was impractical, since it required trained people to do it. Suction pumps worked down to a depth of 7m. Further down large yield handpumps, compressor pumps or electric pumps were needed and these were not practical from either the cost or safety angles. So the problems were not easily overcome, and drilling was more practical.

23. Mr G H READ enquired whether there was any information available on silting up of the porous concrete rings. He also suggested that to extend a programme where additional funding was needed, the money should be borrowed so that the beneficiary paid for the well. The cost per household over a long period of time would be low.

24. Mr TRIETSCH said that affordability was a matter of Government policy. The Government of Tanzania required the rural water supply to be free, and only people with private connections should pay. So he could do nothing except recommend that charges be made. No experience was known of silting up of the rings, but so far there had been no problems.

25. Professor B Z DIAMANT asked whether in view of the urgency of the need to supply water to all by 1990, should Mr Trietsch consider constructing wells without handpumps with adequate precautions to protect the water quality. Mr TRIETSCH strongly disagreed. The wells must be properly covered and buckets should not be used.

Dr B Alma'ssy

Greater Kano Water Supply

26. Dr ALMA'SSY gave an account of the development of Kano over the last twelve years as a dominant commercial centre, with subsequent growth in industry and population, so there was a need for a larger waterworks. The original waterworks had been kept in working order as a standby, The new waterworks was commissioned in 1968 and its capacity was increased from 5 to 20 million gallons per day.

27. Now, with a new generation of young Nigerian engineers there was no longer a need always to turn to foreign consultants. This sort of work could now all be done locally, providing more valuable experience for the young engineers, and so improving standards for the future.

A M Sabari

Operation and Maintenance of Semi Urban Water Supply Stations

28. Mr SABARI explained that in 1974 there was a comprehensive survey to assess the feasibility of using machinery for these water supply stations. If the people had to rely on handpumps, the time taken to actually get the water became very great, so it would be better if machinery were used. He outlined the guidelines, problems etc encountered in the survey and the recommendations which had since been adopted, to provide an easily built and maintained system of water supply.

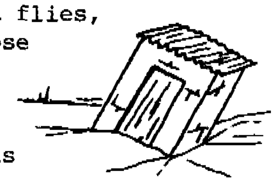
6th WEDC Conference: March 1980: Water and waste engineering in Africa

MORAG BELL and JOHN PICKFORD

PEOPLE AND PIT LATRINES IN AFRICA

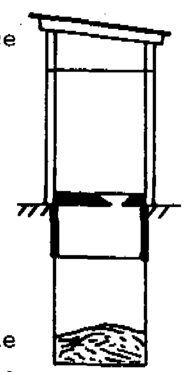
In the design and location of pit latrines people are far more important than concrete and steel bars. A latrine is built once, but if each user visits the latrine twice a day, a good pit may be used a hundred thousand times during its life!

Like people, pit latrines in Africa are found in a great variety of shapes and sizes. They may be good, bad, or indifferent. The simplest, possibly the most common, and certainly the least satisfactory form of pit latrine consists of a hole in the ground about a metre across and two or three metres deep. A couple of logs or rough planks are placed across the top. The users put their feet on the timbers and defaecate through the gap between them. Such simple latrines are dangerous for children and old people, especially at night. They attract flies, emit odours, and often collapse during the rainy season. The timber becomes fouled with excreta and is difficult to keep clean, so worm infections are passed to bare-foot users. The timber is also subject to attack by termites and fungi, and collapse of the floor is not uncommon.



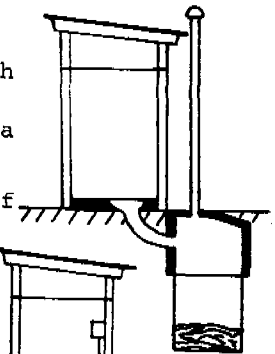
When the pit becomes full another pit is dug. It may take three or four years for an average family to fill an average pit, but in some areas pits fill or overflow every rainy season.

The best simple pit latrines have deep pits in firm but porous soil. A lining near the top prevents collapse of the sides and supports a concrete cover slab with a smooth easily-cleaned surface. The floor is raised above the surrounding ground so that surface water by-passes the latrine. Some pits in East Africa are over ten metres deep. Others are large in plan. The life of such pits may be very long. Owners say they 'never fill up'. In fact there is gradual accumulation of non-biogradable matter, but pits still in use after twenty years are often found.

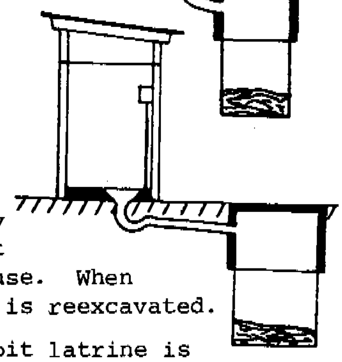


Usually the floor slab and the latrine building are immediately over the pit, but various types of *offset* pit are in use. The pit may be completely outside the latrine building, or partly outside and partly inside.

The Reid's Odourless Earth Closet (ROEC) patented in South Africa with an asbestos cement chute, has been adapted using a more-easily cleaned PVC pipe.

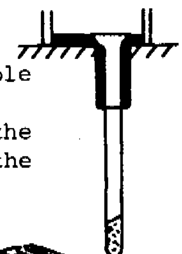


There are examples in Africa of offset pour-flush latrines, although they are more common in Asia. Excreta is flushed down a short length of pipe from a water-seal trap by a small quantity of water. In one type there are two pits connected to the latrine by a Y-junction. When one pit fills the other is put in use. When that is full the first pit is reexcavated.

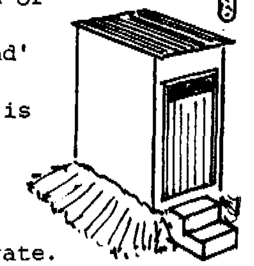


An essential feature of a pit latrine is infiltration into the surrounding soil of liquid - water used for anal cleaning, rainwater in unroofed latrines, surface run-off into low-level latrines and liqour from the breakdown of faecal solids. The accumulation of solid matter depends on a variety of factors, and is obviously more rapid when solids other than faeces are dropped into the pit.

Modifications of the pit latrine include borehole latrines. In suitable soils they can be dug quickly - if equipment is available. The top of the hole inevitably becomes fouled, and the hole fills up quickly.



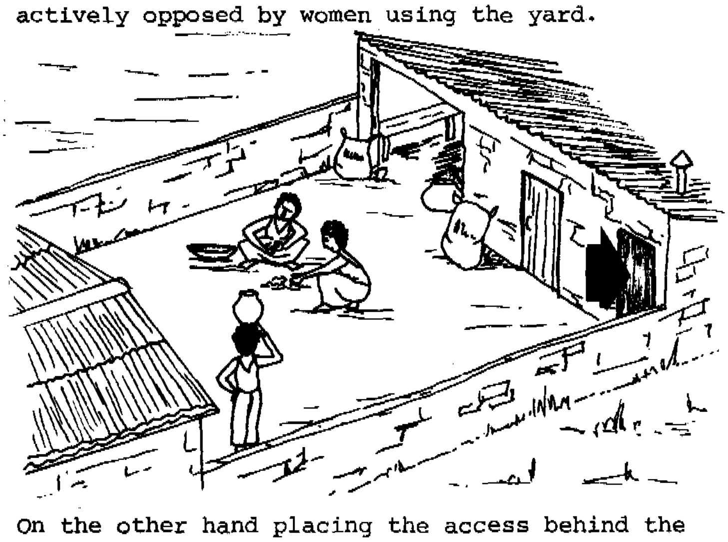
Where the water-table is high or rock makes deep excavation difficult an elevated or 'mound' latrine is sometimes built. Part of the storage capacity is above ground and the walls there should be completely watertight. An open bottom and open joints below ground level allow liquid to infiltrate.



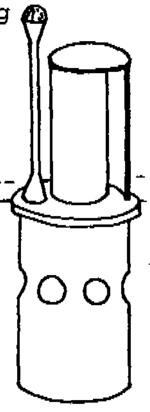
Three aspects of pit latrine technology deserve special attention: the pit lining, removal of accumulated solids, and ventilation.

In many soild a lining is necessary. Soils which appears stable when the pit is dug in dry weather may collapse when the sides are saturated with liquid. In tropical rural areas whole or split bamboos provide a readily-available lining material. Even if they eventually rot, they probably retain the soil until faecal solids build up in the pit. Some pits are lined with masonry or blocks. In fact, some linings are too good. Built with mortar joints and even rendered they prevent the outward passage of liquid. The pit is effectively a cesspit and quickly fills.

Where there is plenty of space and linings are cheap the usual practice is to dig a new pit when the old one is full. This is impossible or uneconomic in high-density housing with small plots or where expensive linings are used. In some municipal areas a tanker emptying service is available, but even when the tankers are capable of lifting solids the operators are often reluctant to empty the pit completely because of the risk of pipe blockage by old shoes and similar objects. With the usual type of floor slab supernatant liquid is removed by inserting the tanker's pipe through the hole, but the slab has to be taken off if the tank is to be completely emptied. Some local 'manual' methods of emptying pits are very unpleasant(1). Consequently many 'improved' designs have a removable slab or access cover outside the building, usually behind it. The best position for the access depends on considerations which have more to do with people - the users - than with technology. In the compound-type layout common in African urban areas the latrine opens on the yard where much of the household activity takes place. In some moslem communities the yard is the preserve of women. People prepare food, cook it and eat it in the yard. Therefore it can reasonably be argued that pit emptying (with the possibility of spillage, bad smells and so on) should not take place in the yard. Access to the front of the latrine may be actively opposed by women using the yard.



On the other hand placing the access behind the latrine moves it outside the owner's view, and some owners like to keep an eye on emptying work for which they pay. An access cover outside the plot is also liable to damage by passing vehicles or causes obstruction in a public thoroughfare.



The main purpose of pit *ventilation* is obviously removal of unpleasant smells from the latrine, and most 'improved' latrines include a ventilation pipe. Reduction of fly-nuisance may be equally important. The Blair Research Centre, who developed the latrine shown here, tested pits with large-diameter ventilation pipes and found that the fly-population was greatly reduced (2). A black pipe on the sunny side of the latrine has been advocated. However, as with the access, the users' choice may over-ride technical considerations. It is pointless providing a highly efficient vent pipe behind the latrine (and consequently outside the compound) if the out-of-sight pipe is soon broken by vehicles or playful youths.

Nuisance from smell, flies and mosquitoes is reduced, or even eliminated completely, if a water-seal is placed between the pit and the latrine. Simple traps are suitable for those parts of Africa where anal cleaning with water is the customary practice. Water-seals cause trouble if solid material is used for anal cleaning. Corn-cobs, stones, leaves, rags, old newspaper and office stationary are widely used in Africa. The trap becomes blocked. A stick or iron bar is used to clear it, and the trap is broken!

The question of anal cleaning brings us right into the orbit of user behaviour and preference. Important factors in the use of latrines (and consequently the best design, location and construction) include the following -
- whether users squat or sit -
- the material used for anal cleaning -
- whether users like to bathe immediately after using the latrine, and whether they bathe in the latrine -
- whether there is an inhibition or embarrassment in the use of the latrine, or do people go there quite openly -
- whether there are any taboos against the use of a latrine by different members of the family: man and women, old and young, and so on -
- whether communal latrines (shared by more than one family) are acceptable -
- whether faeces of infants are put in the latrine.

These and similar matters are governed by culture. Culture of this kind varies within short distances, between urban and rural communities, between old and young, between rich and poor, between educated and uneducated. When cultures intermingle, as in a squatter settlement, the pattern may be very confused, and we come to another consideration: how readily do people of various backgrounds change their habits in a new environment?

* * * * *

How receptive are different people to new techniques? How willing are they to respond to change, to alter their habits and to adopt new patterns of sanitary behaviour? These questions are critical to our understanding of the success and failure of individual schemes. Long-established practices of water-use and excreta disposal may bear a unique significance reflecting cultural taboos and social preferences within communities which are not quickly relinquished. In considering the issue of adaptation reference must be made to the forces which stimulate behaviour patterns.

a. Change may be effected within existing rural and urban communities through external influence. Official programmes for sanitation improvement demand of residents a flexibility and a willingness to adapt. Where customs are firmly established this may be difficult. Under such circumstances knowledge of these habits and preferences is critical at the outset. Indeed it is widely accepted that a degree of community consultation and participation during the course of a project's design, implementation and maintenance are essential prerequisites for success (3).

b. Alternatively change may be precipitated by the individual himself as a result of his decision to move from one environment to another. In the new environment he is faced with alien conditions and circumstances which may force him to change his habits. Indeed free from the customs of the home area he may be more willing to do so. In the Third World and in Africa in particular the most dramatic change of environment is that between rural and urban areas. Today the majority of people who move must cope with this transition.

In broad terms the degree of responsiveness and the speed of adaptation vary with two sets of factors -

- those relating to the individual - his personal background, cultural traditions, economic status and motivation for movement -
- institutional factors including official policies for sanitation improvement and the incentives offered by government to effect change.

As regards the individual migrant, evidence from throughout Africa confirms that rural-urban movement is a selective process, the highest rates of mobility being recorded among the young better-educated (4). For them movement is a conscious decision to seek a better income and more secure employment than is available in rural areas. For this group adaptation to urban life in general may be relatively quick. They are receptive to innovations and adopt new patterns of water use and excreta disposal without difficulty. Indeed for many the rural-urban transition is not great. They are the products of wealthier rural families who may have simple but adequate pit latrines. Formal training at school may have included the basic principles of sanitation and health education. Furthermore the extended family or friends in town fulfil an essential role in their adaptation to urban life by providing accommodation, social and economic security until the young job-seekers are themselves established. Although their urban experience may begin in a low-income housing area with the most basic pit privy, nevertheless the opportunity for social and residential mobility within town is perceived, sought and often secured with relatively little difficulty.

However while rates of movement are highest among the better-educated youth, in absolute terms this group is small by comparison with the large volume of poorly-educated, unemployed rural migrants with no urban contacts and little prospect of upward mobility who move to the squatter settlements on the periphery of African towns. Their spacial segregation presents the most serious set of problems for urban authorities. There is much evidence to confirm that this low income group reproduces many facets of rural life within the urban environment (5). While inevitably the cultural context influences the types of social organisation preserved, nevertheless certain features are shared in common. The traditional kinship system is maintained and frequently extended to include individuals of similar ethnic or regional origin producing a new category of 'fictive' kin. The code of reciprocal rights, duties and obligations which govern the conduct of individuals to each other persists, particularly when such groups are in close proximity to each other. Through the exchange of services (food, information, cash) between kin members and the mutual security they provide, urban social adjustment is facilitated. Further evidence for the rural attachment is reflected in the remittance system and through the frequent return visits of migrants to attend ritual ceremonies. Even the physical appearance of migrant neighbourhoods reflects the traditional style. Their makeshift homes conform to the widespread rural settlement pattern of individual household plots often with a boundary fence and open courtyard. These squatter areas are devoid of basic services with the result that there is no reason for residents to alter their traditional sanitary practices. With no understanding of toilet facilities the open highway or railway track acts as a useful substitute for the fringes of the home village. Lack of instruction in the health risks involved or in the value of simple alternatives means that they do not perceive their habits as a threat.

Under what circumstances is this behaviour likely to change? The influence of institutional factors is critical. It is apparent that policies to raise standards of sanitation achieve greater success when they form part of an overall strategy for the improvement of social infrastructure as a whole. During the 1970s there has been a profound change in attitude towards squatter settlements and the informal sector activities in which a high proportion of squatters are involved. The traditional bull-dozing approach coupled with elaborate and subsidised programmes of resettlement are giving way to policies which seek improvements in situ at costs which can be recovered from the urban dwellers themselves. Squatter upgrading has become an acceptable urban development policy. There are two fundamental reasons for this change in emphasis -

- economic - the rate of low income house - building cannot satisfy the increasing demands of rural migrants -
- socio-cultural - the failure of institutionally-built housing to meet the social needs of rural migrants. Only by a sensitivity to and an awareness of the traditional practices of rural people is their confidence enlisted and new schemes more quickly accepted. Clearly the initial approach is vital to the achievement of success. This basic principle has been harnessed in many upgrading schemes.

The experience of Botswana illustrates the success of such an approach. The Old Naledi squatter settlement on the south-west fringe of the capital city Gaborone, comprises one-third of the city population (ie 10 000 residents). The community dates back to 1963 when the site of the new capital was designated and a camp was needed for construction workers. A decade later when the community had grown to a squatter area 8 000 people resettlement schemes were initiated elsewhere in the city whereby residents should be provided with low income housing. Then two years later in 1975 pragmatism - the sheer volume of rural migrants and the inability on site and service schemes to absorb the numbers involved - encouraged a major shift in official policy. Naledi was to become a legal residential extension of the capital and to be upgraded to predefined standards.

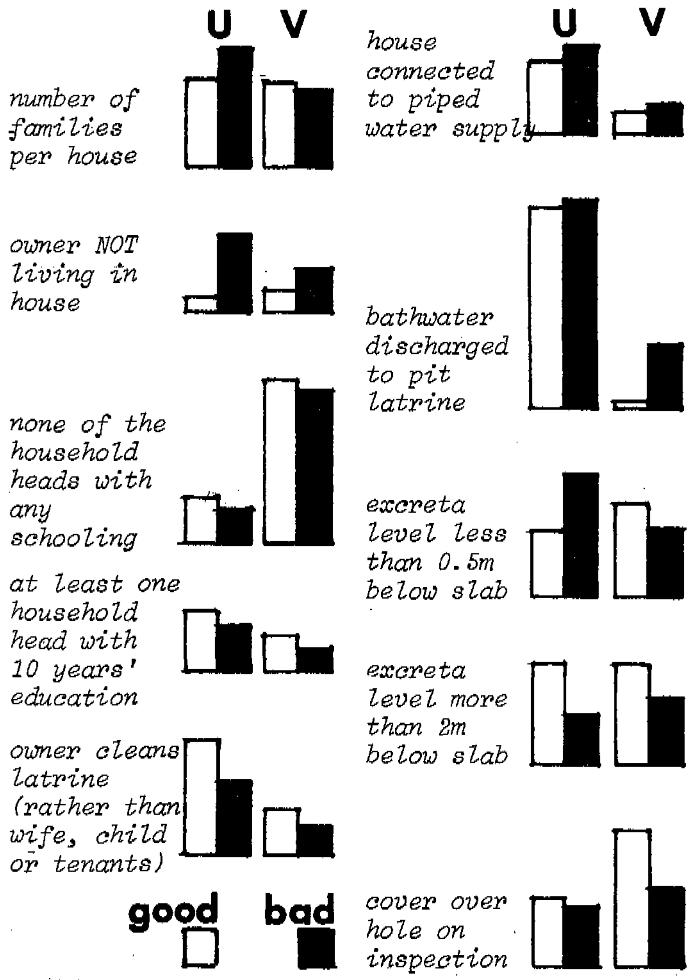
Three basic criteria guide this new approach -
- that the provision of social infrastructure is appropriate only if it can be afforded
- that the costs are recoverable; and
- that the scheme can be replicated elsewhere

Fulfilment of these criteria demands not only a low cost solution to social and environmental problems but also one which is based on the principle of self-help. Indigenous enterprises and initiative are fundamental.

Residents are required to secure a Certificate of Rights over individual plots on a 99 year lease. The procedure by which legal occupancy can be obtained reflects the government's priority attached to improvements in urban sanitation. It is initially required that all plot holders install a latrine. Only when this condition has been met may they contruct a "sound" house. Loans for building materials are provided by the Gaborone City Council together with advice and instruction in building methods. In deciding upon the most appropriate toilet facility for the squatter area extensive research was undertaken by the government and specialised agencies. A system was required which used little water, was simple to operate and maintain and was acceptable to the people. The modified ROEC met all these requirements. A major advantage was that it avoided the need for water carrying and periodic emptying which is socially unacceptable in Tswana culture (as indeed it is in much of Africa). While the provision of appropriate facilities does not ensure improvements in sanitation behaviour, proper use and maintenance is a requirement of continued tenancy and is therefore an important motivating force. The toilet facility is constructed in an outhouse within each designated plot and this structure itself is regarded as a status symbol among the squatter community.

Clearly effective and long-standing improvements in sanitary conditions and behaviour within squatter areas require that the migrant's personal commitment is enlisted. The experience of Botswana emphasises that changes are most effectively introduced if they form part of an overall package of infrastructural developments involving the principle of self-help.

A very thorough study of over 350 existing pit latrines was recently carried out in Dar es Salaam, Tanzania, by the Low Cost Sanitation Unit of ARDHI (Ministry of Lands, Housing and Urban Development) in collaboration with the UK consultants Howard Humphreys and Partners. Analyses of data were particularly interesting when the latrines were divided into 'good' and 'bad', based on their nuisance by smells, flies, mosquitoes and cockroaches. The diagrams below show how various sociological and technical matters influenced the state of the latrines. The survey covered both urban areas (U), which included squatter housing, and villages (V) within the Dar es Salaam Master Plan area.



REFERENCES

1. PICKFORD John. *Pit latrines.* WEDC Technical Note No 2. Loughborough University of Technology, 1980.

2. MORGAN Peter R. The pit latrine - revived *Central African J. Med.*, 1977, 23, 1, 1-4.

3. WIJK-SIJBESMA C v. *Participation and education in community water supply and sanitation programmes.* Technical Paper No 12. WHO/IRC, The Hague, 1979.

4. BYERLEE D. Rural-urban migration in Africa: theory, policy and research implications. *Internat. Migration Review,* 1974, 543-566.

5. DWYER D J. *People and housing in Third World cities: perspectives on the problems of spontaneous settlements.* Longman, London, 1975.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

N EGBUNIWE

ALTERNATIVE EXCRETA DISPOSAL SYSTEMS IN EASTERN NIGERIA

Introduction

Modern sanitary facilities for the disposal of excreta are lacking or may not be possible in many parts of Eastern Nigeria. The possible reasons for this situation are: ignorance of the role of excreta in disease transmission, lack of pipeborne water supplies to many communities, shortage of water where pipeborne water is available, high cost of sewerage, the need to have low cost systems and the placement of sanitation as a low priority item by the state governments. Sanitary facilities in use in Eastern Nigeria are briefly described here. The need for appropriate technologies in sanitation that are safe, effective and economic cannot be over-emphasized in the area under consideration.

Characteristics of Faecal Wastes

Table 1: Some physical and chemical characteristics of faecal materials per person

Composition	Faeces	Urine
Quantity (wet) per day	501-800 gm(1)	950 - 110 gm
Quantity (wet) per toilet	200-301 gm	-
Moisture	70-83%	-
Total Nitrogen	0.5-0.8%	-
Phosphates	0.3-0.4%	-

(1) Values got from measurements of nightsoil at Umuahia and Nsukka.

The quantity of wastes per person per day is an important parameter in the design of disposal systems. Wastes consist mainly of faeces, urine and cleansing materials. Cleansing materials in use in the area include sticks, leaves especially those of plantain and banana, pages of newspapers, walls of toilets and toilet rolls. The faecal output of a person depends on the diet, age, body weight and liquid intake. Some physical and chemical characteristics of human wastes are presented in Table 1. Values got from nightsoil included cleansing materials and some urine. The mean number of use of toilet per person per day in the area is two. The following quantities are proposed as adequate for design purposes:

Faeces including cleansing materials	600 gm per person per day
Urine	1000 gm " "
Total	1600 gm " "

The high output of faeces is due to the high cellulose content of the diets in the area. The low nitrogen and phosphate contents of the faeces tested show low protein and mineral intake of the people of the area.

Bush Method of Excreta Disposal

Table 2: Disposal systems in some towns and villages in Eastern Nigeria

Town or village	Percentage of Population served by				
	Central Sewer	Septic Tanks	Pit Latrine	Bucket latrine	None
Nsukka(1) (excluding the University)	-	32	14	50	4
Enugu (1)	2	34	1	57	6
Ovoko (2)	-	2	90	-	8
Umoye (2)	-	-	89	-	11
Obukpa (2)	-	3	87	-	10

(1) Urban centre
(2) Village

This method includes defecation in parks, uncompleted buildings, market places and open fields. A look at table 2 shows that about 5% of the population of the urban centres studied have no excreta disposal facilities. Most of these people live in shanty towns at the fringes of the urban centres. The percentage that use this method in the rural areas is higher due to reasons already mentioned. There is also a practice in the rural areas of fertilizing the field with excreta. The health hazards posed by this method are enormous.

Pier Latrine: A squatting plate with a hole is constructed on a wooden platform held over the

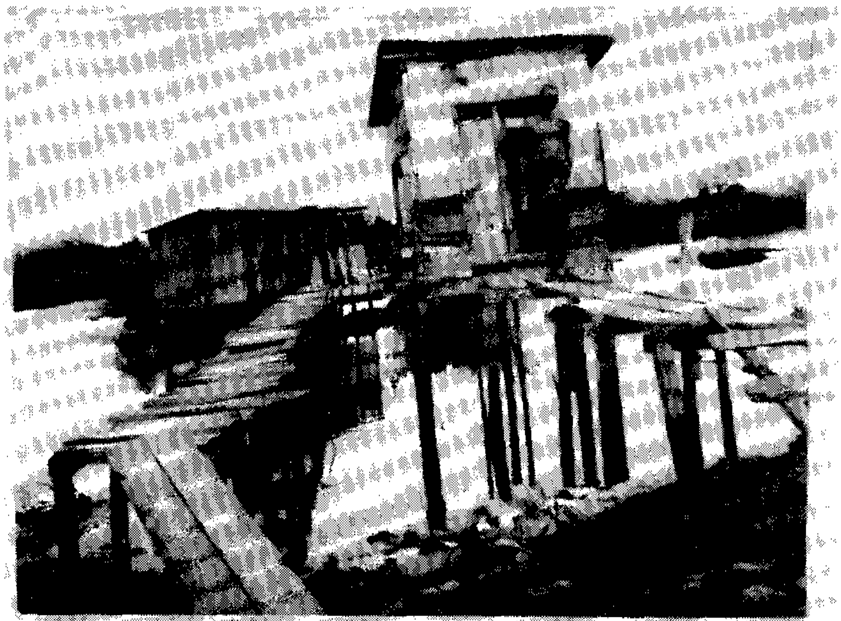


Fig.1: Pier Laterine

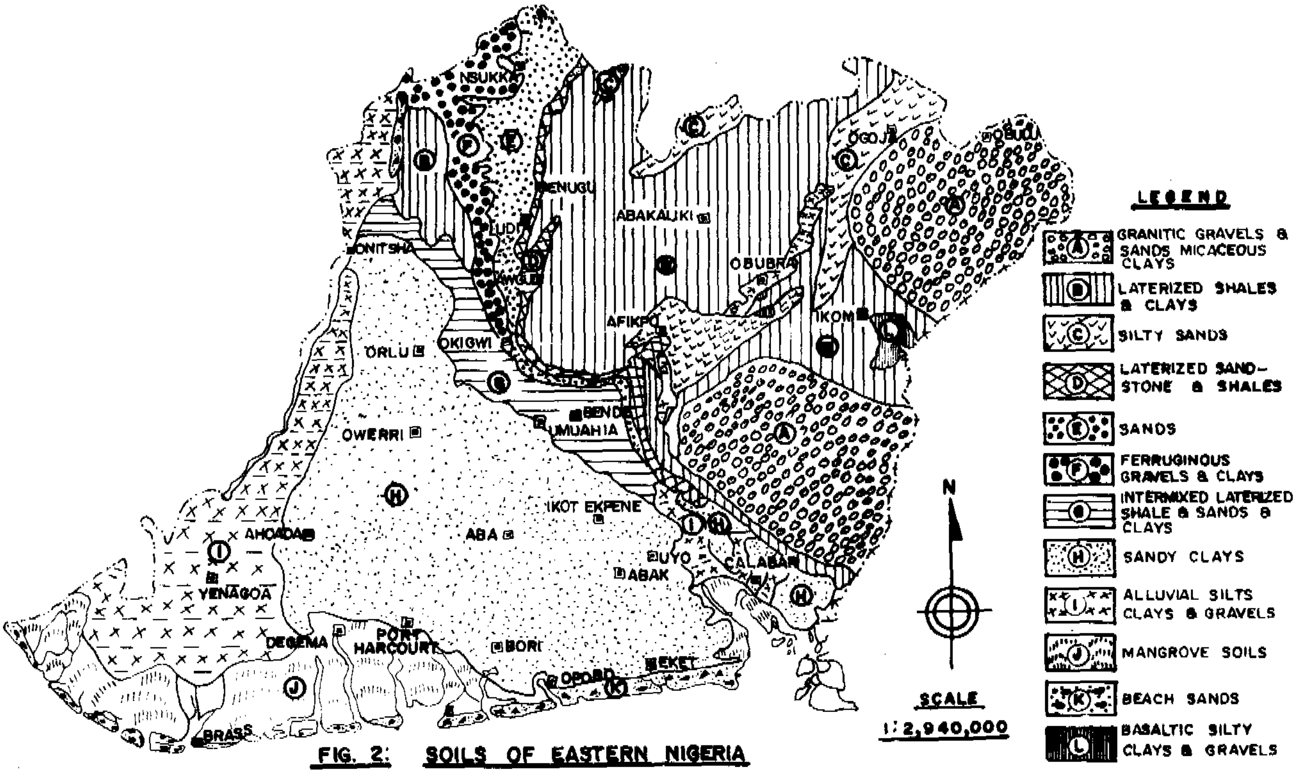


FIG. 2: SOILS OF EASTERN NIGERIA

body of water by tree trunks or planks driven into bed of the river or sea. The platform is connected with banks of the creeks by a wooden bridge (Fig.1). This method is in use in the riverine and estuarine areas of Eastern Nigeria. Studies conducted in Port Harcourt show that 15% of the population depend on this system. Little or no nuisance from smell and flies is associated with this system. It is the cheapest disposal facility in the study area. Tremendous dilution of the wastes is provided by the large bodies of water. Sometimes, the same body of water used for excreta disposal is also used for domestic purposes. The sanitary consequences of this situation are grave.

Pit Laterine: A squatting plate or a wooden seat is constructed over a pit of about .9m in diameter dug in a permeable soil. Referring to fig.2 it could be seen that most of the soils in the study area are laterites and sands. Impermeable clays and basement complex east of Abakaliki and north of Calabar are unsuitable for construction of pit laterines. Table 2 shows that up to 90% of the population in the villages studied depend on this system. Pit laterine is not popular in the urban areas because of the unavailability of land to dig more pits when the old ones are full. The pits in the study area are usually badly constructed and cave-ins are common. Pit laterines when properly built are hygenic and can function without smell or fly nuisance.

Bucket Laterine

Table 3: Disposal Systems in Enugu

Ward	Percentage of population served by				
	Central Sewer	Septic Tanks	Pit Laterine	Bucket Late-rine	None
Ogui Urban area	-	10	2	84	4
Uwani	-	68	-	27	5
Abakpa Nike	-	22	1	70	7
Riverside Estate	99	-	-	-	1
GRA	-	99	-	-	1
Colliery Qtrs.	-	33	5	60	3
Iva Qtrs.	-	6	10	81	3
Ogbete	-	9	1	84	6
P&T & Rlway Qts	-	60	-	40	-
Asaba	-	7	-	83	10
Secreta-riat Qts	-	86	-	12	2
Ogui New Layout	-	37	-	60	3
China Town	-	4	-	84	11
Emene	-	4	4	80	12
New Haven	-	80	-	8	12

A seat is usually built over a bucket located in a rectangular fly-light chamber. This is the system mostly used in the urban areas. Table 3 shows that up to 84% of the population of the urban areas studied use this system. The cost of the bucket is low but the cost of removal and disposal of the bucket contents is becoming increasingly high.

Conservancy system is the method of collecting and disposing of nightsoil from bucket laterines by hired or employed labourers. The conservancy projects are handled by the Health Departments of the Urban Councils. The Health Departments award contracts to registered conservancy contractors. These contractors employ labour and buy necessary equipment approved by the Health Department.

Conservancy Practice in Enugu

Table 4: Conservancy Service At Enugu

Contractor's zone	Staff Population	Annual Expenditure on Staff	Annual Expenditure on equipment	State of health of staff	
				Good	Poor
Ogui, Asata, Ogui Urban & New Layout	40	N 40,000	N 10,000	35	5
Ogbete, Awkunanaw & Uwani	25	33,000	8,000	24	1
Emene & Abakpa Nike	30	36,000	8,000	20	10

Table 4 shows that Enugu is divided into three conservancy districts. A contractor handles each district. The contractors' problems are:

(a) Unavailability of Scavengers since the present labourers are ageing and younger men are hard to come by.
(b) Irregular subventions from the urban councils causing regular strikes of the nightsoil men.
(c) No care of the bucket facilities by the customers.
(d) Over population of the houses.
(e) Shortage of water for cleaning the facilities.

The existing system of conservancy violates all laws of sanitation. Most units each serve a population of over 30 persons and the frequency of collection and disposal of the nightsoil are irregular. The collection chamber is often badly kept. The health hazards resulting from these conservancy practices are alarmingly obvious.

Septic Tank

This is the most popular system in use in most towns in Eastern Nigeria because tanks can be built for single housing units. In 1960 7% of the population of Enugu depended on this system and in 1978 the percentage was over 34. Some urban councils have enacted laws requiring all houses in their local government areas to convert to this system. This has not been possible due to the incessant shortage of water. The septic tanks are usually constructed to take sewage from the W.C. while sullage from the kitchen and bathrooms is run into the street gutters. From the studies at Enugu, Nsukka and Onitsha, the desludging intervals range between 3-5 years and the rate of accumulation of sludge per person per year is between .03 and .06 m^3 with an average of .043 m^3

Aqua Privy: This is a simplified version of the septic tank. It receives exreta through the drop hole and requires only a small volume of added water to maintain the liquid level in the tank. This system is not popular in Eastern Nigeria. Only one aqua privy was located at Abakpa Nike, Enugu. Due to lack of water the owner built a hut on top of his septic tank and drained the sullage from the bathrooms into the tank. A drop hole was made on the slab covering the tank. This privy was constructed in 1975. It is in good structural condition and has operated with little nuisance from smell and flies. The only problem so far encountered is that the tank is a breeding ground for mosquitoes. Aqua privies should provide one of the best compromise systems of sanitation as they need less water, less capital equipment and less maintenance than any other system capable of the same degree of protection from nuisance and disease. A design formula for the tank volume has been given by Mann (1) as $V = PQ + SP$ where

V is the tank volume, P is the average number of users, Q is the average volume of liquid discharged in ℓ/person/day and S is the volume of sludge storage allowed in the tank per person (120 - 150 ℓ/person allows for a desludging interval of 2 years).

Discussion

Excreta disposal system according to Wagner (2) should satisfy the following requirements:-

(a) No contamination of surface soil
(b) No pollution of groundwater or surface water.
(c) No handling of fresh excreta
(d) Excreta should not be accessible to flies or rodents.

The pier laterines will be in use in the estuarine areas of Eastern Nigeria for a long time, because the disposal system is simple and cheap and land may not be available for other types. The creek waters are saline most of the year and there is no possibility of using such waters for domestic use. The laterines can be located such that their beds are never exposed during low tides. Contact with water in bathing and fishing, is still hazardous.

The bucket system will be phased out of the urban areas when staff for the conservancy system are unavailable. The average age of such staff at Enugu is 45 years and with the introduction of universal free primary education, it is unlikely that younger men will join the ranks of nightsoil men. It is noteworthy to point out that the governments of Eastern Nigeria have embarked on massive water supply programmes for the urban centres and this will enable the various laws enacted to compel house owners to change to septic tanks be effective. Septic tanks are very popular in the study area and will replace all other systems as water is available. The rural areas will depend on pit laterines for a long time due to inadequate rural water supply programmes. Efforts should be made to construct better pit laterines. The Vented Indirect Pit (VIP) laterines described by Wright (3) should be introduced since they have been shown to be safe, effective and acceptable from economic and socio-cultural standpoints for people of identical cultural practices. The people should be educated to construct aqua privies when water supply is inadequate and convert them to septic tanks when supplies improve.

References

1. Mann H.I. Sanitation without Sewers. Overseas building Notes,No.168,Building Research Station,England,1976.

2. Wagner E.G. and Lanoix, J.N. Excreta disposal for rural areas and small communities, WHO 1958.

3. Wright A.M. A review of Rural Excreta Disposal Systems, Prog. Wat. Tech. Tech. Vol.11, 211-218,1978.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

K O IWUGO

RESOURCES RECOVERY IN TROPICAL WASTES DISPOSAL: COMPOSTING AND BIOGAS TECHNOLOGIES

1. INTRODUCTION

The major developmental problems facing all developing countries may be summarised as follows :-

1) high urban population growth rate (2-5% per year);

2) low income (per capita G.N.P. less than $450;

3) high infant mortality (120 deaths per 1000 live births);

4) hunger (54grams of protein per day per person);

5) low life expectancy (less than 52 years);

6) illiteracy (43%) literacy rate;

7) lack and inadequate provision of water supply (38% of total population have water supply and a majority of these cannot be supplied more than 60 litres per capita per day) (2)

8) lack and inadequate provision of excreta and wastewater disposal facilities (33% of total have some form of excreta disposal facilities, most of which are totally inadequate).(2,3,4,5)

The provision of adequate and appropriate excreta and wastewater disposal facilities can help considerably in redressing some of these problems. However, it may not be readily apparent to many western-trained environmental engineers and health administrators in African countries that excreta disposal systems other than the conventional water-borne sanitation systems (sewerage systems) can fulfill the following requirements:-

1) low constructional and operating costs;
2) ease of operation and maintenance;
3) non-reliance on imported mechanical parts;
4) low water requirement;
5) less risk of causing surface water pollution;
6) good hygiene;
7) high user acceptance;
8) production of useful by-products (the sale of which can reduce the cost of the facility).

These alternative sanitation systems range from the simple pit latrines to ramifications of conventional sewerage. The systems that encourage the reuse of excreta form the general subject of this paper.

Recycling or reuse of excreta is traditionally practised in many developing countries. The practice, in its insanitary form, has grown out of dire necessity rather than for the primary reasons of environmental control as in the resource-wealthy industrialized countries. The governments of most independent African countries are becoming increasingly aware of the need for massive agricultural development upon which the nutritional level and in certain areas, the very survival of the population depends. The massive investments being made for the construction of irrigation schemes and the increasing amount of chemical fertilizers which are annually imported into several African countries are clear evidence of the high priority being given to agriculture in this part of the world. However, the high cost of chemical fertilizer is not affordable by the peasant or rural farmer. Even when the chemical fertilizers are heavily subsidized and are affordable by the rural farmer, their use may be grossly abused because soil testing services, which will help to identify the deficient nutrients in soils, and the fertilizer best suited to particular crops, are unavailable to him. The demand and consumption of chemical fertilizers are on the increase in several African countries. For instance, additional 400,000 metric tons of fertilizer were imported into Nigeria in 1978 and an additional 700,000 metric tons were expected to be imported in 1979.(6) Per capita consumption of chemical fertilizer in Kenya in 1975 were Potash (0.31kg K_2O) phosphate (2.29kg P_2O_5) and nitrogen (1.51kg N) and the corresponding figures in Ethiopia, a much less developed country than Kenya, were phosphate (0.41kg P_2O_5), and nitrogen (0.29kg N).(7) On the other hand, the per capita yearly nitrogen discharge in human excreta is 5kg; phosphorus is 1.5kg (as P_2O_5); and potassium is 1kg (as K_2O). Micronutrients and organic matter which are excellent soil conditioners are also present in human excreta. As shown in Table 1, the fertilizer value of digested excreta (compost) is much lower than that of chemical fertilizer. However in many developing countries only a small percentage of the population are served by waterborne sanitation while a majority have some other kind of facilities or no facility at all.[2] The situations in Kenya and Zambia [9] are summarized in Table 2 and these are reasonably typical of many African Countries. Under these situations, the quantities of fertilizer that can be realised from undiluted human excreta can be very substantial particularly in the rural areas where a majority of the population of the developing countries live. Although composting renders human excreta virtually free of pathogens and the sanitary application of composts as agricultural fertilizers has been widely demonstrated in many developing countries, [9] there are very few (if any) reported cases of any successful composting systems in operation in Africa. Furthermore, per capita costs of compost toilets have been indicated to be more favourable than those of several other low-cost excreta disposal systems commonly in use in Africa.[3]

This paper attempts to briefly review composting toilets in Africa since these have very high potential for yielding agricultural "fertilizer"(compost) and suggest factors which should be taken into consideration in the design and operation of these waste reuse systems to make them adaptable to the conditions in rural and peri-urban Africa.

2. COMPOSTING

2.1 Technical Principles

Aerobic composting may be defined as the bio-chemcial decomposition of organic waste materials into relatively stable and odourless compost under aerobic and controlled moist conditions. The complex biochemical processes involved are summarized in Figure 1. The large quantity of heat generated during the process effects the destruction of pathogens and thus renders the process very safe from the public health or disease transmission point of view. The time/temperature relationship for aerobic composting cycle is shown in Figure 2 and it is apparent that a period of at least four months is required for the production of a safe compost.

Composting has been thoroughly reviewed in the literature [10,11] and a wide range of excreta composting technologies are known to be available. In general a composting process is fairly easy to operate provided the following conditions are fulfilled:-

(1) the initial carbon to nitrogen (C/N) ratio in the organic material is about 30 : 1;

(2) the initial carbon to phosphorus (C/P) ratio in the organic material is about 100 : 1;

(3) the moisture content is about 60%;

(4) there is periodical agitation or "disturbance" of the composting mass;

(5) the aeration rate through the composting mass is maintained at about $1m^3$ air/day/kg volatile solids at initial stages of operation of the system;

(6) the initial temperature is not greater than about $50^{o}C$;

(7) the particle sizes of the composting material range from about 10mm to about 80mm;

(8) pH of the composting mass is maintained between 6.5 and 8.5.

2.2 Composting Toilets

2.2.1 Designs and Performances in Africa.

There are two main types of composting toilets namely the continuous and the batch toilets. The several variations of these two types of composting toilets have recently been reviewed by Winblad[13] Nimpuno [14] and Kilama.[15]

In general, batch composters are of the double vault variety (see figure 3, 4 and 5). One vault is used until it is about 70% full, when it is filled up with earth and sealed, and then the other is used. When the second vault is full, the contents of the first one are removed and may be used as agricultural fertilizer. In order to satisfy the C/N ratio and moisture content requirements, either urine is excluded and ash is added as in the Vietnamese practice (see Figure 5) or organic domestic refuse, wood-chips sawdust or ashes are added to the composting toilet and free percolation of urine into the soil may also be allowed as in the Botswana and Tanzanian trials.[3, 15, 16]

The exact design and operation of composting toilets in Africa are uncertain because detailed and systematic studies are yet to be conducted. However, Chinese, Vietnamese and Indian experiences [17,18,19] indicate that batch composting toilets perform very satisfactorily. The study in Tanzania [3, 15] (which is perhaps the most detailed so far in black Africa) indicate that the batch double-vault composters are versatile but sensitive to misuse. The study [15] suggested that these composters will operate well if plenty of grass or other carbon source are added, if water is not put into them and therefore the moisture content is kept in the range 40 - 55% and if they are used by less than around 15 people. The compost from the vault which was sealed for at least six months contained no more pathogenic organisms than the soil in the same locality. The modified Gopuri (see Figure 4) was recommended for general adoption. The study [3,15], however, failed to indicate the effect of grass addition on the filling time of the vault or the effect the mode of addition of the grass or the form in which the grass was added (i.e. whether as fresh or dried or burnt grass) on the time required to obtain a safe compost (sealing period of the vault). These factors are bound to affect the rational design

Table 1:- Nutrient Content of a Fertilizer and some "Wastes" (10)

Constituent			Concentration as % of Dry Solid				
	Primary Sludge	Activated Sludge	Digested Sludge	Fertilizer	Farm Compost	Municipal Compost	Nightsoil
Total nitrogen	4.5	6.0	2.0	6.0	0.4	3.5	0.6
Phosphorus as P_2O_5	2.0	2.5	1.5	10.0	0.3	3.5	0.2
Potash as K_2O	0.5	0.7	0.5	6.0	0.5	1.8	0.3
Total	7.0	9.2	5.0	22.0	1.2	8.8	1.1

Table 2:- Sanitation Facilities in some African Countries [8,9]

Facility	Urban Zambia (1976)	Rural Zambia (1976)	Lusaka (Zambia) (1976)	Kenya (excluding Nairobi) 1973
Flush toilet	43.9	3.5	37.3	6.0
Sewerage	-	-	-	-
Aqua-Privy	4.8	0.5	1.2	-
Pit latrines	40.1	33.5	53.7	40.0
Bucket	1.3	-	2.7	3.0
None	9.9	62.5	4.7	51.0
Total %	100.00	100.00	100.00	100.00

of batch composters for the rural and peri-urban areas of Africa particularly as grass, weeds and similar plants are the most accessible and affordable biodegradable organic materials which can help maintain the delicate C/N ratio in composters. The Botswana study [3, 16] was much shorter than the Tanzanian study [3, 15] and the major indication from that study [3, 16] is that batch composting toilets might prove very popular particularly if the municipal authorities would be willing to help empty the vaults.

Continuous composting toilets, differ from the batch or double vault composters in that they allow for the removal of compost from a single chamber (see Figure 3). Although this system seems to have performed satisfactorily in several Scandinavian countries [20, 21] has evaluated the possibility of their adoption in some African countries, continuous composting toilets have been found unsatisfactorily in the two African countries, Botswana and Tanzania where they have been tried. In Botswana [16] the continuous composting toilets were found to suffer considerably from fly and odour nuisance and "dry" composts were rarely produced in any of the systems under trial. They were also found to be sensitive to the degree of user care and the number of users. The Tanzanian investigators[15] pointed out that the sloping floor of this type of toilet required more skill for its construction and also the risk of pathogenic organisms being washed down to the desludging port. A further interesting observation from the Tanzania study [15] is that there was no significant difference between the continuous composters with and without channels to promote the aeration of the pile. A difference of about 7^{o} in the slope of the floor was also found not to cause a significant difference in performance.

The total annual substructure costs for composters built in Botswana and Tanzania have been summarized as follows [3]:-

	Botswana	Tanzania
Batch Composter (lined)	$34	$15
Batch Composter (unlined)	-	$14
Continuous composter	-	$16

The Chinese composting methods which have recently been reviewed by McGarry [19] also appear to offer potential for adoption in the rural and peri-urban areas of Africa. These are reproduced in Figure 6.

2.2.2 Apparent Deficiencies in the Designs and Operations of Composting Toilets in Africa

The designs of the several composters which are being evaluated in Africa [15, 16] have operated satisfactorily in several other countries outside Africa. Operational rather than design factors may, therefore, be more important in ensuring the good performance of composters in tropical Africa.

The shortage of refuse and biodegradable organic materials, which may help to maintain the delicate C/N ratio in the composting mass and also absorb excess moisture, has generally been mentioned as a cause of the poor functioning of composters in the rural and peri-urban areas of Africa. However, grasses, weeds and similar plants are abundant in these areas and what is now most needed is an evaluation of the mode of addition of these readily available biodegradable materials and also the best possible form (whether as fresh, dried or brunt materials) in which to add these materials so that they do not adversely decrease the filling time of the vault or prolong the duration of the composting process.

Water is a common anal cleansing material in several African communities [15](particularly the moslem community). It is impossible to regulate the quantity of water used by an individual for anal cleansing. This practice may severely hamper the performance of the designs of composters which are currently under trial in Africa.[15, 16] In communities where there is a prevalent use of water for anal cleaning, one wonders what would be the merits and demerits of the composter design shown in Figure 7. The slatted bed and the sloping floor of this design are clearly attractive features since these will ensure uninterrupted and continuous drainage of urine.

2.2.3 Potential for the Adoption of Compost Toilets in Africa.

Pit latrines are undoubtedly the most prevalent excreta disposal system used in tropical Africa.[3,8,9,23,24,25] A major disadvantage of pit latrines is that, when full, they must be taken out of service and another unit built. Furthermore, pit latrines have very little potential for resource recovery. The operation of pit latrines in some African countries [9,23 24,25] is such that when a pit is full, it is covered with earth and the new pit is dug adjacent to the filled pit. This mode of operation is somewhat similar to that of a double-vault compost toilet. Thus considering the facts that composting toilets have a high potential for resources recovery and are of comparable cost [3]with improved pit latrines, they should be attractive for adoption in tropical Africa.

In both rural and urban areas where crops are grown near the house, and where there are no cultural barriers to reusing human waste products, the compost can be used to improve gardens and also to refill eroded soils. In dense urban areas where people have little or no space for gardening, or in areas where the reuse of human waste products is abhorrent, the "in-yards" disposal of the compost may present a slight problem. This problem is however not insurmountable as the compost can be used on community basis to refill street potholes and such similar purposes.

Composters are demanding in terms of care and attention by the users (fulfilment of the requirements in Section 2.1). The involvement of the municipal authority at some stages of execution of compost toilet programmes may be inevitable. Composting toilets, particularly the continuous type, are generally too complex for self-help programmes, so that in areas where there are relatively well organised municipal authorities (e.g. East and Central African Countries) these will <u>INITIALLY</u> have to be responsible for organising construction and also plan carefully the financial arrangements by which the users will pay for the system. Users should be encouraged to attempt the construction of future composters when familiarity has been gained with the system and designs standardized. This approach has worked well with the construction of pit latrines in Zambia [9]and the response of the local user to the construction of ROEC latrine in Botswana [26]was very encouraging.

Although users may indicate some feelings of reluctance to emptying their composters (as in Botswana [16]and this may be seen as an area calling for the involvement of the municipal authority,[3] it should be remembered that the success rate of African composters has been very low indeed. When real composts have been and are being produced in African composting toilets, this apparent reluctance on the part of the users to empty their composters may greatly decrease. In cases where the reluctance persists, the user may privately arrange for his composter to be emptied as is the practice with the emptying of aqua privies, septic tanks and similar sanitation systems in several West African countries.[24] The private contractor may be able to sell the compost to other members of the community who have no objections to using compost as fertilizers (just as cow-dung which is relaized from animals reared by the Fulanis of Northern Nigeria are sold to non-fulani members of the community who use the cow dung on their gardens). On the other hand, the use of the compost for land reclamation purposes should not be ignored.

Unlike the pit latrine, which can be converted to a pour flush toilet,[27] there is no potential for economically converting a composting toilet into another type of toilet. However, compost toilets, like the improved ventilated pit latrines, can serve as an economically alternative (reserve) excreta disposal system in established urban areas of Africa where flush toilets have been already installed but where water supply is intermittent and irregular [23,24]to ensure the continuous and hygienic functioning of the flush toilet system.

3. SUMMARY

This presentation has attempted to review and assess the potential of compost toilets in Africa. The following observations are made:-

(1) Although composting toilets, of whatever type, requires a considerable amount of conscientious care by the users, double vault composters, which are designed to accept both

excreta and urine and to which organic wastes are added to ensure that the delicate C : N ratio and moisture content requirements are met, will be easier to adapt to the African environment. Designs such as shown in Figure 7 may be developed for wider application.

(2) Although there is usually a shortage of refuse in the rural and peri-urban areas of Africa to ensure the proper operation of compost toilets, there is abundant grass, weeds and similar materials in these areas and these should be suitable substitute for conventional refuse particularly if they are properly added (e.g. used in filling up the compost toilet when 2/3 full or burning the grass and using the resultant ash to cover the excreta after every use.) In fact, this proposal, if successful, will help in the general up-grading of the rural African environment which is often bushy.

(3) Although there is a lack of tradition of using fertilizer and reusing human waste products in agriculture in Africa, and this is generally seen as a drawback in adopting composters, SUCCESSFUL COMPOSTERS WHICH PRODUCE COMPOSTS WHICH ARE CLEARLY DISTINGUISHABLE FROM HUMAN EXCRETA ARE YET TO FUNCTION IN TROPICAL AFRICA. Unitl this happens, it will continue to be a supposition that the use of compost is not likely to be favoured in African agriculture for social and cultural reasons.

(4) Even where composts cannot be used as fertilizers (e.g. in dense urban areas where gardens are unavailable) they can be used in filling street potholes and levelling eroded footpaths, etc.

(5) The unit costs of composters in some African countries [3] is very comparable to the corresponding costs of the ventilated improved pit latrine. Composters, however, do not require to be resiting when full and as a result can serve as an economically alternative (reserve) excreta disposal system in urban areas of Africa where flush toilets have already been installed but where water supply is intermittent and irregular to ensure the continuous and hygienic functioning of the flush toilet system.

(6) The traditional practice of resiting a new pit latrine adjacent to the used pit in several African communities may facilitate the adoption and construction of double vault composting toilets in these communities.

Africa remains a continent riddled with poverty, hunger and a range of chronic debilitating diseases, the transmission of which related to poor environmental conditions and insanitary habits particularly with regard to the disposal of human and animal excrement and community wastes. Whereas the training and outlook of the public health engineer from the resources of wealthy industrialized countries largely tends to emphasize the disposal of wastes in order to upgrade the environment (and as a result improve public health), the African public health engineer has the additional onus of developing and implementing waste disposal process that will augment the very limited natural resources such as food, fertilizer, and water in his continent. Some possible approaches are summarized in Figure 8.

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to my colleagues Dr Richard Feachem of the Ross Institute of Tropical Hygiene and Professor Duncan Mara of the University of Leeds, England who have stimulated my interest in the problems of alternative excreta disposal systems for developing countries. I am also grateful to Mr J Kalbermatten, and other officials of the World Bank for their encouragement during the research project which generated the thoughts expressed in this paper.

REFERENCES

1. World Bank Report, Washington, (1974).

2. World Health Organization, "Community Water supply and excreta disposal in developing countries", World Health Statistics Report, 29 (10) 543 - 603 (1976).

3. FEACHEM R G, MARA, D D and IWUGO, K O. "Alternative Sanitation technologies for urban areas in Africa", P.U. Report No.RES 22, World Bank Washington (1979).

4. KALBERMATTEN, J M, "New Prospects for urban excreta disposal in developing countries", Prog.Wat.Tech., 11, 225-234 (1979).

5. IWUGO, K O., "Appropriate Sanitation technology planning and implementation in Africa", Environmental Pollution Management 9, 100-102 (1979).

6. ONWUZURIKE, C., "Fertilizer in our agriculture", Daily Times, Lagos, Wednesday April 25, (1979).

7. Food and Agricultural Organization (F.A.O.) Yearbook, Rome, (1975).

8. MARA, D D., "Sewage treatment in hot climates", John Wiley, Chichester, (1976).

9. IWUGO, K O., MARA, D D., FEACHEM R G., "Sanitation Studies in Africa - Site report No.4, Lusaka and Ndola, Zambia" P.U.Report No.RES 21, World Bank, Washington (1979).

10. GOTAAS, H B., "Composting: Sanitary disposal and reclamation of organic wastes", World Health Organization, Geneva (1956).

11. SHUVAL, H I., "Nightsoil Composting", P.U. Report No.RES 12 World Bank, Washington (1977).

12. GRAY, K R, SHERMAN, K and BIDDLESTONE, A J. "Review of Composting, Part 2 - the practical process", Process Biochemistry, pp 1 - 7, October (1971).

13. WINBLAD, U., "Composting latrines - a review of existing and proposed systems" IRCWD News, WHO International Reference Centre for Wastes Disposal, Duebendorf, Switzerland, June (1977).

14. NIMPUNO, K, "Scandinavian mouldering latrines and the biopot", in Sanitation and Developing Countries, ed. Arnold Pacey, John Wiley and Sons, Chichester, (1978).

15. KILAMA, W L. and WINBLAD, U., "Composting toilets in the tropics: a review and appraisal" Prog.Wat.Tech. 11, 335-340 (1979).

16. BLACKMORE, M D., BOYDELL, R A., and MBERO, N. "Choice of Technology in Botswana", in Sanitation in Developing Countries, ed. Arnold Pacey, John Wiley and Sons, Chichester, (1978).

17. McMICHAEL, J K., "The double septic bin in Vietnam" in Sanitation in Developing Countries, ed. Arnold Pacey, John Wiley and Sons, Chichester (1978).

18. McGARRY, M G. "Excreta treatment and reuse in China" in Sanitation in Developing Countries, ed. Arnold Pacey, John Wiley, Chichester (1978).

19. McGARRY, M G., "The importance of wastes reuse". Prog.Wat.Tech., 11, 325-334 (1979).

20. RYBCZYNSKI, W., POLPRASERT, C and McGARRY, M G., "Low cost technology options for Sanitation - a state-of-the art review and annotated bibliography" Int.Development Research Centre, Ottawa, Canada (1978).

21. W.H.O., "Compost - an annotated bibliography on compost, compost quality and composting, 1971-1977", WHO International Reference Centre for Wastes Disposal, CH-8600 Dubendorf, Switzerland (1978).

22. WINBLAD, U, "Evaluation of waste disposal systems for urban low income communities in Africa"., SPC Report No.3. Scan Plan Co-ordinator, Denmark, (1972).

23. IWUGO, K O., MARA, D D., and FEACHEM, R G., "Sanitation Studies in Africa - Site report No.1, Ibadan, Nigeria", P.U. Report No.21 World Bank, Washington, (1979).

24. IWUGO, K O., MARA, D D., and FEACHEM, R G., "Sanitation Studies in Africa - Site report No.2, New Bussa, Nigeria", P.U. Report No.21 World Bank, Washington, (1979).

25. IWUGO, K O., MARA, D D., and FEACHEM R G., "Sanitation Studies in Africa - Site report no.3, Kumasi, Ghana", P.U. Report No.21, World Bank, Washington (1979).

26. ENDRST, J., "Botswana's self-help community" IDRC Reports, 8, 12-13 (September 1979).

27. World Bank, "Appropriate technology for water supply and wastes disposal in developing countries, - (IV) Sanitation program planning: a field manual" World Bank, Washington (1978).

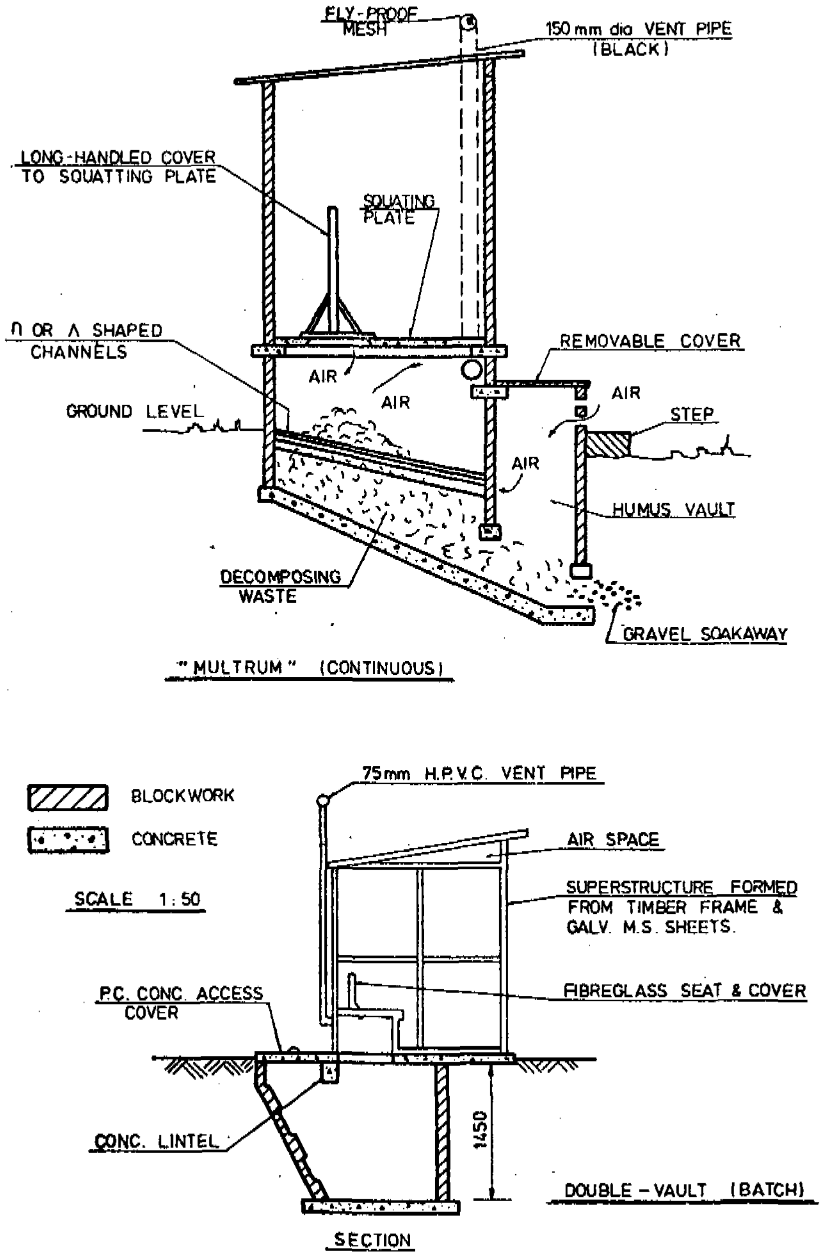


FIG. 3 : COMPOST TOILETS UNDER TRIAL IN BOTSWANA. (16)

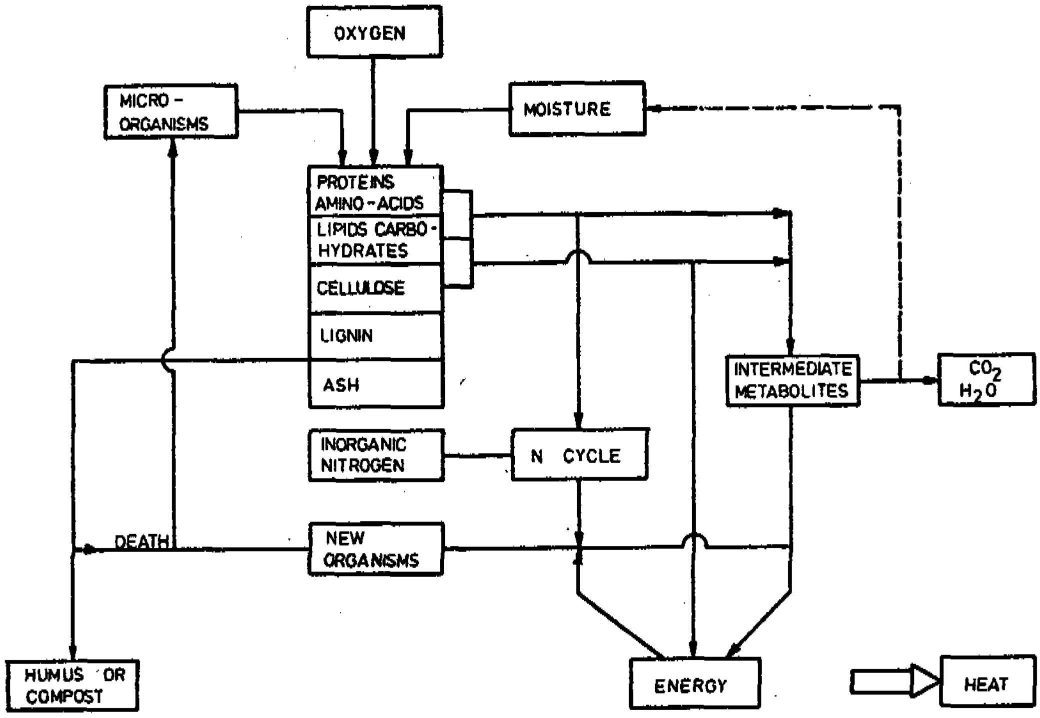


FIG. 1 : BIOCHEMICAL PATHWAYS OF THE COMPOSTING PROCESS.

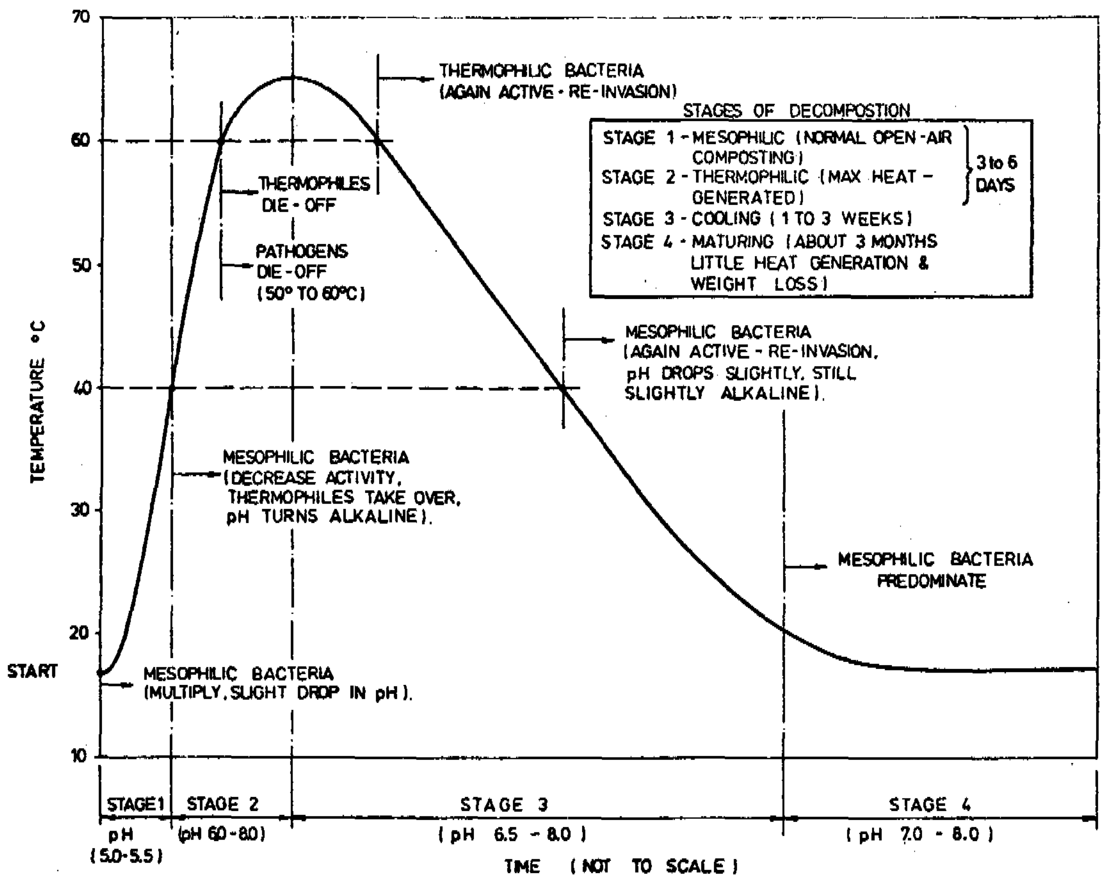
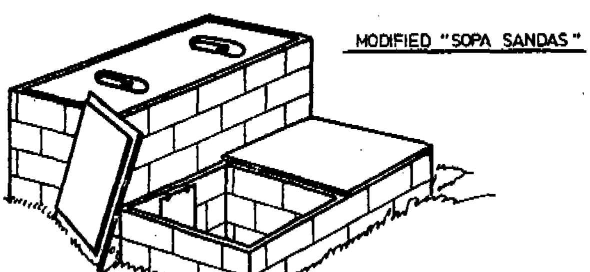


FIG. 2 : TYPICAL TIME / TEMPERATURE RELATIONSHIP FOR AEROBIC COMPOSTING CYCLE.



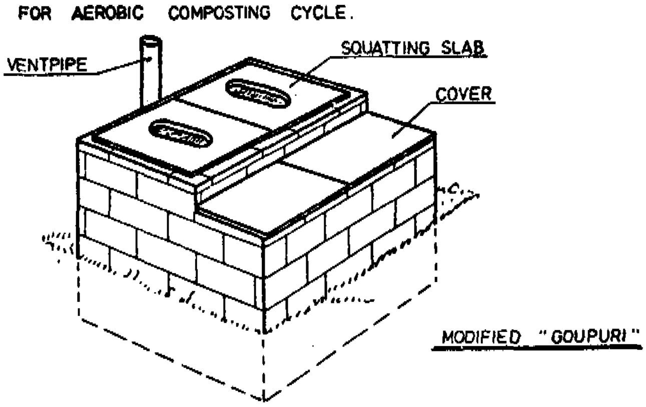


FIG. 4 : TANZANIAN DOUBLE - VAULT COMPOSTING TOILETS. (15)

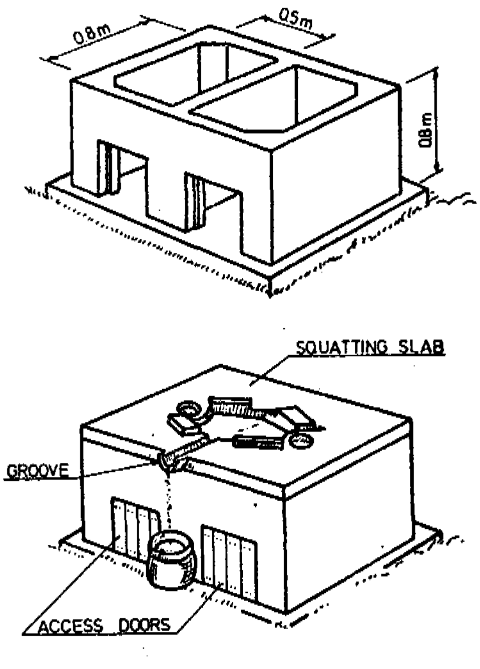
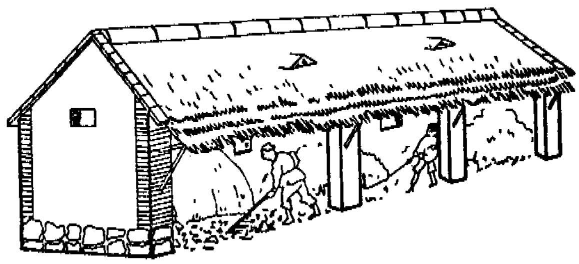
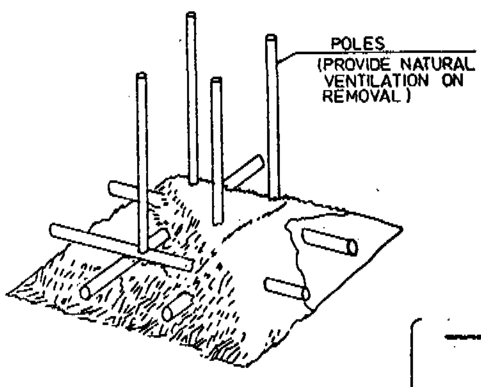


FIG. 5 : VIETNAMESE DOUBLE - VAULT COMPOSTING TOILETS. (20)



A. THE GRANULAR FERTILIZER STORAGE SHED.



B. THE THERMOPHILIC, OR FOUR - COMBINED - IN - ONE METHOD OF AEROBIC COMPOSTING.

FIG. 6 CHINESE COMPOSTING METHODS. (19)

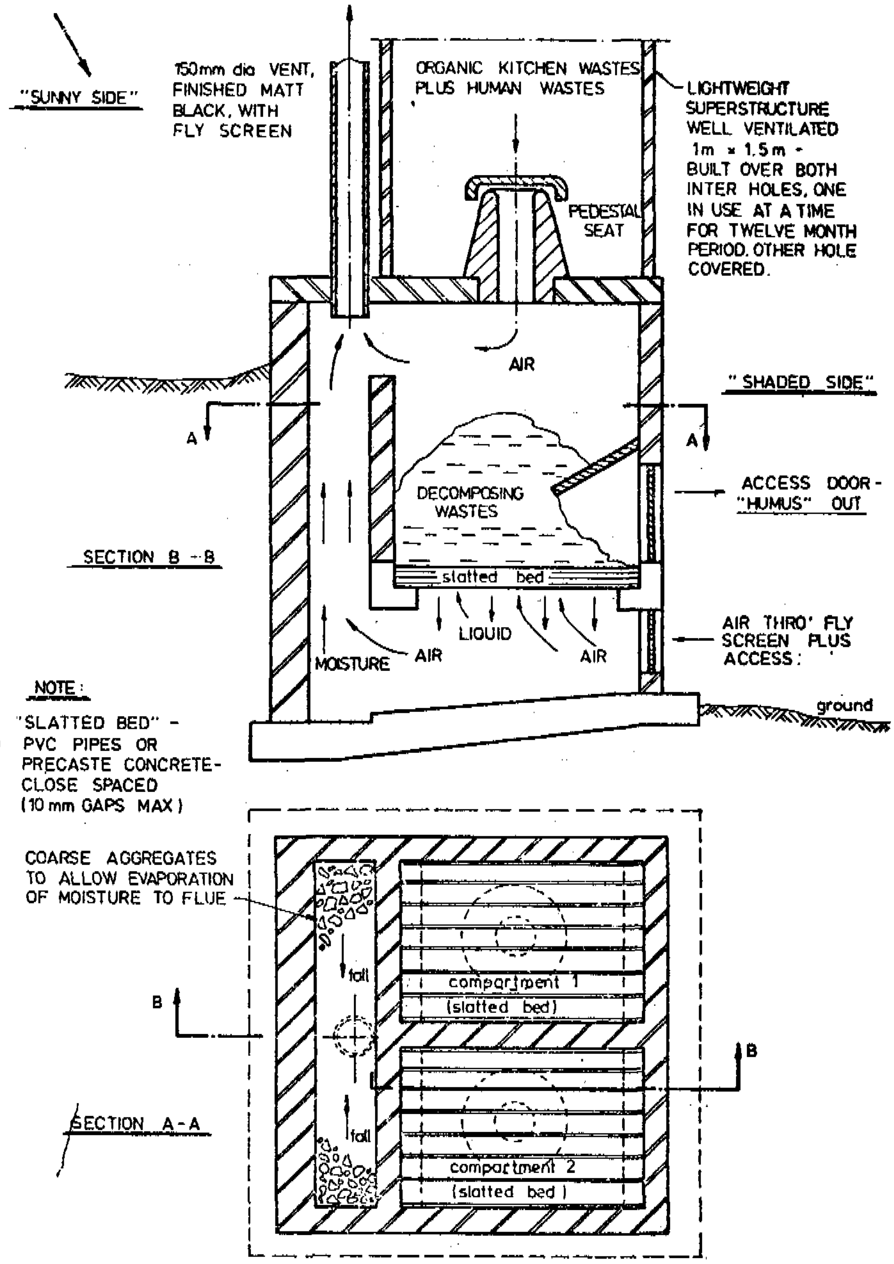


FIG. 7 : DOUBLE - VAULT COMPOSTING TOILET (PROPOSED DESIGN)

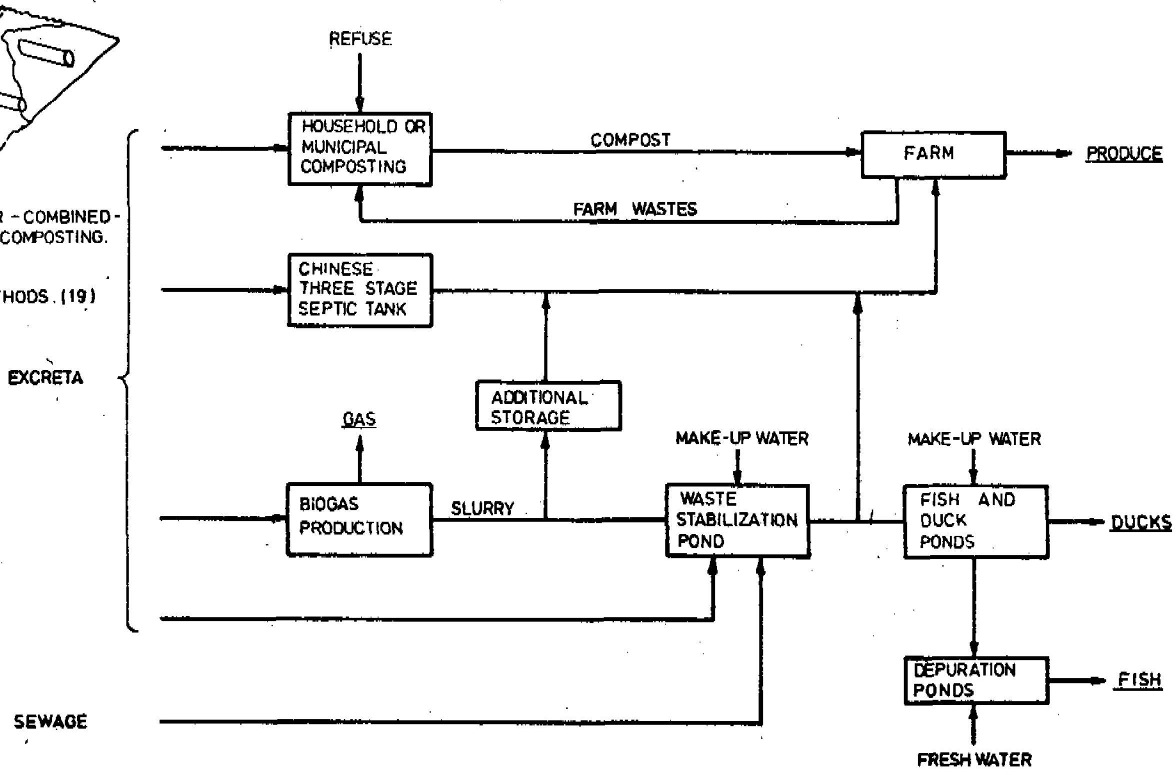


FIG. 8 : INTEGRATED WASTE REUSE PROCESSES. (27)

6th WEDC Conference: March 1980: Water and Waste Engineering in Africa

ALBERT M WRIGHT

THE VIP LATRINE

INTRODUCTION

During the past five years there has been an active search in several places for a range of sociologically and politically acceptable low-cost sanitation options for developing countries. One upshot of this search is the VIP latrine.

The term VIP latrine stands for Vented Indirect Pit latrine. Any pit latrine whose pit is vented and off-set from its superstructure is a VIP latrine. The pit may be completely off-set from its superstructure, as it is with the ROEC or Reids Odourless Earth Closet patented in 1944 in South Africa, or it may be off-set just sufficiently to allow a free drop of faeces from the squatting hole or pedestal seat into the pit. Like the conventional pit latrine, the VIP latrine is a low-cost on-site water-indepependent latrine. But it has several advantages over the conventional pit latrine. It is hygienic, virtually free from odours, and it is free from house flies. it is emptiable and structurally safe to use. It is potentially affordable and acceptable to many low-income communities, furthermore, existing bucket or pan latrines can be readily converted into VIP latrines.

The object of this paper is to summarise the salient features of VIP latrines developed at Kumasia.

SALIENT FEATURES

Basic & Alternative VIP Latrines

Two types of VIP latrines have been developed. These are the basic and the alternating VIP latrines. In the basic VIP latrine there is one vented pit for every latrine compartment. In the alternating VIP latrine, however, two adjacent vented pits are accessible from each compartment. The number of pits required in alternating VIP latrines is always one more than the number of compartments.

There are basic VIP latrines of the ROEC type which have been in use for the past twenty years without emptying. But the design of this type of VIP latrine does not allow sufficient time for the pathogen destruction before emptying a pit which has become full. This disadvantage is overcome in the alternating VIP latrine. In this system, one of the two adjacent pits is used whilst the other is withdrawn from use. When the pit in use becomes full it is withdrawn from use and the second pit is brought into use. When this also becomes full, the first pit is emptied and returned into use. In this way the two adjacent pits can be used alternately for a long time. Provided a filled pit is emptied at least one year after its withdrawl from use, it would be free from all pathogens except for a few Ascaris ova[1].

The alternating VIP latrine is recommended for long term usage whereas the basic non-alternating VIP latrine is recommended for temporary or infrequent usage.

Type of Ownership

The VIP latrine can be designed for three types of ownership, namely, individual or private ownership. A special type of group ownership is a two-compartment alternating VIP latrine constructed for two families with adjoining property having a common boundary wall. In this situation, the two compartments are constructed on either side of the rooms.

Size of Vent Pipes

In Kumasi, two sizes of vent pipes have been tried, and both have proved successful in single-compartment alternating VIP latrines. These sizes are 75 m.m. diameter galvanised iron pipes and 100 m.m. diameter asbestos cement pipes. Slight odours are noticed during certain times of the day when both sizes of vent pipes are used in multiple compartment communial alternating VIP latrines. No such odours are noticed in communial non-alternating VIP latrines. Vent pipes should extend at least 600 m.m. above the highest point in the toilet room, and the top end should be covered by a fly screen.

Pit Geometry

Two types of pit geometries have been tested in field trials in Kumasi. In the first type the face of the pit at the squatting end was inclined at an angle of 60° to the horizontal to allow the dropping faecal matter to slip down this inclined face. In the other, the near-end wall face was vertical. Upon inspection after two years, it was found that the rate of solids accumulation in the pits with inclined walls was lower. It is therefore recommended that the near-end walls of pits should be sloped.

Pit Ecology

In conventional pit latrines house flies and cockroaches are usually found. In the VIP latrines that have been built in Ghana no houseflies have been reported, cockroaches have been reported in a few cases, but in a number of installations Psychodidae of the genus Telmaltoscopus have been seen. Also known as moth flies, sewage flies or drain flies, these Pyschodidae are believed to be quite harmless and are also seen in modern bathrooms where they grow on the slime layers on hand wash basin drains. In high ground water areas Culex pipiens fatigans have been identified in the superstructure.

Pit Capacity

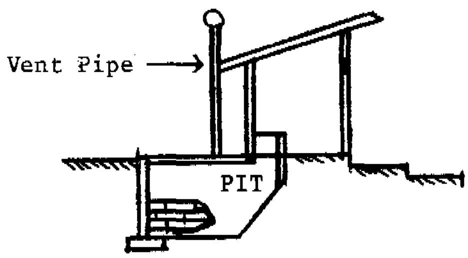
Mara et al (1978) recommend that pit capacities may be based on an excreta production rate of 0.06m^3 per person per year for dry pits and of 0.04m^3 per person per year for wet pits. Present experience in Ghana shows that the rates of accumulation may be lower due to partial digestion. But for the present these figures may be used for conservative design.

REFERENCES

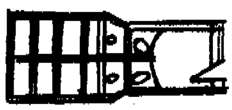
1. Feachem R.G. et al (1978) "Health Aspects of Excreta and Wastewater Management" Part 1 - Review and Analysis. IBRD Washington D.C. U.S.A. October 1978.

2. Mara D.D. et al (1978) "Appropriate Sanitation Alternatives A field Manual Manual" Energy, Water & Telecommunications Dept. The World Bank October 1978.

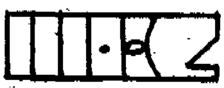
DOMESTIC VIP LATRINES



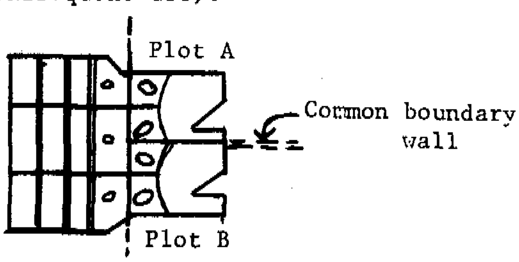
Sectional View : VIP Latrine



Plan : Alternating VIP Latrine
(For long-term domestic use)



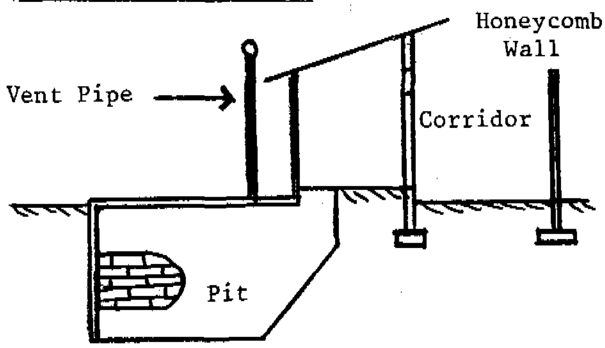
Plan : VIP Latrine (For temporary or infrequent use).



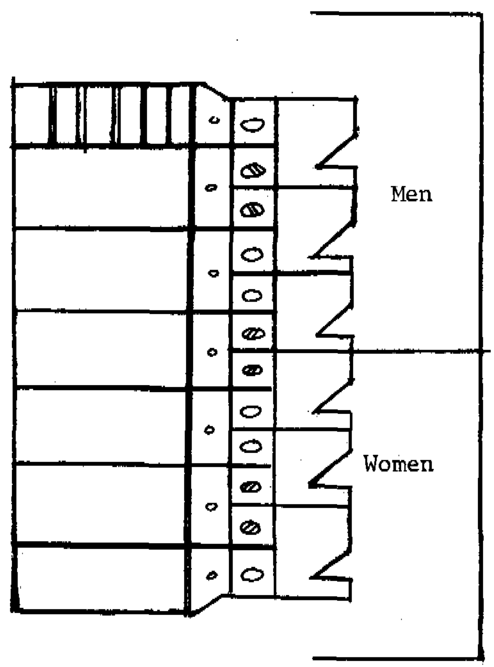
Two adjoining alternating VIP Latrines.

(For long-term use where common boundary wall exists)

COMMUNAL VIP LATRINES



Sectional View : Communal VIP Latrine



Plan : Communal Alternating VIP Latrine
(For long-term use)

NOTE: Drawing not to scale

Session 6: EXCRETA AND OTHER WASTE DISPOSAL

Discussion

Morag Bell and John Pickford

People and Pit Latrines in Africa

Dr Morag BELL said that the emphasis made in the paper was on the problems created by the movement of population from rural to urban areas. Problems caused by poorly educated, unemployed immigrants in squatter areas could be to some extent alleviated through low-cost technology and self-help schemes. The people were encouraged to build their own pit latrine, and programmes were started to make them more aware of the advantages of better sanitation and frequent washing.

2. The cultural practices of the people were taken into account by a study of the types of pit latrine most suited to different circumstances. Where these programmes had been carried out, they have been most successful and have gone a long way towards alleviating problems and making a better environment.

3. Mr John PICKFORD described the various types of pit latrine, both good and bad, with the help of slides. He emphasised that there were no rules to govern which type of pit latrine would be found in a particular area. Local tradition was most important in the choice of most suitable details.

4. Mr J N GITONGA commented on the importance of cultural traditions. He said that in some areas of Kenya men were not allowed to enter a privy in the presence of women or children. This type of very strong tradition was hard to break. In another area of Kenya where an outbreak of cholera occurred the Government tried to prevent the spread of the disease by making the people build pit latrines, but the people still continued to go out into the bush, refusing to use the pits. Funerals were another problem, since everyone attended them. They helped to spread the disease and eventually the Government had to ban them. There was a great outcry at this. The problem was a lack of education and understanding. How should we combat these problems?

5. Mr PICKFORD thought it was wrong to try to break traditions. It was better to use them and to gradually adapt them. If at first the people would not use the same latrine, then for a time they would have to have separate ones, perhaps over the same pit. It was important to understand what the people wanted; then if what was provided came close to what they wanted there was more chance of success.

6. With reference to cholera outbreaks, in Tanzania it was found that the disease was being spread by the practice of the women washing the bodies before the funerals. They washed the body but then did not wash their own hands afterwards.

7. Dr T O EGUNJOBI emphasised the need to take account of the socio-cultural characteristics of the people before proposing a type of waste disposal system for them. At a very local level, there could be differences between households. For example, in a traditional Nigerian compound there might be Muslims who used water for cleansing and Christians who used paper. So where should the line be drawn in an attempt to find a suitable solution to a set of circumstances?

8. Mr PICKFORD thought it a good question. In Dar es Salaam, where 60% of the population were Moslem and 40% Christian, 98% used water for anal cleansing. So it was important not to have any preconceived ideas.

9. Mr T R CROSSLEY said that an important part of the Ghana Urban Development Programme's study of squatter area upgrading comprised research into ways and means of increasing the earning capacity of the people. He asked if Dr Bell had any experience of this type of research elsewhere.

10. Dr BELL said that in Botswana many people in these areas were involved in the informal sector, which was regarded as illegal in many countries. By giving squatters legal rights of tenure and also legalising some of these informal sector activities, it was possible for these people (who would otherwise be unemployed) to pay back loans, albeit in nominal amounts over a long period.

Dr N Egbuniwe

Alternative Excreta Disposal Systems in Eastern Nigeria

11. Dr EGBUNIWE described the various types of sanitation facilities found in Eastern Nigeria. Each had its particular problems, and now people tended to want a latrine inside the house instead of in an outhouse, so obviously pit latrines were not suitable for this. The most popular facility was the

septic tank, but there were problems due to lack of water. Eventually the septic tank would replace all other methods, but this would take time.

12. Professor B Z DIAMANT commented that the average percentage of the population of Africa as a whole who used pit latrines was 21%, so the 90% quoted for this area was remarkably high.

13. Mr D K OMODARA asked how to prevent the problem of cockroach breeding in septic tanks. Dr EGBUNIWE replied that he had never had this problem.

Dr K O Iwugo

Resources Recovery in Tropical Waste Disposal: Composting and Biogas Technologies

14. Dr IWUGO explained that his paper was the second half of a paper on biogas technologies which would be presented in September 1980 at the GIAM VI Conference. The paper arose out of experience gained when consulting for the World Bank, surveying low cost sanitation systems.

15. It was usually difficult to convince officials of the benefits of waste disposal and water supply systems. People in Africa tended to believe what they saw, so systems which produced something useful were more likely to succeed. From composting toilets the people got fertiliser as well as a toilet and so this encouraged them to use the system. The composting system could not replace chemical fertilisers but would be a valuable supplement. Dr IWUGO described the principles of the composting process and the types of toilets. Summarising, he said that conventional sanitary engineering had always looked at prevention of disease, but in Africa there should be more emphasis placed on recycling in a low-cost system.

16. Dr O C IGWE asked about the socio-cultural effect of any decision made about an appropriate system for an area. Dr IWUGO answered that so far in Africa, no-one had produced good compost, but once the people had been shown that it was possible to make a good compost which would be useful to them, any socio-cultural problems would be overcome. Technology had often been found to overtake beliefs and tendencies.

Professor Wright

The VIP Latrine

17. Professor WRIGHT said that the paper described the results of a research project with the object of identifying different systems for rural excreta disposal and to modify or adapt the most suitable for Ghana. Twentyfour different systems were studied and ranked. The pou-flush came out on top and second was the ROEC. So the commission became to develop the ROEC into the Ventilated Indirect Pit.

18. Dr E A ANYAHURU asked whether any studies had been undertaken on the conversion of the VIP to a water-carried system. He also asked about the biodgradability of sticks and newspapers, and whether twenty years is too long and impractical a life for a VIP latrine.

19. Professor WRIGHT said that the VIP was essentially a water-independant system for use where water was not readily available. If people then became able to afford something else, it would be possible to convert the pit to a septic tank.

20. The VIP had a good appetite and would accept most organic wastes, the rate of fill would be affected. VIPs of the ROEC type had been in use for twenty years, but new designs would fill up in about two years, thus allowing people to get into the habit of emptying them.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

SULEYMAN O ADEYEMI

LOCAL MATERIALS AS FILTER MEDIA IN NIGERIA

INTRODUCTION

For purely economic reasons, sand from the nearest river-bed to water treatment plants are being used as filter media. Besides, Nigeria is endowed with other materials which can be suitable as filter media. Examples of such material are bituminous coal, coke coal, and caramies.

However little is known about the properties of these materials in their local form. In spite of this, local sand is being substituted for imported sand as filter media in many of the new treatment works.

The common practice is to determine the suitability or non-suitability of the sand simply on the basis of sieve analysis alone. This is definitely an insufficient basis to accept or reject any sand as filter media.

Even when the particular sand has been selected, the problem of operating the filter optimally arises because of the lack of sufficient knowledge of its characteristics.

The objective of the research project is to determine the suitability of any of the local materials, develop performance criteria through pilot plant studies and improve design and operation in order to meet the desired quality goals.

However in this paper, we will report the results of the studies conducted to determine the physical characteristics of the sample sand from various locations in the country, full-scale plant studies of the performance of a filter plant using local sand as media, and pilot plant studies to compare the performance of some of the local sand.

PHYSICAL CHARACTERISTICS

Some of the physical properties presently measured include percentage solubility, percentage usable, % too coarse, %too fine, specific gravity, size, fall velocity, sphericity. Others that need to be measured are filtrability index and durability.

Table 1 shows the properties of the stock sand from a number of locations in the country. It can be seen that for most of the sample sand, their effective sizes lie outside the standard requirements of 0.35 - 0.70mm (1). The uniformity coefficient for a few of the sample sand falls within the acceptable range of 1.3 - 1.7 (1).

The obvious inference is that only a small percentage of the stock sand is directly usable as filter media. However in a country where labour is still relatively cheap, it may not be uneconomical to use the graded stock.

The percentage solubility of the samples is well within the specification and a lot of them were found to be clean.

The sphericity for most of the different sizes in each stock sand ranges from 0.4 to 0.8.

The values in the table represent the averages. They do not compare well with the value for Leighton Buzzard ($\psi = 0.85$) or NCB anthracite ($\psi = 0.7$) (2).

FULL-SCALE STUDIES

The 5.5mgd (25 l/d) Zaria water treatment plant commissioned in 1975 has been using the sand from the bed of river Galma as its filter media. The filter media consists of 24 inches (61cm) sand of 14 mesh - 25 mesh grading, 4ins (10.2cm) of coarse sand (6mesh - 14mesh), 10ins (25.4cm) of pebbles (6mesh - ½"). The average filter flow rate is 2.2gpm/ft^2 (1.4mm/s).

The purpose of the full scale plant studies is to evaluate the performance of the filtration process over a period of time. The performance criteria include filtrate quality, Break through Index and head loss pattern.

For the periods of study, the effluent

Table 1: Properties of the stock sand

Sources	Specific gravity	P_{10}	$U = \frac{P_{60}}{P_{10}}$	Solubility %	ψ	P_1%	P_2%	P_3%
Jibiya	2.62	0.17	3.41	0.2	0.6	28.0	52.2 d=0.48mm	80.2 d=1.25mm
Minna	2.66	0.22	2.50	0.3	0.57	80.0	42.0 d=0.48	NIL
Gora	2.54	0.34	4.41	0.3	0.63	30.0	15.0 d=0.43mm	45.0 d=1.0mm
Batsari	2.66	0.25	6.60	0.4	0.58	24.0	23.6 d=0.46mm	47.6 d=1.0mm
Lagos	2.75	0.22	1.82	1.4	0.53	20.0	78.0 d=0.5mm	NIL
Sokoto	2.71	0.30	3.33	0.2	0.53	42.0	17.9 d=0.47mm	59.8 d=1.0mm
Kaduna	2.64	0.30	1.77	1.1	0.51	60.0	49% d=0.48mm	NIL
Kwall	2.69	0.34	2.33	0.6	0.49	50.0	12% d=.45mm	62.0 d=1.1mm

P_1 = % Usable
P_2 = % too fine
P_3 = % too coarse

turbidity was consistently less than 1.0JTU averaging about 0.6JTU. The turbidity removal was ususally about 90% just after backwashing declining to 60% just before the next backwashing.

Figure 1 is a graph of filter quality as a ratio of the inlet quality (C/co) with filter run time. The rise which is referred to as the filter breakthrough is terminated at value of 0.28. This is higher than the acceptable value of 0.2 for a 24ins filter depth (3).

Figure 2 shows the headloss pattern for a typical filter run. The graph is almost linear indicating that there is filtration (or clogging) with depth. This is a desirable phenomenon for deep bed filters.

The average breakthrough Index K = 1.28×10^{-3}. It falls between the values for water receiving average degree of pretreatment and high degree of pretreatment (4).

PILOT PLANT STUDIES

The purpose of the pilot plant studies was to compare the performance of the stocksand from river Galma with anthracite coal-sand media under both coagulated and uncoagulated influent water.

The studies was then extended to compare the performance of three sand samples which closely satisfy standard specification for physical properties (Zaria, Kaduna and bar beach, Lagos).

The pilot plant was set up at the Zaria water treatment plant.

The pilot filter containing the river Galma sand performed equally well as the dual media with the effluent turbidity much less than 1.0JTU for coagulated influent water. As expected the performance of both

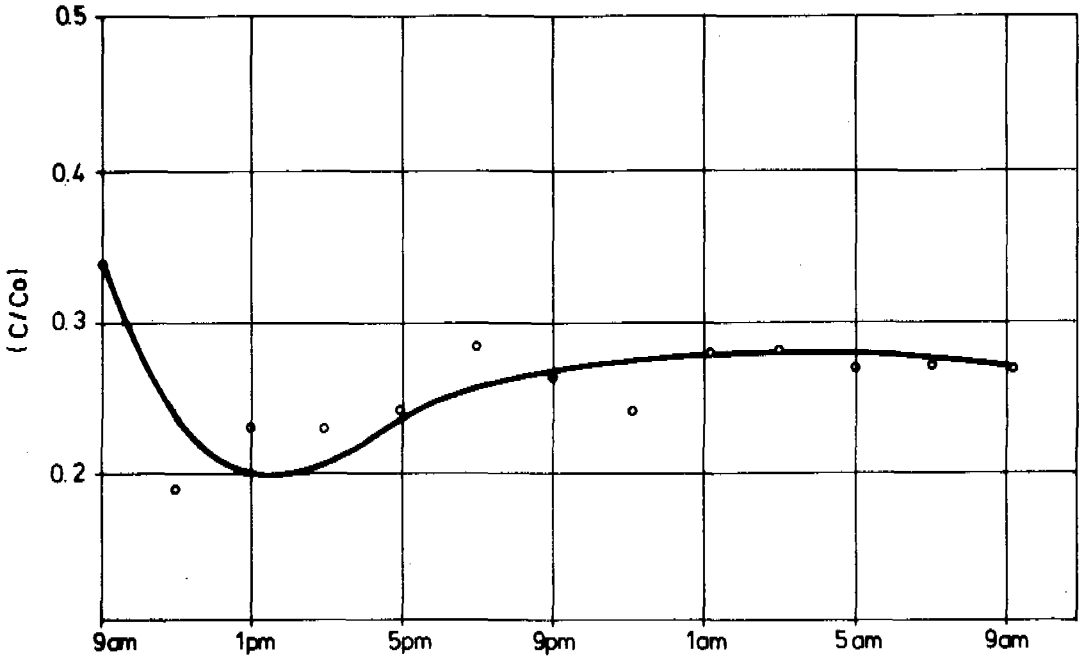


FIG. 1 FILTRATE QUALITY (C/Co) VARIATION WITH TIME OF FILTER RUN.

filters were poor for uncoagulated influent water.

Figure 3 shows the headloss pattern for both pilot filters. Characteristically, the headloss developed by the dual media is lower, less rapid, and more linear. However the headloss pattern for the pilot filter is not different from that of the full scale.

The comparative peformance studies clearly show that the Lagos bar beach sand and river

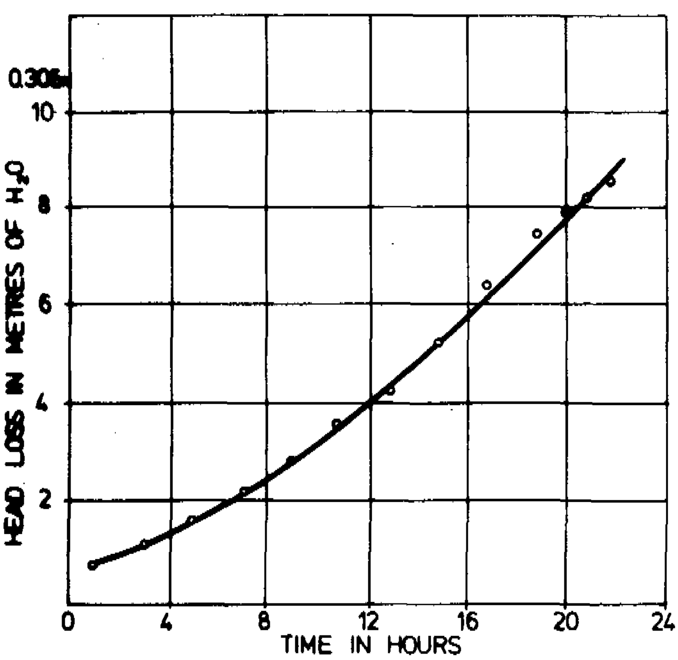


FIG.2 HEAD LOSS Vs TIME OF FILTRATION.

Kaduna sand perform better than the river Galma sand in terms of turbidity remowal efficiency, filter run length time and head-loss development.

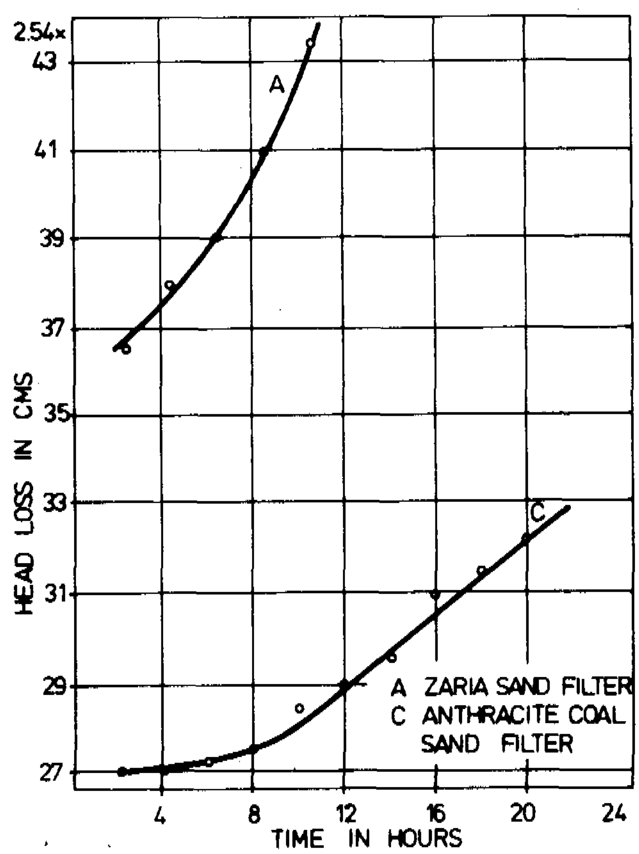


FIG.3 HEAD LOSS Vs TIME OF FILTRATION

CONCLUSION

The standard specification set for the various physical properties of a filter media can be met by the locally available sand even if it will require major regrading. But in a country with cheap labour, this may not be too uneconomical.

However the other aspect that is under active study is the modification that can be made to the present design criteria and standards (such as ideal filtration rate, optimum filter depth, type of flocculant and dosage) in order to make them more relevant to local materials, and conditions.

REFERENCES

1. Culp G.L. and Culp R.L. New Concept in Water Purification, Van Nostrand Co., New York, 1974 (A book).

2. Ives, K.J. Specification for grannlar filter media, Effluent and Water Treatment Journal, June 1975, 296-305.

3. Cleasby J. L. "Filtration" in Physico-chemical process for water quality control Wiley-Interscience, 1972 (A book).

4. Fair, M.F. Geyer J.C., Okun D.A. Water and wastewater engineering volume II Wiley and Sons, 1966 (A book).

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KALYANPUR Y BALIGA

DEVELOPMENT OF SMALL SCALE SYSTEMS FOR IRON REMOVAL FROM GROUNDWATERS

Direct transfer of technology of iron removal systems for groundwater treatment in use in developed countries is considered not desirable for developing countries in general, and small scale water supplies in particular. A research project was undertaken from July 1976 to July 1979 at the University of Science and Technology, Kumasi, Ghana, which this paper describes.

The methodology of the research project consisted of:
1. Identification of candidate systems from literature, correspondence and International visits.
2. Field survey to supplement available groundwater quality data as well as identification of a level of iron concentration acceptable to rural consumers, (vis-a-vis the Standards), for treatment targets.
3. Laboratory studies of candidate systems including modification of conventional systems.
4. Field testing of promising systems for development into technologies for practical application and dissemination.

After analysis of available information, a project staff visited India, Bangladesh, Tanzania and Malawi. Consequently the Domestic Iron Removal Unit (DIRU) and the Madras-type system were selected for testing in Ghana. In addition a conventional system was also selected to evaluate possible improvement of iron removal efficiency by plain sedimentation through the use of granular media in a sedimentation tank, in conjunction with slow sand filtration.

The field survey was carried out using questionnaires to assess user attitudes, and a field laboratory kit to determine ground water quality. A total of 187 boreholes were seen in 83 towns and villages of which 73 were found in operating condition at the time. An average iron concentration of 1.38 mg/l in the range of 0-19 mg/l was found, with 12 samples out of 47 showing concentrations above 1.0 mg/l. The highest concentration considered to be acceptable by some respondents was found to be 4.0 mg/l though others considered levels as low as 1.45 mg/l as unacceptable. It was found that some respondents was found to be 4.0 mg/l though others considered levels as low as 1.45 mg/l to be unacceptable. It was found that iron concentration alone may not be the basis for accepting or rejecting water.

The laboratory experiments using synthetic water showed that only about 11% of iron precipitates were removed by plain sedimentation with raw water iron levels in the range of 1.8-3.5 mg/l for a detention time of 60 minutes. Removals up to about 30% were observed when gravel of approximate size of 50mm was used as the granular medium in the sedimentation tank under a detention time of 60 minutes based on void volume. Slow sand filtration following aeration and granular media sedimentation, under flow rates from 0.12-0.4 $m^3/m^2/h$ produced satisfactory effluent with iron concentration in the range of 0.17-0.03 mg/l. The relevant ranges of pH and alkalinity were 6.9-7.8 and 67-92 mg/l respectively. While studies of granular media sedimentation tank extended to about 100 days of operation, filter studies were limited to five days of operation at each rate of flow.

Time constraints compelled the field testing of DIRU without prior laboratory studies. The DIRU was set up at a village near a borehole with a handpump. The iron concentration however was found to vary unusually very much in the range of 8.5-72.0 mg/l. During the operation of the unit with each bucketfull of water being poured intermittently, results of 17 days of operation showed an average effluent concentration of 42.0 mg/l. However continuous operation at flow rate of 0.72 $m^3/m^2/h$ on filter, for a two hour period on two days, gave an average effluent concentration of 0.12 mg/l from an average influent concentration of 15.8 mg/l. These results should be considered tentative in view of the short-term nature of testing.

It was considered desirable to modify the non-submerged filter of basic DIRU into a submerged filter to improve performance. The modified DIRU was able to produce an average effluent quality of 0.06 mg/l iron from an average influent of 15.9 mg/l based on two days operation of two continuous hours each.

Under similar operating conditions, but with two basic DIRU in series, average effluent concentration of iron was found to be 0.3 mg/l (evidently influenced by a single high value of 1.3 mg/l). Other modifications have been proposed but not tested. Because of the limited nature of the field testing programme so far carried out, it is recommended that more extensive field testing be carried out, including a prototype based on laboratory studies.

Acknowledgement is made of financial and material support of Health Sciences Division of International Development Research Centre Ottawa, Canada, and the assistance of project and management committee staff.

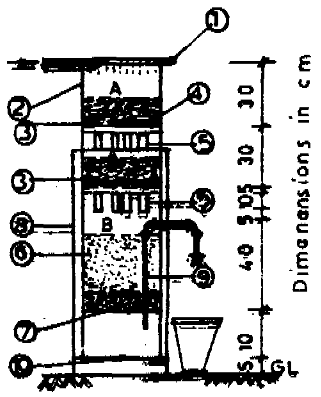

FIG 3(a) MOBIRU-1

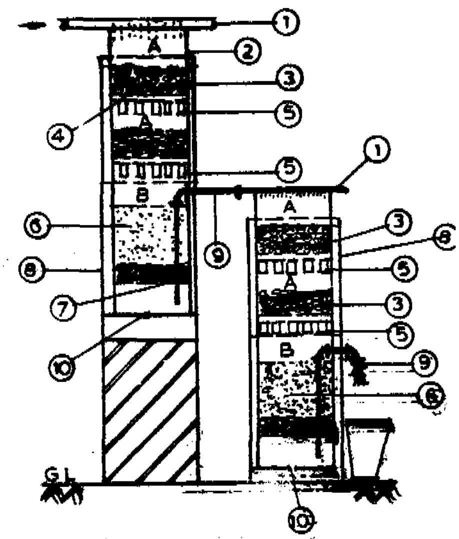

FIG BIRU-4

MODULAR COMPONENTS

A. CONTACT AERATOR B. SUBMERGED FILTER

LEGEND

1. 25mm PIPE INLET WITH HOLES AT 25mm C/C
2. GALVANISED IRON SHEET CYLINDER OF 37cm dia
3. 2.6cm CHARCOAL LAID 15cm DEEP
4. PLATE WITH 1.4cm HOLES AT 2.5cm C/C
5. VENTILATORS 2.5cm x 10cm
6. SUBMERGED SAND FILTER WITH 30cm COARSE SAND OVER 5cm LAYER OF 1.25cm GRAVEL
7. PLATE WITH 1.25cm HOLES AT 1.25 C/C
8. WOODEN FRAME
9. ø 2.5cm OUTLET PIPE
10. DRAIN

6th WEDC Conference: March 1980: Water and waste engineering in Africa

S OLESZKIEWICZ, J A OGUNROMBI, A FLOREK, A O ABATAN and J WOJDYLO

THE CONCEPT OF A DEPRESSURIZED WATER TANK

INTRODUCTION

Water storage tanks are readily constructed of concrete, mainly because of their durability and low maintenance costs. However, they require heavy reinforcement to resist the hydrostatic pressure of the contained water because of the low tensile strength of the concrete. In the case of cylindrical reinforced concrete tanks, the reinforcement amounts to about 15 kg per cubic metre of stored water and a little use is made of the high compressive strength of the concrete. For prestressed concrete tanks, the compressive strength of the concrete is partly utilised in supporting the prestressing tendons made from high tensile steel. This results in a reduction of the total reinforcement to about 10 kg per cubic metre of stored water. The use of concrete is also high, amounting to about 0.20 m^3 per cubic metre of stored water in the case of reinforced tanks and to about 0.15m^3 per cubic metre of stored water for prestressed tanks.

The high usage of structural materials in water storage tanks would be drastically reduced if the hydrostatic pressure inside could be balanced by the atmospheric pressure from outside. One way of achieving this would be to construct an hermetically sealed tank which could then be evacuated to remove the air from inside. The empty tank would then be prestressed by the outside air pressure, producing mainly compressive stress in a properly shaped tank and fully utilising the compressive strength of the concrete. As the tank is filled with water, the compressive stress decreases but provision can be made to eliminate any undesirable tension. A further consideration is that an hermetically sealed tank will protect the stored water against pollution.

A preliminary study has been carried out in the Department of Civil Engineering, Ahmadu Bello University and a model of a depressurised plain concrete tank has been constructed. These investigations have shown that the concrete required for such a tank can be considerably reduced when compared with a conventional prestressed concrete container even when reinforcing steel is not used at all.

DESCRIPTION OF TANK AND MATERIALS

The depressurized water tank model is assembled of 32 precast plain concrete curved plates. The pentagonal and hexagonal plates are 30 mm thick and the radius of their curvature is 735 mm. The tank is spherical with internal diameter 1440 mm and capacity 1.66 cu. m. The joints between the plates are filled with epoxy resin. The tank is provided with two sight - perspex glasses, a connector to vacuum pump on the top and another connector to a water source at the bottom.

The tank is founded on a plain concrete base cast in steel sheet cylinder with diameter 810 mm and height over ground level of 555 mm. This cylindrical support rests on a circular concrete mat of diameter 1400 mm.

Casting of the Concrete Plates

The plain concrete plates were cast in accurate timber formwork and compacted on the vibrating table with medium amplitude of vibration. The composition of the concrete mix was 1: 1.25 : 1.8 with w/c = 0.47. The Ordinary Portland Cement, local sand and gravel up to 10 mm were used. Slump of the concrete mix was about 30 mm. The strength of concrete after 28 days of hardening was (36 cubes were tested):

Mean strength:	48.04 N/mm^2
Standard Deviation:	3.72 "
Coefficient of Variation:	0.078

These results show that the degree of control was excellent. The characteristic strength of concrete, f_{cu} = 40N/mm^2 was gained after 28 days of hardening and f_{cu} = 50 N/mm^2 at the time of assembling the tank.

Joints between the Plates

The concrete plates were manufactured with high accuracy and the gap between the plates is 5 mm. The tank was assembled on the testing site with the joints filled up with epoxy resin

Araldite CY 219, hardener HY 219 and clean siliceaus fine filler with ratio 3 : 1 and 3½ : 1 (filler to resin). The resin hardened after 24 hours but did not flow excessively out of the previously mechanically fixed joints. Testing of bond between the hardened resin and concrete on standard briquettes (tension) showed failures out of the layer of resin in all tested specimens.

External Coating of the Tank

The external coating of the concrete tank was provided by the use of 2 to 3 layers of Decadex. This paint is used for covering roofs.

Laboratory tests were carried out to check the use of Decadex for a depressurized structure. The tests were performed on concrete discs with diameter 250 mm and thickness 30 mm which were subjected to vacuum on the uncoated side through the cover of a desicator. Mean results of 5 concrete discs for a specified number of Decadex coatings are presented in Table 1. The applied initial vacuum in all cases is 700 mm Hg. The loss of vacuum in pump is only 150mm Hg within 5 days which is negligible.

Table 1. Maintanance of Vacuum by Plain Concrete Discs Coated with Decadex

No. of Coatings	Vacuum Maintanance Time
Uncoated	7mins. 10secs
One Coating	8hrs
Two Coatings	14hrs
Three Coatings	100 hrs

INSTRUMENTATION

The unit is designed for continuous collection of ground water from a borehole on the basis of the concept of a depressurized water tank with suction pipe lines leading to a borehole as shown in Fig. 1. The storage tank, when depressurized by a vacuum pump sucks water and stores it until its delivery by a water pump to its required destination. The level of water in the tank can be monitored with an external level indicator. The connected vacuum meters in Fig. 1 measure the negative pressure inside the tank before and during pumping. Automatic control is provided which enables the vacuum pump to be turned on when the water level is below that required. The water pump is turned on when water level is above that required and is switiched off when the tank is empty. The vacuum pump is of type Spedivac JSC 50B (0.75 HP) while the water pump is of type Bavesford B20A0 (0.25 HP).

TESTING OF THE TANK

The tests presented below were carried out on the tank without any external coating.

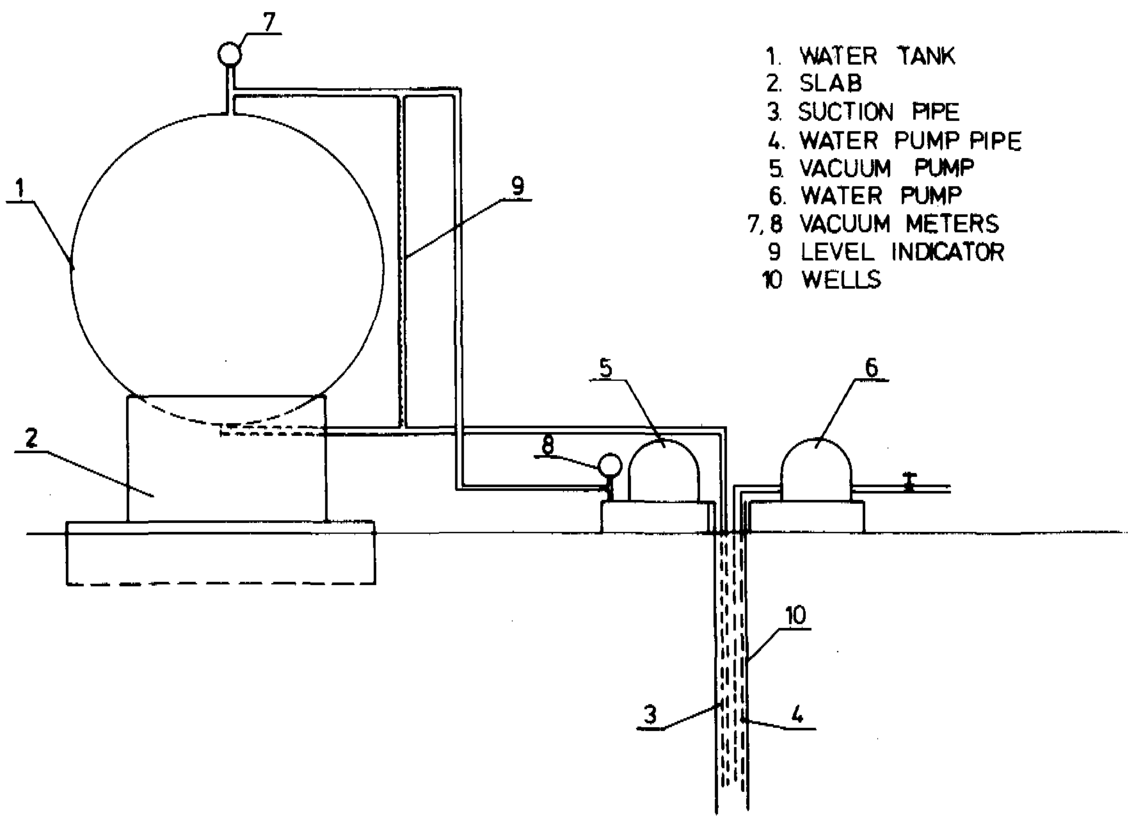

FIG. 1 THE INSTRUMENTATION AND AUTOMATION OF WATER SUPPLY SYSTEM.

The Empty Tank with Applied Vacuum

The vacuum in empty tank was maintained for a sufficiently long time. A maximum of 50% of absolute vacuum, i.e. 380 mm Hg was applied to the tank to avoid excessive loading. The observed reduction of vacuum is shown in Fig. 2.

The Tank Filled with Water

Water was sucked into the tank at 75 mm Hg vacuum with inlet at the bottom and stored water at ground level. The stability of vacuum was good enough since water was continuously sucked into the tank for some time after closing the supply of the vacuum. The tank was completely filled with water through a 20 mm diameter plastic hose connected to the inlet pipe within 48 minutes. During this period, the reading of the vacuum pump gauge was 178 to 203 mm Hg and the corresponding reading inside the tank was between 50 to 75 mm Hg. The former reading was for the completely filled tank (i.e. water at top of tank).

If the vacuum, in a partially or completely filled tank, is no longer maintained by a vacuum pump, and if the outlet is opened permanently, an interesting observation of the balanced condition between the hydrostatic pressure of water and vacuum was noted. After a short time from this balanced condition, water flows through the outlet at the bottom of the tank. If such a free flowing of water is required, then the tank is self-emptying. However, the time taken is rather long; e.g. about 20 hours.

STRAIN/STRESS DISTRIBUTION IN TANK

Tokyo Sokki electrical resistance strain gauges, type PC 10 with a gauge length of 10 mm, gauge factor of 2.09 and strain range of 2% were used to measure the strains. The adhesive used was Swiss Araldite. A Tokkyo Sokki Strain-Meter equipment was used to record the strains.

The gauges were installed approximately in perpendicular pairs in the circumferential and meridional directions on both the inside and outside surfaces of the tank. Hence, each gauge of the pair was approximately at the same angle of colatitude. There were fourteen gauge pairs on the inside and outside surfaces of the tank. Internal gauges and portions of the leads were waterproofed also with Swiss Araldite.

The experimental stress distributions for the spherical tank both in the circumferential and meridional directions were monitored for the empty tank with 50% vacuum, partially and completely filled tank. With vacuum only, the strains range from - 0.00004 to 0.0008. For the 50% filled tank,

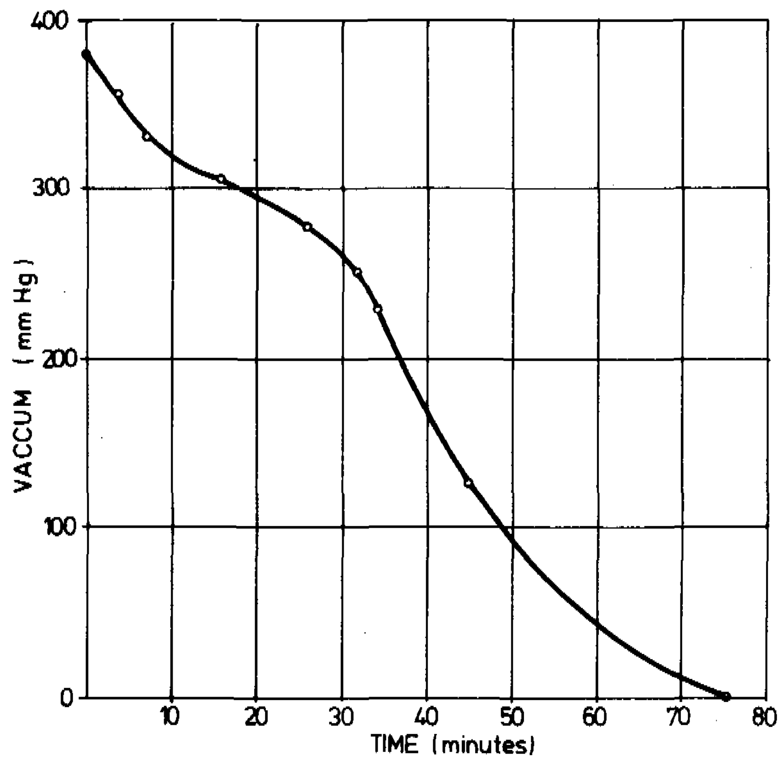

FIG.2 REDUCTION OF VACUUM WITH TIME.

the range of strains were more critical along the meridional direction ranging from -0.00004 to 0.0008 while for the completely filled tank, the corresponding strain range is from - 0.00003 to 0.0009. The stresses were computed from the strains using a nominal value of E_c = 34 KN/mm^2 corresponding to the characteristic strength of f_{cu} = 50 N/mm^2 at the time of assembling the tank. For all cases recorded, the largest variation in stresses is of the range - 1.36 to 30.60 N/mm^2 which are within the permissible working stress zone.

QUALITY OF WATER STORED UNDER VACUUM

A preliminary study on the effect of vacuum on the water quality was carried out in an erlemeyer flask which was maintained at a vacuum of about 250 mm Hg. Groundwater was stored (half-full) in the flask at this vacuum. The water was analysed for its initial parameters including the desolved oxygen (DO), pH and the total bacterial count. After three days of storage in the flask, the water was again analysed for the same parameters.

The preliminary results indicate a decrease in the DO value to about 13% of its initial value and an increase of about 6% in the pH value. Also, the total bacterial count was observed to decrease by about 45%. The observed decrease in DO value was probably due to difference in its partial pressure in the water and in the air above the water which may result in its escape in an attempt to maintain an equilibrium. Similarly, other gases including CO_2 may escape. The removal of CO_2 may tend to raise the pH of the water. While the vacuum may have some effects on the micro-organisms in the water, prolong storage and other enviromental factors may tend to decrease the bacterial counts. However, more research is required in order to establish these results.

CONCLUSIONS

The results of the preliminary experimental tests on the concept of a depressurized water tank lead to the following conclusions:

The maintenance of equilibrium between hydrostatic water pressure and vacuum in tank is easy to keep. Therefore, it is possible to store water with very small stresses in the tank.

All operations required to verify the concept are not complicated and the controls to prevent losses are simple. Hence, in the absence of a skilled operator, a simple safety value can be provided.

The tank may be used as a storage tank to be filled or emptied at will. The outlet of water may be increased or decreased by controlling the vacuum existing in the tank accordingly. Similarly, the tank could be used to replenish a small confined aquifer in its vicinity.

The full compressive strength of concrete can be utilized using the proposed concept with considerable savings in the material even in the absence of any reinforcing steel.

Precast segments of the tank can be mechanically mass produced in concrete factories and easily assembled on site without any construction equipments or with light construction equipment if the tank has very large dimensions.

Additional analytical and experimental research to ascertain fully the above prelinary findings are desirable. Investigations into the use of alternative energy sources and alternative means of water purification just close to the tank are currently underway at Ahmadu Bello University in order to make the tank completely self operational in the production of safe, drinkable water.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

J O OYENNGA

LOW COST SANITATION IN BUILDINGS

INTRODUCTION

The subject title as its name implies gives an instant thought of sanitation applicable to a rural area; for obviously, in an urban area where good pressure water mains, electricity supply, public sewers and sewage treatment works invariably exist, the sanitation no longer becomes a low cost one.

This paper has attempted to treat on this basis problems and solutions to them of popular but very important areas of sanitation which touch on the habit of the society generally. These include principally water supply and sewage disposal.

WATER SUPPLY

Estimation of Demand

While many authorities, books and others suggest quantities required per head per day as ranging between 81 litres (18 gallons) and 382.50 litres (85 gals), I have come to a figure of only 50 litres (11 gals) for people in rural areas based on facts and recorded over a period of time.

During a rural sanitation visit with a team of Public Health Inspectors in the areas of the former Western State of Nigeria, experiments made on dwellers of residences revealed that an adult female who uses slightly more quantity of water than male would bathe satisfactorily on a stout galvanised bucket of water of about 18 litres (4 gals) in the morning. Drinking takes a very maximum of 4.5 litres (1 gal) for a whole day for a manual worker. Cooking (cleaning of meat, fish or vegetables) 6.75 litres (1.5 gals), washing of plates and cooking utensils also 6.75 litres (1.5 gals) and the remaining 13.5 litres (3 gals) built up daily towards the weekend provides some 100 litres (22 gals) about 6 bucketsfull with which clothing is washed just before a bath on Sunday morning.

Rainwater

Rainwater is naturally very pure and would have been an ideal source for the provision of low cost water supply to dwellings but it unfortunately has its many problems including that of collection of suspended impurities as it falls through the atmosphere.

Roofs and other surfaces receiving rainwater for collection and storage are invariably open and large areas, which readily attract and harbour pollutants. These of course include dust, birds and insect droppings, accumulation of organic matter etc. It is also very irregular being seasonal in nature and for these reasons does not offer a satisfactory provision.

Rivers and Streams

Where a river or stream is the only available source of supply for a rural area, the method of purification should principally be sedimentation and filtration. The risk of possible pollution is greatest in water from these sources and in addition, contain heavily suspended particles of river sand and many foreign matters. Some form of coagulants are sometimes introduced into the water at sedimentation stage to assist and hasten the process. Good practice is to allow the water to be undisturbed for a period of between 18 and 24 hours for optimum results.

There are various methods of achieving end results from this system. They all almost invariably require electric pumps and other sophisticated equipment. As the scope of this paper is limited only to rural areas, treatment method to water required in small households will be discussed.

A small circular covered and vented plastic cistern 135 litres (30 gals) is installed on a wooden platform raised 1.52 (5 ft) in the kitchen or other suitable area in the house. This quantity represents a 24 hour actual demand in a household of two adults and three children after allowing for the probable simultaneous usage. Fig. 1 shows the installation and working principles of a typical system. After having a dialogue on the possible commercialising of this equipment with Messrs Metalloplastica, assurance was given for full cooperation upon approval by a local authority. Arrangement if necessary may be incorporated for the manual dosing with chlorine depending on the source of water and degree of pollution.

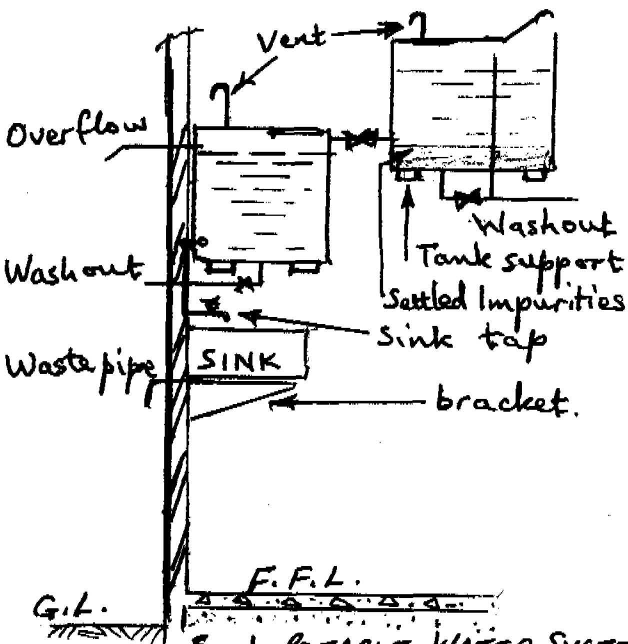

FIG 1. POTABLE WATER SYSTEM

Wells

Water from wells should be similarly treated. Well water is normally drawn by a bucket and windlass (See Fig.2) The advantages include:-

(a) a considerable saving of time and energy involved in not having to walk the distance to the nearest river or stream to fetch water and

(b) convenience; while the disadvantages include:-

(a) high initial capital outlay in providing a well, and

(b) the constitution of a much greater risk of pollution especially after a heavy storm.

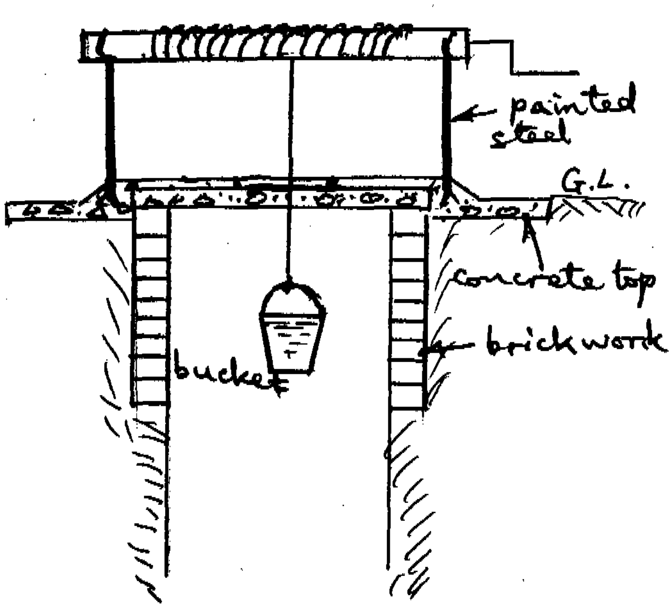

FIG 2. A WELL

Sewage Disposal

The principal aim of providing low cost sanitation on sewage disposal is to effect a relatively small proportion of crude sewage matter to be changed into an effluent reasonably stabilised and ready to be discharged into streams without causing any nuisance. In this connection, the septic tank readily comes to mind. However, for a septic tank to function, one requires good pressure piped water to automatically supply and cease as necessary from the flushing cisterns plus other pumping equipment. This then boils down to high cost sanitation quite reminiscent of a fully developed urban area.

Pit Salga

The pit salga may now be critically looked into for possible modification and improvement. It appears that this may be the only solution combining efficiency with economy.

Pit salgas are normally of between 0.75m and 1.00m diameter and anything up to 10.00m in depth. Care must be taken not to site one within 10.00m vicinity of a well which source is used as drinking water. One of the most important features is adequacy of ventilation which must be suitably provided. Method of construction of a typical pit salga is shown in Fig. 3. It may be roofed over with advantage of use during inclement weather. This system has been known to exist for well over a century but usually abused by users where salgas are badly constructed and local mass education programmes are not organised.

When its construction and use is properly supervised, claims to the merits of the system include:-

1. Comparatively "low cost", which is the cream of the subject matter.
2. Efficiency - will not breed flies nor smell.
3. Minimum area of land is required being just only 0.8m diameter as stated.
4. A disused pit, left for a period of two years or more undisturbed may be re-excavated and cleared for use again.
5. Excavated humus is a useful fertiliser for farmers.
6. In suitably porous land, a pit salga may last 8 to 10 years providing completely trouble and maintenance free use. Fig.4 shows a table of comparison of costs and life between a septic tank and a pit salga.

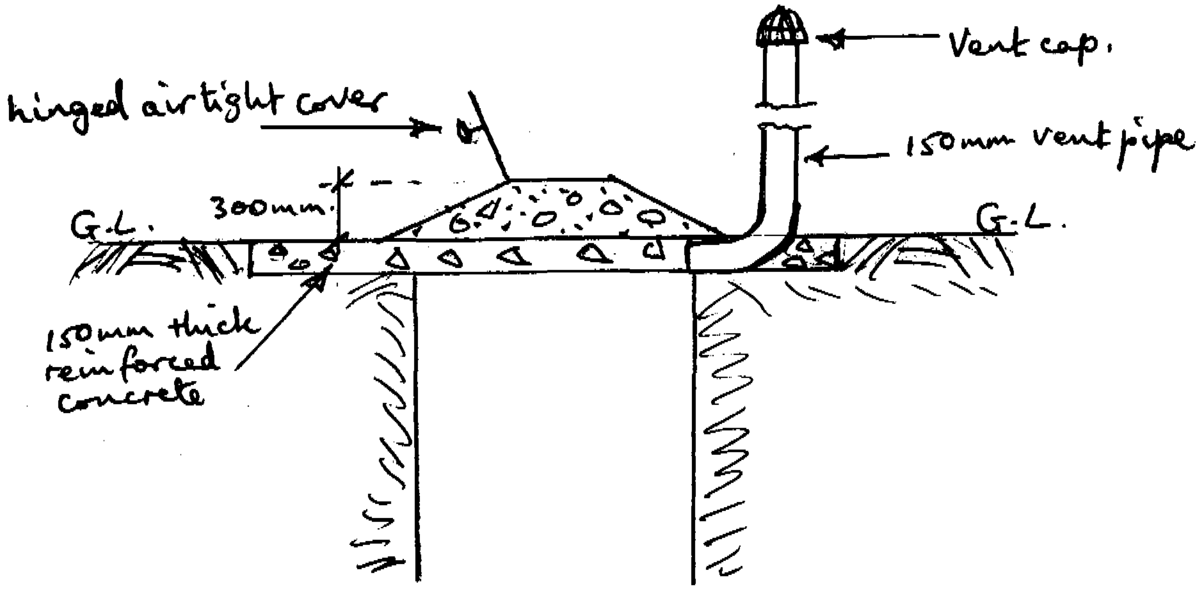

FIG 3. A PIT SALGA

CONCLUSION AND RECOMMENDATION

While pipeborne potable water supply from the treated source to the point of consumption is accepted as the most hygenic, it is correspondingly the costliest. Heavy and specialised equipment, the professionals, specialists and others involved in running the system characterise huge sums of money associated with it. A local authority would normally charge or levy water rates even if subsidised. In a society, the type in question where per capita income is ₦250,00, a water rate of ₦80.00, one of the lowest ever, is very unlikely to be met and therefore, the foregoing low cost methods are the most suitable and practicable.

If put to practice, the systems of provision of low cost sanitation discussed here could yield tremendous results beneficial to health. At present, Nigeria improves the state of health of her citizens as more and more State Governments introduce free health schemes. In many other African countries today where the financial and economic situations are not as buoyant as to permit Government involvement in such free health schemes, the aforementioned systems will prove valuable to local people.

Existing sanitary regulations and bylaws especially those applicable to the rural areas should be enforced by the various local authorities. Obsolete sections should be deleted while new ones which should reflect modern concepts and tradition have to be enacted.

Mass appeal and open invitation should be extended to our engineers, scientists, manufacturers and others to come out with ideas and produce simple designs, appliances and gadgets which would considerably improve on the sanitary living standard of the society.

Incidentally, at the time of going to press, a news flash, broadcast on the Federal Radio Corporation of Nigeria quoted a State Government as setting out to award contracts for rural electrification of 58 towns and villages. There is no doubt that no sooner the scheme is completed than central or municipal water supply scheme follows. If this pattern of action is taken by all our state governments, there will be little or no rural areas as such lacking sanitary facilities left at the end of the century. Then, who knows? The problem may turn the other way round; namely, "High Cost Sanitation in Urban Areas".

Table 4a Comparison of Initial Cost between a Septic Tank and a Pit Salga for 30 years - Amount in Nigerian Naira (₦)

YEAR	1950	1955	1960	1965	1970	1975	1980
Septic Tank	240.00	450.00	600.00	800.00	1050.00	1200.00	1700.00
Pit Salga	13.00	18.00	40.00	62.00	80.00	110.00	160.00

Table 4b Comparison of Maintenance Cost

YEAR	0	5	10	15	20	25	30
Septic Tank	NIL	300.00	600.00	800.00	1000.00	1080.00	1160.00
Pit Salga	NIL	NIL	New Salga	NIL	New Salga	NIL	New Salga

Table 4c Comparison of Total Cost (Initial and Maintenance) for a period of 30 yrs.

YEAR	1950	1955	1960	1965	1970	1975	1980
Septic Tank	240.00	540.00	900.00	1040.00	1240.00	1320.00	1400.00
		450.00	530.00	730.00	930.00	1230.00	1530.00
			600.00	800.00	1000.00	1300.00	1600.00
				800.00	1000.00	1300.00	1600.00
					1050.00	1350.00	1650.00
						1200.00	1500.00
							1700.00

YEAR	1950	1955	1960	1965	1970	1975	1980
Pit Salga	13.00	13.00	53.00	53.00	133.00	133.00	293.00
		18.00	18.00	58.00	58.00	138.00	138.00
			40.00	40.00	120.00	120.00	230.00
				62.00	62.00	170.00	170.00
					80.00	80.00	240.00
						110.00	110.00
							160.00

TOTAL COST IN NAIRA

References

1. Mc Guiness and Stein - Sanitary Drainage. M & E Equipment in Buildings Fifth Edition by Wiley, 1971.

2. The Public Health Engineer Vol.7 No. 2 of April 1979 by Crane.

Session 7: WATER TREATMENT, STORAGE AND DISTRIBUTION

Discussion

Dr S O Adeyemi

Local Materials as Filter Media in Nigeria

Dr ADEYEMI explained that two years ago the Government studied a list of imported items, and decided that the import of sand should stop for economic reasons. This made it necessary for water treatment plants to look elsewhere for sources of filter media. Problems arose because American and British sand, formerly imported, had standard characteristics, but local sands were of unknown character, and so no prediction could be made of their performance. He described how important the pilot plant studies were since a particular sand could not be accepted or rejected on its physical properties alone.

2. Mr D YOUNG did not understand part of Table 1, and wondered whether p1, p2 and p3 were intended to be in that order. Dr ADEYEMI explained that p3 was the percentage above which the sand was too course.

3. In reply to a question about experimentation on backwashing, Dr ADEYEMI said that it was necessary to backwash every 20-30 hours. There was some weight loss. Experiments had been done by continuously backwashing the sand over 100 hours. This was the equivalent of three years' life for the filter. The measured weight loss was found to be not more than 1%.

4. Professor A M WRIGHT asked what form the work would eventually take. Dr ADEYEMI replied that the main objective was to see if design parameters could be modified, and to find the best pre-treatment combined with the type of material available. The operators must then be guided and taught. The more found out about these materials, the more problems could be solved.

Dr K Y Baliga

Development of Small Scale Systems for Iron Removal from Groundwaters

5. Dr BALIGA reported that his paper was a result of a recent project at Kumasi, supported by IRDC of Canada. Iron was not a health hazhard when it occurred in drinking water. The problem was an aesthetic one, in that if offered water tasting of iron, people might instead opt for water which had a real health risk. So iron removal was necessary, but it had been a difficult task. The general idea was to develop suitable laboratory solutions which could then be transferred to the field. So far the results had only been tentative, but hopefully they would be better in the future.

6. In reply to a comment that oil drums used as filters corroded very easily, Dr BALIGA explained that groundwater contained a great deal of carbon dioxide and so had a low pH, and this was why the drums corroded. For the Kumasi experiments, synthetic water with a pH of 6.9-8.0 was used, so there were no corrosion problems. The filter was not backwashed since it was a slow sand filter. A rapid sand filter was not suitable for rural areas. Regeneration of the sand filter was by scraping off the top 20-30mm, so all slow sand filters needed regular maintenance.

S Oleszkiewicz, J O Ogunrombi, A Florek, A O Abatan and J Wojdylo

The Concept of a Depressurised Water Tank

7. Professor OLESZKIEWICZ described a form of concrete water tank which needed no reinforcement. The concept was one of reverse loading by air pressure. If air was removed from the tank and the tank was then connected to a water supply, the tank filled due to atmospheric pressure. When the water was taken out of the open container the level in both fell and the tank emptied. Because there was no previous experience of this type of tank, a model had been made which was available for inspection.

J O Oyennga

Low Cost Sanitation in Buildings

8. Mr OYENNGA said that the paper was based on wide experience and showed that what was needed must be low cost and must avoid the use of such mechanical aids as pumps in rural areas. The typical Nigerian was very conscious of cost, which would be the deciding factor. A major problem was the lack of communication between the people and the Government. Designers and engineers did not come from the area they were dealing with and so could not argue for the people. If they were on the spot things might be different.

T M ALUKO

WATERBORNE SANITATION IN NIGERIAN CITIES

INTRODUCTION

The central sewerage system remains the most satisfactory method for the treatment and disposal of municipal wastewater and it is the method adopted in most cities in the countries of Europe, America and other parts of the developed world. It is also the ambition of towns in the developing countries where in many cases sanitation facilities are very poor indeed to have the central sewerage system.

Both enlightened opinion in Nigeria and the world health community have from time to time expressed concern over the grossly inadequate facilities for sanitation in Lagos the Federal Capital of Nigeria. Succeeding Governments have for some fifty years been commissioning Consultants to look into the problem. Each time the consultants have made proposals for waterborne sanitation. But each time the Government has found that the difficulties associated with the implementation of these proposals have been so great that the proposals have had to be shelved. Unfortunately, when a decade or so after a succeeding Government turned again to the proposals, they were found to be already out of date and that the difficulties associated with the implementation on the earlier occasion have become more complex.

Problems of Waterborne Sanitation in Nigeria:

The inability of successive Governments to implement the proposals for a central sewerage system in Lagos is due to the serious problems associated with the central sewerage system as an engineering service (ref.1). High capital cost is the first of these problems. The Consultants for the 1966 proposals for the drainage and sewage disposal facilities for Lagos estimated that the scheme would cost £178m for 4.35m people which was the estimated population of Lagos in the year 2005, the end of the design life of the project (ref.2). This works out at £41 (₦82) per capita for both liquid and solid waste collection and disposal. The latter, however, accounted for less than ₦2 leaving the capital cost of the liquid waste facilities at a solid ₦80 per capita.

An analysis of ten water supply projects carried out in the then Western Nigeria in the five year period 1961-66 showed that the per capita cost of these supplies varied from £3.23 in Oyo (pop. 271,500) to £11.65 in Shaki (pop. 50,000). The average per capita cost was £4.62 (₦9.64) for an average population of 169,400. From the little information available on electricity capital costs in Western Nigeria during this same period, the average per capita cost appeared to be just under £4 (₦8.00). The conclusion from this analysis is that sewerage is by far the most expensive of these three engineering services (ref. 1).

This very expensive engineering service has about the lowest political appeal in the comity of engineering and social services which compete for Government's attention in the allocation of scarce financial resources in the annual budget. With the exception of a few pumping stations and the structures of the sewage treatment works, usually tucked away in an out-of-the-way area of the city, nearly most parts of a sewerage project are literally buried underground. This contrasts with water, electricity, schools, hospitals, roads and bridges which not only cost much less, but actually exist, in most cases, as imposing structures which the electorate can see for themselves.

Added to the high capital cost, the physical construction of a network of sewers in an existing town will lead to dislocation of traffic and general dis-organisation of business life. This will be so in view of the poor town planning in the first instance, which has resulted in most cases in narrow streets with inadequate building line on them. In addition, there is the need for public acquisition of land and property which could be a time consuming and frustrating experience. In the older parts of towns like Lagos and Ibadan, the streets are so narrow and winding that they are hardly discernible, and individual buildings hardly face on to any recognisable streets and follow any identifiable building line. The excavation for and the laying of sewers in these areas becomes practically impossible without combining it with slum clearance, together with attendant re-housing problem (ref. 1).

Finally, the usually held view that Africa is a continent in which natives live in a very large number of villages and collections of huts is not true in Nigeria where there is a great incidence of urbanism, particularly in the South Western part of the country. The 1963 Census showed that there were at that time 23 towns with populations of 100,000 and over in Nigeria, sharing a total population of 5,043,386 or 9.1% of the total population of 55,670,046 for the whole country. Fourteen of the 23 towns are situated in the area now covered by the states of Oyo, Ondo, Ogun and Lagos, all within a radius of 160 km of Ibadan in Oyo State. It is noted in passing that there was in 1963 no single town with a population of up to 100,000 in Liberia, Senegal, Mali or Gabon; Sierra Leone, Uganda and Tanzania had one such town each; Ethiopia, Kenya and Sudan two each; and Ghana three. The process of urbanism has of course progressed since 1963 and many more towns than 23 can now be expected to have exceeded the 100,000 mark.

The main problem posed by a big town is the relatively high capital cost of a sewerage scheme compared with other government projects like schools, hospitals and water supply. Had the population of Lagos been 122,000 in 1965 instead of 1,220,000, the £178m estimate for the proposed central sewerage scheme would come down to a very much smaller figure which the Government might have found more acceptable. The interesting inference here is that the outlook for municipal waterborne sanitation is brighter in the smaller towns than in the larger ones.

Sewerage Capital Costs:

An analysis of the consultants' estimate of the capital cost of the Lagos Central Sewerage and solid waste disposal proposals is quite revealing. The sewerage component alone was estimated to cost £126m or 71% of the estimated total cost of £178m, the treatment plant, pumping stations, and the solid waste disposal components all costing only 29% of the total cost (ref.2). A similar analysis of waterborne sanitation installation for what is most probably Nigeria's first town with the central sewerage system, the Black Arts Festival Town (FESTAC CITY) off Lagos-Badagry Road in Metropolitan Lagos, shows the total cost to be ₦11.72m for a design population of 75,000 which works out at ₦156.27 per capita, 1975 prices. The sewerage component of this cost is ₦6.53m or 55.7% (ref. 3,4).

The extra cost of land and property acquisition and of excavating for and laying sewers in an existing city of the complexity of Lagos would, no doubt, account for part of the disproportionately high cost of the sewerage component in the Lagos proposals. It will probably be found however that even when adjustment has been made for this, the sewerage component cost is still relatively high.

The Gilbert Associate proposals for Lagos under discussion cover an area of some 100km^2 and would cater for a design population of 4.35 million. Festac City, on the other hand, covers an area of only some 16km^2 while the sewerage scheme will cater for a design population of just 75,000. Ibadan, the capital of Oyo State however, does compare more favourably in size with Lagos than does Festac City. Luckily too another firm of consultants, Maclaren International, did submit to the then Western State Government in 1971 a Master Plan for Wastes Disposal and Drainage for Ibadan (ref. 5). The area covered by the Master Plan is roughly 140km^2. Details of the population catered for in the Ibadan proposals are not immediately available, nor are they seriously relevant. What is relevant however is the fact that the sewer sizes mentioned in the scheme appear to range between 8 inches (200mm) to 60 inches (1.5m). The Lagos proposals do not get down to sewer size details but sizes of 60 inches (1.5m) were mentioned in parts of the Report. The largest sewer in the Festac City scheme appears to be 900mm, with the average size being much smaller than this.

Understandably, sewers start being small from the beginning of a scheme where the sewage flow is small. They then increase in diameter as more and more tributary sewers join them bringing in more sewage to increase the flow. This continues until a particular sewer terminates in another sewer or at a pumping station or flows into an outfall sewer, which in most cases will be the largest sewer in a scheme. It is understandable then why the largest sewer in a small town like Festac City is smaller than the largest sewer in a big town like Lagos or Ibadan.

Table 1 is compiled from one of the tender documents submitted in 1975 for the construction of the Victoria Island Sewerage Scheme in Lagos (ref. 6). It shows the variation of cost per unit length of reinforced concrete pipes with increasing diameter, the cost including the actual pipe supply and laying operations but excluding earth excavation and back-filling. Fig. 1 drawn from Table 1 is not a straight line but a smooth curve which shows that sewer construction cost varies logarithmically with diameter. For this particular curve the following relationship has been developed:

$$C = 0.11\, d^{1.69} \qquad (1)$$

where C = cost per foot of sewer, in Nigerian Naira

d = diameter of sewer, in inches.

The gradient of this curve is the same as that of the curve developed from Table 2 showing the results of a study in reinforced concrete sewer constructions costs in Kansas City, U.S.A. reported by Howells D.H. 1964 (ref.7):

$$C = 0.55\, d^{1.70} \qquad (2)$$

where C = cost in US dollars/ft of sewer,

d = diameter of sewer in feet.

TABLE 1

REINFORCED CONCRETE SEWER PIPE COSTS
VICTORIA ISLAND (1975)

Pipe diameter (inches)	Cost/ft length ₦	Cost/dia.inch/ (ft/length)
20	17.40	0.87
21	17.40	0.85
24	23.70	0.90
27	28.00	1.04
30	33.60	1.12
33	39.80	1.21
36	45.00	1.25
42	60.60	1.44

$$\text{Cost} = 0.11 \, (\text{diameter})^{1.69}$$

TABLE 2

REINFORCED CONCRETE SEWER PIPE - KANSAS CITY
MO., AUG. 1, 1962

Diameter of pipe in ft.	Cost/ft of length	Cost/diameter in ft of length
0.67	$0.296	$0.037
1.00	.744	.062
1.50	1.188	.066
2.00	1.752	.073
2.25	2.214	.082
2.50	2.580	.086
3.00	3.492	.097
3.50	4.536	.108
4.00	5.712	.119
4.50	6.966	.129
5.00	8.460	.141
5.50	9.966	.151
6.00	11.952	.166
7.00	14.784	.176
8.00	19.488	.203

$$\text{Cost} = 0.55 \, (\text{diameter})^{1.70}$$

The analysis of Table 1 shows that a 30 inch (750mm) diam. sewer costs approximately twice while a 42 inch (1.05mm) diam. sewer costs approximately 3.5 times a 20 inch (500m) diam sewer. It explains why the average cost per unit length of sewer in a project is greater in a scheme with greater incidence of large diameter sewers than in another scheme in which there are few large diameter sewers. It explains why the Lagos Sewerage proposals which have a much larger incidence of large diameter sewers must cost more than the Festac City scheme per unit length of sewer since there are few large diameter sewers in the latter scheme. This fact must partly account for the relatively low figure of 55.4% which the sewerage cost bears to the whole scheme in the Festac City scheme compared with 71% in the Lagos proposals.

Thesis for an Interim Programme of Waterborne Sanitation in Towns

It is postulated here that while the difficulties earlier analysed will continue to make the outlook for the central sewerage system in existing towns in Nigeria bleak, there are areas of these towns that can now enjoy the benefits of limited waterborne sanitation facilities provided a number of criteria are met. The first of these criteria is the existence of an area either owned or under the control of an authority that recognises the advantages of waterborne sanitation and is both willing and able to pay for these facilities in the area under its control. The second criterion is the need for development concerned not to be extensive in area. The largest sewers in an estate that is only a few square kilometres in area will in all probability not be bigger than 450mm to 600mm diameter. The cost of sewer construction per unit length will be relatively small in such an estate according to the case already established above.

The domestic septic tank is the simplest example that meets the two criteria. Here a single building developer undertakes the capital cost of a sewage disposal device which serves an area that is so small that the sewerage component is reduced to the very minimum possible, a 100mm diameter pipe of some 3 to 10 metres length. Other cases that will meet these criteria are primary and secondary schools, Universities, hospitals, police barracks, military barracks, industrial estates. Others yet are government residential areas, housing estates, resettlement schemes and satellite towns.

The few waterborne sanitation facilities in Nigeria are those installed in pockets of developments in towns in which the criteria described above have been satisfied. A short account of some of such facilities in the Lagos Area will now be given. Fig.2 shows a map of the Metropolitan Lagos Area and the location of the treatment plants mentioned.

Waterborne Sanitation Installations in Lagos:

The first of these waterborne sanitation facilities in Lagos is the 50,000 gallons ($227.5m^3$) per day capacity "Oxigest" Model 31R80 package plant installed in the University of Lagos in 1965 to cater for the canteen, domestic and laboratory wastes from a student population of 1000. It is a contact stabilisation modification of an activated sludge process plant. The treatment plant caters for buildings in an area no larger than 1 to 2 km^2.

The second example is the treatment plant serving the Military Cantonment of the Nigerian Army in Ikeja. The Cantonment covers an area of some $2km^2$, and consists of the usual accommodation for officers and other ranks, offices, a hospital and other facilities. The raw sewage from these buildings is carried in an 18 inches diam. concrete gravity sewer to the treatment plant some two and a half kilometres away at the edge of the swamp the other side of the heavily trafficked Ikorodu Road. The ultimate design population is 18,000. The treatment plant is the conventional trickling filter preceded by primary clarifier and followed by a secondary clarifier, a sludge digester and sludge drying beds.

The third of the installations in Lagos is the Ikeja Industrial Estate Trade Effluent Plant. The original plant had a design capacity of 640,000 gallons ($2912m^3$) per day and was meant to serve all the factories in the $0.75km^2$ Estate. However only a very few of the factories were connected to the plant, which was out of order for long periods at a time. The 1965 cost was £500 which worked out at £31.2 per capita for a 16,000 population equivalent which is rather high.

Another Oxigest plant of 200,000 gallons ($910m^3$) per day capacity was built by the Lagos State Development Corporation in 1966 to treat the sewage from a group of 45 buildings covering an area of just 29 acres ($0.12km^2$) in one of its housing estates in Surulere. The capital cost in 1966 was £61,000 or only £12.2 per capita.

In 1967 a plant similar to the plant at the Ikeja Military Cantonment was built for the Nigeria Police at the Southern Police College, Ikeja. It has a design capacity of 45,000 gallons ($205m^3$) per day to serve a population of 1500. The budget cost in 1966 was £28,350 which works out at £18.9 per capita.

Finally, a Clow Model CS-660-F7-100 plant was built in the Lagos Teaching Hospital in 1976. It is like the "Oxigest", with a design capacity of 660,000 gallons ($3003m^3$) per day and a total BOD loading of 1650lb (750 kg) per day. The 1976 estimated cost was ₦473,000 which at an assumed population equivalent of 11,900 works out at ₦39.74.

It is mentioned in passing that a number of the treatment plants mentioned here were either out of order or were functioning inefficiently when visited in the last two years. One thing or the other had gone wrong which had not been put right either due to lack of knowledge of what to do or the non-availability of essential spare parts.

Government Reservations, Housing Estates, Satellite Towns:

Government reservations and housing estates are developments usually physically separated from existing towns and they are usually in many cases not bigger than university campuses or military barracks in size. They satisfy the conditions of development being under single control and of reasonably small size compared with towns. Unlike existing towns government reservations and housing estates have usually followed good town planning layouts with good building lines. They therefore are easily amenable to the construction of new sewerage schemes at no prohibitive cost to Government or the organisation that owns the housing estate.

It is not a very wide hop from a housing estate or Government reservation catering for 10,000 people to a satellite town in which 20,000 to 50,000 people will live. Where such a satellite town is to be a new creation the sewerage scheme would be planned as one of the engineering services and installed as such as part of the land development from the very beginning. When however what is contemplated is the sewerage of an existing satellite town the case still satisfies the conditions of manageable size and development being under single control, and the scheme can therefore be carried out, possibly in phases.

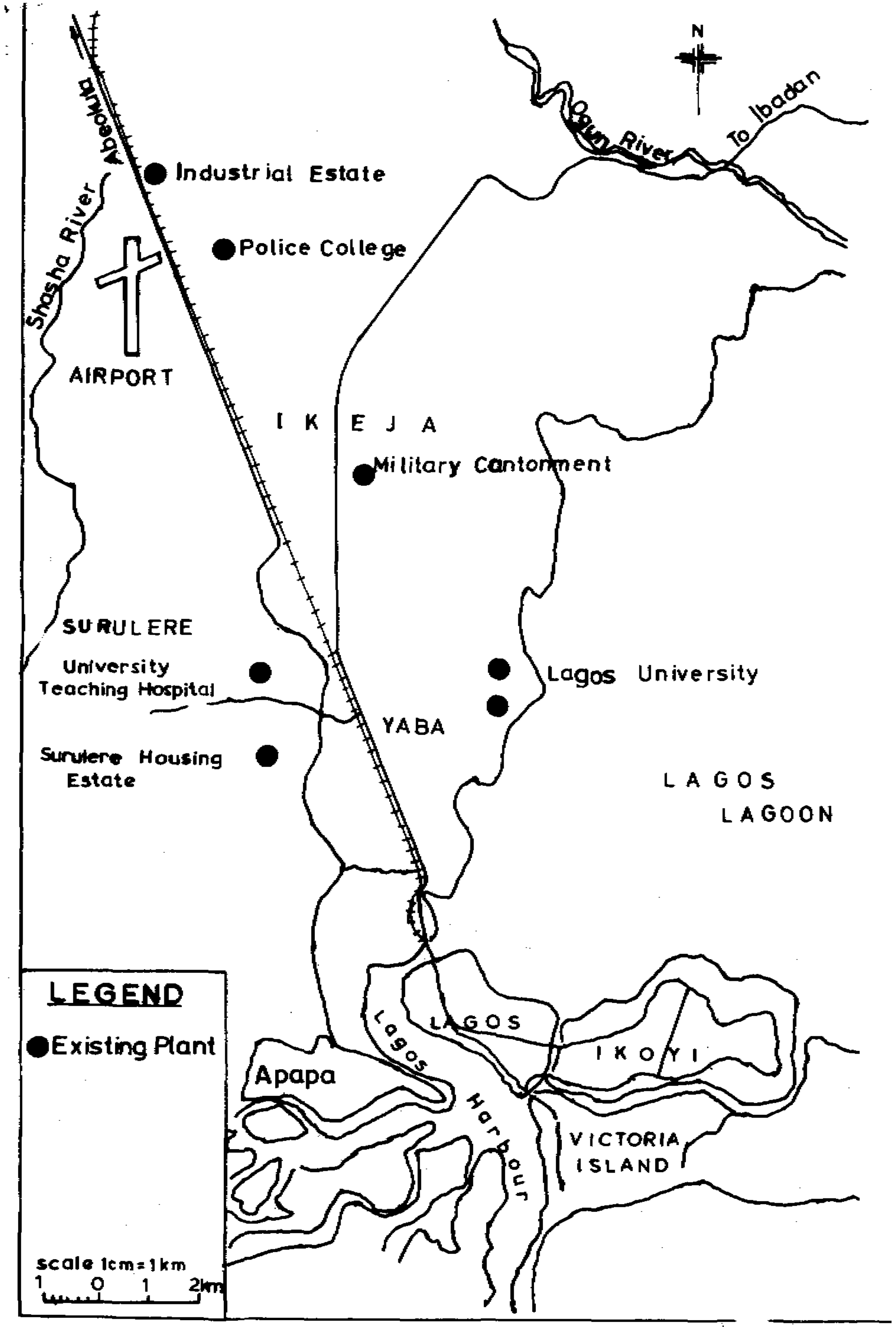

FIG.2. SOME SEWAGE TREATMENT PLANTS IN METROPOLITAN LAGOS.

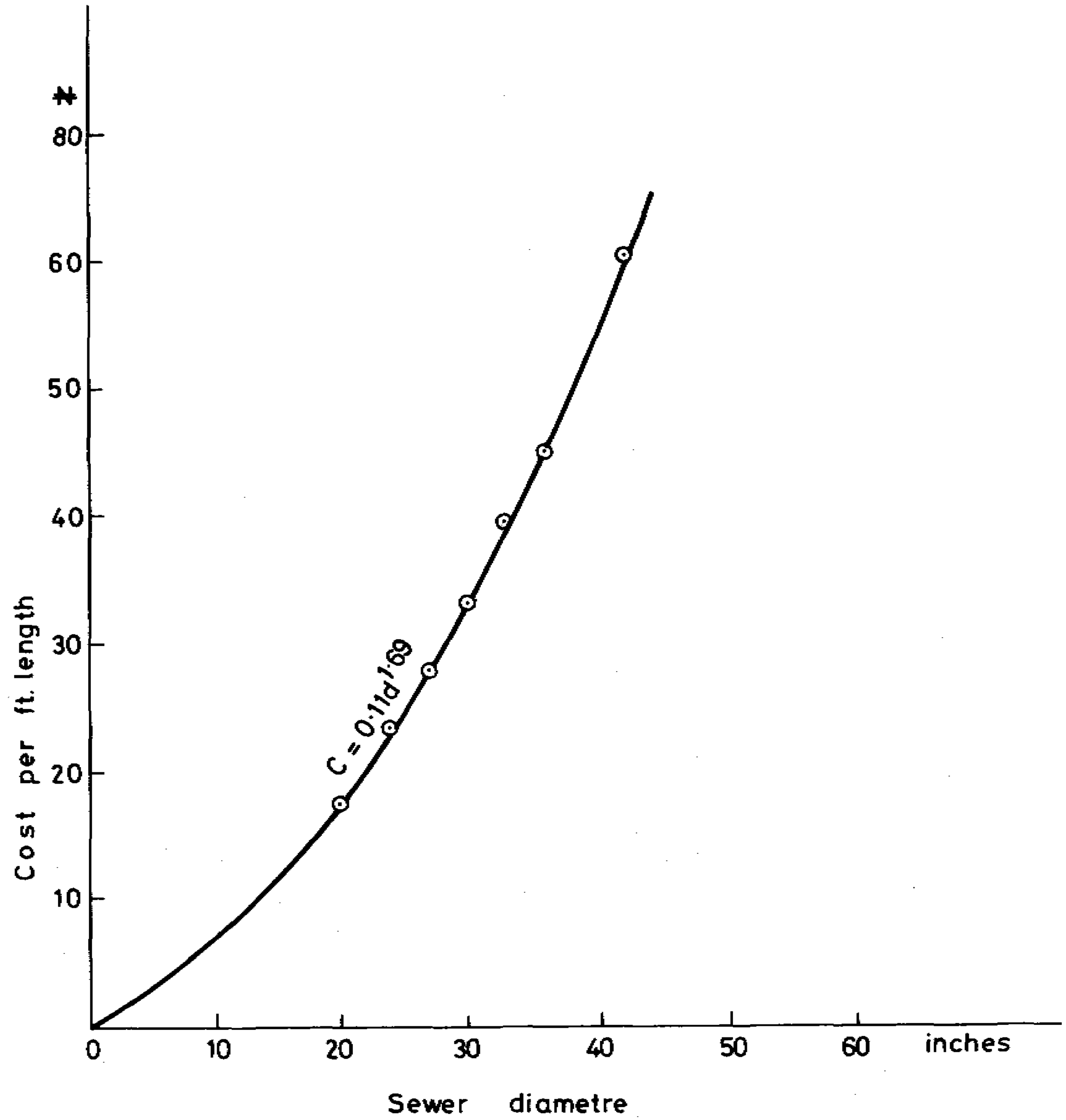

FIG.1. REINFORCED CONCRETE SEWER COSTS, VICTORIA ISLAND, 1975.

CONCLUSIONS:

It is unrealistic to under-rate the massive problems of the central sewerage system in towns in Nigeria and other developing countries. They will make this highly desirable engineering service unattainable in these towns for quite a while. It is however possible to identify pockets of existing or proposed development inside or outside these towns which are small in size and are owned by authorities that are both able and willing to pay for the construction of waterborne sanitation facilities in them. Governments should embark upon an interim programme of sewerage schemes in such areas.

REFERENCES

1. ALUKO, T M., 1976 "The Upgrading of Privy Methods of Sewage Disposal by the Biodisc Process". Ph.D. Thesis, University of Lagos.

2. SIMPSON, R W., 1966 (Manager, Environmental Engineering Division). "Lagos: Sewerage, Storm Drainage, Refuse Disposal - Preliminary Economic Analysis and Master Plan for Metropolitan Area of Lagos". Gilbert Associates Inc., Consultants, Reading, Pennsylvania, U.S.A.

3. DOXIADIS ASSOCIATES INTERNATIONAL, 1977. "Feasibility Study for the Connection of the Sewerage Systems of Ojo Cantonment and Low Cost Satellite Town to the Sewage Treatment Plant of the Black Arts Festival Town". Federal Housing Authority, Festac City, Lagos.

4. DEGREMONT S A., 1977. "Sewage Treatment Plant for 75,000 Inhabitants: Instructions for Operation and Maintenance". Manual prepared by Consultants of Plant for Black Arts Village, Lagos.

5. MACLAREN INTERNATIONAL LTD., 1971. "Master Plans for Wastes Disposal and Drainage, Ibadan" Vol.III. Report prepared by Consultants for WHO and Western Nigeria State Government.

6. MACLAREN INTERNATIONAL LTD, 1975. "Victoria Island Sewerage Scheme. Contract for Sewage Collection System etc." Contract Document for construction of sewerage scheme for Lagos State Government.

7. HOWELLS, D H. (Chief of Branch), 1964, "Sewer Construction Cost Index". U.S. Department of Health, Education and Welfare. Public Health Service Publication No.1132.

WILLIAM C BOYLE and R J OTIS

TREATMENT OF SMALL FLOWS WASTEWATER-ON-SITE WITH INTERMITTENT SAND FILTRATION

In the evaluation of alternate onsite treatment and disposal processes for residential or commercial wastewaters, there are a number of criteria which may be used in the selection process including costs, health, environment, esthetics, safety, social adaptation, and technology. Site constraints often dictate final process selection and the disposal method will dictate wastewater quality required prior to disposal. If suitable soils exist on site to employ one of the subsurface soil absorption methods of disposal, the quality of wastewater required is minimized due to the assimilative capacity of the soil. Where suitable soil conditions do not exist onsite, other methods of disposal that require a higher quality wastewater may be necessary. In these situations, a relatively low cost process that has been successfully employed for many years may be considered; the intermittent granular filter. This paper reviews the current application of intermittent granular filters for onsite wastewater treatment.

Intermittent granular filtration may be defined as the intermittent application of wastewater to an artificial bed of granular material (usually sand) which is underdrained to collect and discharge the final effluent. One of the oldest methods of wastewater treatment known, intermittent filtration, if properly designed, operated and constructed, will produce effluents of very high quality. Currently, many intermittent filters are used throughout the United States to treat wastewater from small commercial and institutional developments and individual homes. The use of intermittent granular filters for upgrading stabilization ponds has also become popular.

DESCRIPTION

Intermittent granular filters are beds of granular materials, usually sand, 0.6 to 1 meter deep and underlain by graded gravel and collecting tile. Wastewater is applied intermittently to the surface of the bed through distribution pipes or troughs. Uniform distribution is normally obtained by dosing so as to flood the entire surface of the bed. Filters may be designed to provide free access (open filters) or may be buried in the ground (buried filters). A relatively new concept in filtration employs recirculation of filter effluent (recirculating filters). Figure 1 depicts these three general systems.

The mechanisms of purification attained by intermittent filters are complex and not well

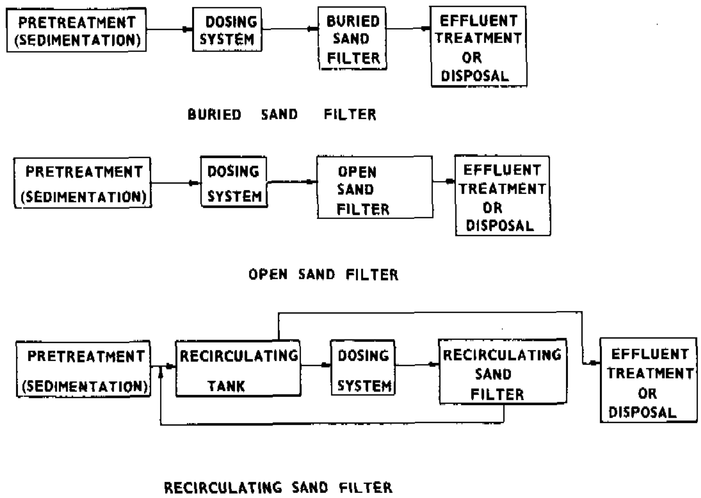

Fig 1. SAND FILTER SYSTEMS

understood, even today. Filters provide physical straining and sedimentation of solid materials within the media grains. Chemical sorption also plays a role in the removal of some materials. However, successful treatment of wastewaters is primarily dependent upon the biochemical transformations occurring within the filter. Without the assimilation of filtered and sorbed materials by biological growth within the filter, the process would fail to operate properly.

Since filters entrap, sorb, and assimilate materials in the wastewater, it is not surprising to find that the interstices between the grains fill and the filter eventually clogs. Clogging may be caused by physical, chemical, and biological factors. Physical clogging is normally caused by the accumulation of stable suspended materials within or on the surface of the sand. It is dependent upon grain size, porosity and wastewater suspended solids characteristics. The precipitation, coagulation, and adsorption of a variety of materials in wastewater may also contribute to the clogging problem in some filter operations (ref.1). Biological clogging is due primarily to an improper balance of the intricate biological population within the filter. Toxic components in the wastewater, high organic loading, absence of dissolved oxygen, and decrease in filter temperatures are the most likely causes of microbial inbalances. Resultant accumulation of biological slimes and a decrease in the rate of decomposition of entrapped wastewater contaminants within the filter accelerates filter clogging. All forms of pore clogging occur simultaneously throughout the filter bed. The dominant clogging mechanism is dependent upon wastewater characteristics, method and rate of waste application, characteristics of the filtering media and filter environmental conditions.

FACTORS AFFECTING PERFORMANCE

The degree of stabilization attained by an intermittent filter is dependent upon: (1) the type and biodegradability of wastewater applied to the filter, (2)the environmental conditions within the filter, and (3) the design characteristics of the filter. Reaeration and temperature are two of the most important environmental conditions that affect the degree of wastewater purification through an intermittent filter.

Proper selection of process design variables also affects the degree of purification of wastewater by intermittent filters. A brief discussion is presented below.

Media Size and Distribution

The successful use of a granular material as a filtering media is dependent upon the proper choice of size and uniformity of the grains. The size of the granular media affects the quantity of wastewater that may be filtered, the rate of filtration, the penetration depth of particulate matter, and the quality of the filter effluent. Granular media that is too coarse lowers the retention time of the applied wastewater through the filter to a point where adequate biological decomposition is not attained. Too fine a media limits the quantity of wastewater that may be successfully filtered and will lead to early filter clogging. This is due to the low hydraulic capacity and the existence of capillary saturation characteristic of fine materials. Metcalf and Eddy (ref.2) and Boyce (ref.3) recommended that not more than 1 percent of the media should be finer than 0.13 mm. Recommended filter media effective sizes range from a minimum of 0.25 mm up to approximately 1.5 mm. Uniformity coefficients for intermittent filter media normally should be less than 4.0 (ref.4,5,6,7,8).

There are a variety of granular media that may be used for intermittent filters including sand, anthracite, garnet, ilmenite, activated carbon, and mineral tailings. The media selected should be durable and insoluble in water. Total organic matter should be less than 1 percent and total acid soluble matter should not exceed 3 percent. Any clay, loam, limestone, or organic matter may increase the initial adsorption capacity of the sand, but may lead to a serious clogging condition as the filter ages.

The arrangement or placement of different sizes of grains throughout the filter bed is also an important design consideration. A homogeneous bed of one size media does not occur often in practice. Numerous fine and coarse stratified layers of granular media occur throughout the bed due to construction practice; thus, making it nonhomogeneous. In a bed having fine media layers placed above coarse layers, the downward attraction of wastewater is not as great due to the lower amount of cohesion of the water in the larger pores (ref.9). The coarse media will not draw the water out of the fine media; thereby, causing the bottom layers of the fine material to remain saturated with water. This saturated zone acts as a water seal, limits oxidation, promotes clogging, and reduces the action of the filter to a mere straining mechanism.

Hydraulic Loading Rate

The hydraulic loading rate may be defined as a volume of liquid applied to the surface area of the sand filter over a designated length of time. Hydraulic loading is normally expressed as cm/day or gallons/d ft^2. Values of recommended loading rates for intermittent sand filtration vary throughout the literature and depend upon the effective size of sand and the type of wastewater. They normally range from 3 to 60 cm/d (.75 to 15 gal/d ft^2).

Organic Loading Rate

The organic loading rate may be defined as the amount of soluble and insoluble organic matter applied per unit volume of filter bed over a designated length of time. Organic loading rates are not often reported in the literature; however, early investigators found that the performance of intermittent granular filters was dependent upon the accumulation of stable organic material in the filter bed(ref.1, 9). To account for this, hydraulic loading rates today are often prescribed for a particular type of wastewater. Low loading rates are suggested for raw wastewater with increasing rates suggested for primary settled, septic tank treated, and secondary treated effluents. A strict relationship establishing an organic loading rate, however, has not yet been clerly defined.

Depth of Media

Depths for intermittent granular filters were initially designed to be 1.2 to 3.0 meters; however, it was soon realized that most of the purification of wastewater occurred within the top 0.2 to 0.5 meters of the bed (ref.9). Additional bed depth did not improve the wastewater purification, but not to any significant degree. Most media depths used today range from 0.6 to 1.0 meters. The use of shallow filter beds helps keep the cost of installation low. Deeper beds tend to produce a more constant effluent quality, are not affected as severely by rainfall or snow melt (ref.10), and permit the removal of more media when cleaning operations are necessary.

Dosing Techniques and Frequency

Dosing of intermittent filters is critical to the performance of the process. The system must be designed to insure uniform distribution of wastewater throughout the filter cross-section. Sufficient resting must be also provided between dosages to obtain aerobic conditions. In small filters, wastewater is applied in doses large enough to entirely flood the filter surface with at least 8 cm of water; thereby, insuring adequate distribution. Dosing frequency is dependent upon media size but should be greater with smaller doses for coarses media.

Dosing methods that have been used include ridge and furrow application, drain tile distribution, surface flooding and spray distribution methods. Intermittent filters in use today are often built below the ground surface and employ tile distribution.

The frequency of dosing intermittent filters is open to considerable design judgment. Most of the earlier studies used a dosing frequency of 1/day. Studies investigating multiple dosages have concluded that the BOD removal efficiency of filters with media effective size greater than 0.45 mm is appreciably increased when the frequency of loading is increased beyond twice per day (ref.11). This multiple dosing concept is being used successfully in recirculating sand filter systems (ref.12). These installations use a media with effective size ranging from 0.3 to 1.5 mm and a dosing frequency of approximately once per 30 minutes.

FILTER PERFORMANCE

A summary of the performance of selected intermittent filters based on experience with wastewaters generated from rural households in the U.S.A. appear in tables 1, 2, and 3. These tables illustrate that intermittent filters will produce high quality effluents with respect to BOD_5 and suspended solids.

TABLE 1
PERFORMANCE OF SUBSURFACE INTERMITTENT FILTERS – SEPTIC TANK EFFLUENT

Filter Characteristics: Eff. Size (mm)	Uniformity Coefficient	Hydraulic Loading (cm/d)	Depth (m)	Effluent Characteristics (mg/l): BOD	SS	NH_3^-N	NO_3^-N	Filter Run (Months)	Reference
0.24	1.0	4	0.8	2.0	4.4	0.3	25	34	[14]
0.30	4.1	4	0.8	4.7	3.9	3.8	23	>40	[14]
1.0	2.1	4	0.8	4.3	4.9	3.7	24	>48	[14]
2.5	1.2	4	0.8	8.9	12.9	6.7	18	>48	[14]
0.17	11.8	0.8	1.0	1.8	11.0	1.0	32	>23	[10]
0.23–0.36	2.6–6.1	4.6	0.6	4	12	0.7	17	-	[7]

TABLE 2
PERFORMANCE OF FREE ACCESS INTERMITTENT FILTERS

Source	Filter Characteristics: Eff. Size (mm)	Unif. Coef.	Hyd.Loading cm/d	Depth (m)	Dose Freq. (per day)	Effluent Quality (mg/l): BOD	SS	NH_3^-N	NO_3^-N	Filter Run (Months)	Reference
Septic Tank	0.23–0.25	-	18	1.5	-	23*	-	8	32	6 - 9**	[9]
Septic Tank	0.41	-	9.2	1.5	-	11*	-	3	46	6 - 9**	[9]
Trickling Filter	0.27	-	45.6	1.5	-	17*	-	2	29	6**	[9]
Trickling Filter	0.41	-	18.4	1.5	-	18*	-	2	33	Raked 6"dp./12mo**	[9]
Primary	0.25	-	11	.75	1	6	6	5	19	4.5	[11]
Primary	0.25	-	18.8	.75	2	3	8	2	22	36	[11]
Primary	1.04	-	–	.75	2	28	36	10	13	>54	[11]
Primary	1.04	-	56	.75	24	4	9	3	17	>54	[11]
Septic Tank	0.45	3.0	20	.75	3–6	8	4	3	25	~ 3	[15]
Extended Aer.	0.19	3.3	15.2	.75	3–6	3	9	0.3	34	~12	[15]
Lagoon (Summer)	0.19	9.7	36.4	.9	1	2	3	0.5	4.0	~ 1	[16]
Lagoon (Winter)	0.19	9.7	36.4	.9	1	9.4	9.6	4.6	1.0	~ 4	[16]

*Estimated from "oxygen consumed"
**Weekly raking 3 inches deep

TABLE 3
PERFORMANCE OF RECIRCULATING INTERMITTENT FILTERS***

Filter Characteristics: Eff. Size (mm)	Unif. Coeff.	Hyd. Loading (cm/d)	Depth (m)	Recycle (return/forward)	Dose	Effluent Quality (mg/l): BOD	SS	NH_3^-N	NO_3^-N	Mtnce	Reference
0.6–1.0	2.5		0.9	4/1	5–10 min/ 30 min	4	5	-	-	Weed/rake as req'd	[12]
0.3–1.5	3.5	12–20*	0.6	3/1–5/1	20 min/ 2–3 hr	15.8**	10.0**	8.4**	-	Rake 1/week	[17]
1.2	2.0	12*	0.9	4/1	5 min/ 30 min	4	3	-	-	Weed removal	[18]

*Based on forward flow
**Overall averages 12 installations (household flow to 25,000 L/day plant)
***Septic tank effluent

Normally, nitrogen will be transformed almost completely to the nitrate form provided the filter remains aerobic. The exchange capacity of most sand used is low and phosphorus removal after bed maturation is low. Use of calcareous sand or other high aluminum or iron materials intermixed within the sand may produce significant phosphorus removal. Chowdhry (ref.13) and Brandes et al (ref.14) reported phosphorus removals up to 90 percent when addition of 4 percent "red mud"(high in Al_2O_3 and Fe_2O_3) were made to medium sand. Intermittent filters are capable of reducing total and fecal coliform by 2 to 4 logs (ref. 7,13,15).

DESIGN CRITERIA

Table 4 summarizes suggested design criteria for intermittent granular filters used for onsite wastewater treatment. Loadings are based upon typical wastewaters generated in rural households in the U.S.A. (170L/capita/day).

TABLE 4
SUGGESTED DESIGN CRITERIA FOR INTERMITTENT FILTERS

ITEM	BURIED FILTERS	FREE ACCESS FILTERS: SEPTIC TANK EFFLUENT	AEROBIC EFFLUENT	LAGOON EFFLUENT	RECIRCULATING FILTERS
Media					
Depth (m)	0.6	0.5 Min	0.6 Min	0.75–0.9	0.6 Min
Effective size (mm)	.35–1.0	.35–1.0	.35–1.0	.15– .75	0.3–1.5
Uniformity Coefficient	<3.5	<4	<4	-	<4
Physical					
Configuration	Duplicate filters Each to handle 1/2 flow Dosing system	Duplicate filters Each to handle entire flow Dosing system	Single filter Dosing system	Duplicate filters Each to handle entire flow Dosing system	Single filter Recirculation tank Recirculation pump
Hydraulic					
Loading (cm/d)	3–5	20	20	32–60	12(Forward Flow)
(gal/dft^2)	.75–1.25	5	5	8–15	3
Recirculation ratio	--	--	--	--	3:1–5:1
Dosing Schedule (No./day)	3–5	3–5	3–5	Continuous 24 hours	8–12

OPERATION AND MAINTENANCE

Intermittent filters require relatively little operational control or maintenance. Once wastewater is applied to the filter, it takes from a few days to two weeks before the sand has matured (ref.13,15). BOD and suspended solids concentrations in the effluent will normally drop rapidly after maturation. Dependupon media size, rate of application, and ambient temperature, nitrification may take from 2 weeks up to 6 months to develop. Cold weather start-up should be avoided since maturation of the media may not fully develop (ref.1).

Clogging of the filter which is dependent upon organic loading to the filter, media size and uniformity will eventually occur as the pore space between the media grains begins to fill with inert and biological materials. Once hydraulic conductivity falls below the average hydraulic loading, permanent ponding will develop. Although effluent quality may not suffer initially, anaerobic conditions within the filter will result in further rapid clogging and a cessation of nitrification. Application of wastewater to the filter should be discontinued when continuous ponding occurs at levels in excess of 0.3 meters above the sand surface.

Since buried filters can not be easily serviced, the media size is normally large and hydraulic application rates are low (usually less than 5 cm/d). Proper pretreatment maintenance is of paramount importance. Free access filters, on the other hand, may be designed with finer media and at higher application rates. Experience has indicated that intermittent filters receiving septic tank influent will clog in approximately 30 and 150 days for effective sizes of 0.2 mm and 0.6 mm respectively (ref.15). Aerobically treated effluent can be applied at the same rates for up to 12 months if suspended solids are under 50 mg/l (ref.11,15). Results with recirculating filters using coarse media (1.0-1.5 mm) indicate filter runs in excess of one year (ref.18).

Maintenance of Media

Maintenance of the media includes both routine maintenance procedures and media regeneration upon clogging. These procedures apply to free access filters only. The effectiveness of routine raking of the media surface has not been clearly established, although employed in several studies (ref.1,9,12,15). Filters open to the air may require occasional weed removal as well. Cold weather maintenance of media may require different methods of wastewater application. Use of insulated covers have permitted trouble free winter operation in areas with ambient temperatures as low as -40°C(ref.15)

Eventually, filter clogging requires media regeneration. Raking of the surface will not in itself eliminate the need for more extensive rehabilitation (ref.1,15). The removal of the top layer of sand and replacement with clean sand when sand depths are depleted to less than 0.6 to 0.7 meters appears to be very effective for filters clogged primarily by a surface mat. In-depth clogging, however, often prevails in many intermittent filters requiring oxidation of the clogging materials. Resting of the media for a period of time has proven to be very effective in restoring filter hydraulic conductivity (ref.15).

Other Maintenance Requirements

The successful operation of filters is dependent upon proper maintenance of the pretreatment processes. The accumulation of scum, grease, and solid materials on the filter surface due to inoperative pretreatment will result in premature filter failure. This is especially critical for buried filters.

Routine maintenance requirements have not been well documented for intermittent filtration but visits on site should be made four times per year to check filters and their appurtenances. Based on a meager data base, unskilled manpower requirements for buried filter systems would be less than 2 man days per year for examination of dosing chamber and appurtenances and septic tank. Free access filters may require from 2 to 4 man days per year for media maintenance and placement and examination of dosing chamber, septic tank, and appurtenances. Power requirements would be variable, depending upon the dosing method employed, but should be less than 0.1 kwhr/d. The disposal of waste media from free access filters may amount to $0.08 m^3/m^2$ surface area each time media must be removed.

REFERENCES

1. Schwartz, W.A., et al. Project Report of Pilot Studies on the Use of Soils as Waste Treatment Media. Federal Water Pollution Control Agency, Cincinnati, Ohio. 1967.
2. Metcalf, L. and H.P. Eddy. American Sewerage Practice, Volume III. McGraw-Hill, New York. 1935.
3. Boyce, E. Intermittent Sand Filters For Sewage. Municipal and County Engineering, 72, 177. 1927/
4. Department of Health, Education, and Welfare. Manual of Septic Tank Practice. PHS Publication No. 526, Washington, D.C. 1967.
5. Recommended Standards for Sewage Works. Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, Health Education Office, Albany, New York. 1960.
6. American Society of Civil Engineers. Filtering Materials for Sewage Treatment Plants. Manual of Engineering Practice No. 13, New York. 1937.
7. Salvato, J.A., Jr. Experience with subsurface Sand Filters. Sewage and Industrial Wastes, 27, 909. 1955.
8. Water Pollution Control Federation. Sewage Treatment Plant Design, Manual of Practice No. 8, Washington, D.C. 1967.
9. Clark, H.W. and S. Gage. A Review of Twenty-One Years Experiments Upon the Purification of Sewage at the Lawrence Experimental Station. 40th Annual Report, State Board of Health of Massachusetts, Public Document No. 34. 1909.
10. Brandes , M. Effect of Precipitation and Evapotranspiration on Filtering Efficiency of Wastewater Disposal Systems. Ontario Ministry of Environment, Publication No. W70. May, 1970.
11. Emerson, D., Jr. Studies on Intermittent Sand Filtration of Sewage. Florida Engineering and Industrial Experimental Station, University of Florida, Bulletin No. 9. 1954.
12. Hines, J. and R.E. Favreau. Recirculating Sand Filter: An Alternative to Traditional Sewage Absorption Systems. Proceedings of the National Home Sewage Disposal Symposium.
13. Chowdhry, N.A. Underdrained Filter Systems-Whitby Experiment Station. Ministry of the Environment Interim Report, Part 2, Ontario, Canada. 1973.
14. Brandes, M., N.A. Chowdhry and W.W. Cheng. Experimental Study on Removal of Pollutants from Domestic Sewage by Underdrained Soil Filters, Proceedings of the National Home Sewage Disposal Symposium. ASAE Publication Proc. 175. 1975.
15. Small Scale Waste Management Project. Management of Small Waste Flows. Report No. EPA 600/2-78-173. 1978.
16. Harris, S.E., et al. Intermittent Sand Filtration for Upgrading Stabilization Pond Effluents. Journal of Water Pollution Control Federation, 49, 83. 1977.
17. Teske, M.G. Recirculation - An Old Established Concept Solves Same Old Established Problems. 51st Annual Conference of the Water Pollution Control Federation, Anaheim, California. 1978.
18. Bowne, W.C. Experience in Oregon With the Hines-Favreau Recirculating Sand Filter. Northwest States Conference on Onsite Sewage Disposal. 1977.

6th WEDC Conference: March 1980: Water and waste engineering in Africa

KEN ELLIS

AERATED LAGOONS FOR THE TREATMENT OF INDUSTRIAL WASTEWATERS IN DEVELOPING COUNTRIES

Stabilization ponds must constitute the principal technique involved in the prevention of surface water pollution in most developing countries. Their simplicity allied with their efficacy and low cost ensures that they are always the initial system to be considered for the purification of wastewaters.

On occasions, however, local factors can prevent the employment of stabilization ponds. Generally these factors might be summarized as

(i) a shortage of land, or the high cost of the available land;
(ii) the high strength of the received wastewater, particularly when mixed with some industrial wastewaters. This factor becomes of importance if an anaerobic lagoon cannot be used for environmental reasons;
(iii) the necessity to protect the purity of groundwater supplies, in which case it might be essential to line the pond bottoms;
(iv) the need to produce an effluent which is not heavily laden with algae.

Should the employment of stabilization ponds not be practicable it is of importance to resist the extreme alternative of moving to conventional wastewater treatment technology which is not only expensive in construction and operation but which also necessitates a high degree of technical control. As an appropriate alternative to stabilization ponds, that does not require either highly sophisticated plant or a high level of technical control, aerated lagoons must be considered. At their simplest aerated lagoons are stabilization ponds which are uprated by the installation of an aeration system. This might be either a mechanical surface aerator or a bubble-type of aerator. Particularly aerated lagoons can be justified for the treatment of many industrial wastewaters. In the industrial situation not only is land availability frequently limited, but also some technical expertise is usually employed in the industry.

TYPES OF AERATED LAGOON

Aerated lagoons can be conveniently divided intc three groups (1):

(i) Aerated stabilization ponds
(ii) Facultative aerated lagoons and
(iii) Completely-mixed aerated lagoons.

AERATED STABILIZATION PONDS

These represent a simple means of uprating existing stabilization ponds. The aerator (or mixer) is employed more to mix the water than to aerate it. The aerator merely brings the oxygen demand in the deeper water into contact with the oxygen source near to the surface. It is a means of overcoming the difficulties associated with stratification. The majority of oxygen utilized is derived not directly from the aerator, but either from direct surface adsorption through the undisturbed surface or as a result of the photosynthetic action of the algae present. Settlement of an organic sludge will still be expected as will the anaerobic stabilization of this sludge, if the temperature is warm enough. No final settlement lagoons is required and the effluent produced will still be heavily laden with algae.

It has been suggested (2) that a simple aerator positioned close to a stabilization pond inlet will not only satisfy any large, immediate oxygen demand but will also assist in the even spread of sludge over a wide area of pond bottom.

FACULTATIVE (OR PARTIALLY SUSPENDED) AERATED LAGOONS

With these much of the required oxygen will be adsorbed directly as a result of the action of the aeration system. There will still be a substantial amount of sludge settlement together with anaerobic sludge digestion, but there will also be an appreciable suspension of active solids (20 - 80 mg/l) assisting in the aerobic stabilization of the organic waste. As the water in the lagoon is continually turned over and because of the attenuation of its light transparency by the partial suspension of active solids, the algal content is far less than with stabilization ponds. Again, it is unusual to require an additional settlement lagoon following the limited turbulence of a facultative lagoon.

The installed power required for this type of lagoon is usually accepted as being between 1.0 and 2.0 w/m^3 of lagoon volume (3,4) although one authority (5) suggests as much as 4.0 w/m^3. 1.0 w/m^3 represents the power required to hold about 20 mg/l of solids in suspension, although an MLSS of 50 to 80 mg/l has been suggested as being necessary (6). If an effluent with only a low suspended solids content is essential it is a relatively simple matter to create a quiescent settlement zone near to the effluent discharge point, protected by baffles above and below the surface.

As a result of the settlement of much of the organic suspended material, and of its subsequent anaerobic stabilization when the temperature permits, there is frequently found to be a substantial seasonal feed-back of the partial breakdown products to the aerobic water layer. Appreciable anaerobic digestion only occurs as the sludge temperature exceeds about 18°C (7,8). For this reason there is only settlement of organic solids during cold-weather periods followed by an intense period of enhanced anaerobic activity as the temperature rises seasonally. During hot weather the extra load - seasonal feed-back - resulting from the leachage of organic acids and alcohols from the digesting sludge can impose an additional 50% load onto the aerobic zone.

COMPLETELY-MIXED (FULLY SUSPENDED) AERATED LAGOONS

As the name implies there is no settlement in these lagoons and consequently all the solids are in suspension. The vast majority of the required dissolved-oxygen is supplied by the aeration device and because of the continual turbulence and high opacity of the suspension no algae are produced.

These are in fact embryonic activated sludge systems but in which there is no sludge-return system and in which the concentration of suspended solids is perhaps only 0.2 to 0.4 kg/m^3 instead of the 2.0 to 6.0 kg/m^3 required by the conventional process. Because there is no sludge-return it is essential that the nominal retention period should be sufficient to allow the rate of new sludge production in the unit to balance the loss of sludge with the effluent. As a result there is a critical retention period (trc) for each particular unit below which the activity will quickly drop as the concentration of active solids falls. This is suggested (9) as being

$$trc = \frac{1}{0.33.Y.K.Li}$$

The power required is suggested as being about $6w/m^3$ (3) but others (5) raise this to as high as 20 w/m^3. The lagoon depth is usually between 3 and 5 m although they can be as deep as 6.0 m. Since there is no sludge settlement there is no seasonal feed-back to moderate the increased hot weather efficiency and as a result the design should be for the coldest month. Nominal retention periods are normally in the range of 1.0 to 2.0 days.

AERATORS

Aerators can either be mechanical surface aerators or one of the systems employing compressed-air and air-bubbles.
The original mechanical surface aerators were normally vertical-spindle rotating cone devices mounted on a transverse bridge. The development of anchored, floating aerators has resulted in simpler designs and the use of larger lagoons. Generally these aerators are 'low-speed' aerators operating at 3.0 to 6.0 rpm and resulting in both a high oxygenation efficiency and in a substantial mixing effect for the lagoon contents. Much higher speed floating aerators employing smaller impellers at up to about 2500 rpm are also available. These tend to be cheaper but neither in their oxygenation efficiency nor in their mixing effect (10) do they compare with the lower speed aerators. All vertical-spindle mechanical aerators require an erosion-resistant concrete slab, at least three times the diameter of the impeller (10), set below the aerator. Kessener-type, horizontal spindle aerators can also be employed set either against the lagoon bank or mounted on pontoons.

Compressed-air systems are of three types. There is the minimum-submersion, coarse bubble aeration grating of the Inka process. There is also the conventional diffused-air system relying on fine-bubble diffusers set on the lagoon floor. Thirdly, there is the coarse-bubble diffuser of the Polcon process in which the emitted bubbles pass upwards through a 'helixor' to provide extended air/water contact time. This latter system has been employed successfully for the treatment of beat-sugar wastewater in the UK. The beneficial effect of the warm compressed air has resulted in an appreciably higher-than-normal mixed-liquor temperature and consequently in increased biological activity. Conversely, surface aerators have been found to create a beneficial cooling effect which can moderate the temperature of over-hot industrial wastewaters without resorting to a specific cooling system. It is suspected that the Polcon system only rivals the efficiency of other aeration systems in the deeper lagoons.

REQUIRED REACTOR VOLUMES

Various authors have suggested a variety of approaches to the determination of reactor volume requirements. Some authors (11,12) have employed the first-order biological rate approach for complete-mix reactors conventionally used for the systematic design of stabilization ponds. This has been modified by Thirumurthi (13) who assumed that the reaction-rate decreases as the reaction progresses. This led him to employ the rate equation $\frac{dc}{dt} = KC^n$
in which he suggests the factor n as being between 1.076 and 1.115.

However, since the operation of the aerated lagoons depends upon the suspension of an appreciable concentration of active solids it is justified in assuming that the rate of reaction depends not only on the concentration of biodegradable material remaining but also on the concentration of active solids in suspension. This approach has been accepted by several authorities (3, 6, 14, 15, 16).

The rate of removal of BOD is assumed to be directly proportional to both the lagoon BOD (Le and the concentration of active solids (X)

hence $$\frac{dL}{dt} = k.X.Le \qquad \text{(i)}$$

With a material balance of

Biodegradable material entering	=	Rate of biodegradable decay	+	Biodegradable material leaving	
Q.Li	=	$V.\frac{dL}{dt}$	+	Q.Le	(ii)

substituting (i) into (ii) and rearranging

$$Le = \frac{1}{1+k.X.\frac{V}{Q}} = \frac{1}{1+k.X.t_r} \qquad \text{(iii)}$$

$$\text{and } t = \frac{Li - Le}{k.Le.X} \qquad \text{(iv)}$$

$$\text{and } A = \frac{Q}{D.k.X.}\left(\frac{Li}{Le} - 1\right) \qquad \text{(v)}$$

The concentration of active solids, X, can be obtained from a cell balance (16), assuming that the input of cells in the crude sewage is negligible.

Rate of change of biomass in system	= cell synthesised during reaction	- Endogenous respiration	- Cell loss in effluent	
V.dX	= Q.Y.(Li-Le)	- b.X.V.	- Q.X.	(vi)

as at a steady state $\frac{dX}{dt} = 0$

$$X = \frac{Y(Li-Le)}{1 + b.tr} \qquad \text{(vii)}$$

These equations can be applied both for a completely-mixed lagoon and for a facultative lagoon as the reaction rate constant k is the same for both being independant of the concentration of micro-organisms.

Tikhe (16) has developed a further expression to give the minimum total retention period for a completely-mixed lagoon followed by a facultative lagoon. (This system requires no final settlement pond.)

$$t_T = \frac{1}{Y.k.Le-b} + \frac{Le-Lf}{X_f.k.L_f} \qquad \text{(viii)}$$

In this only Le is variable and by differentiating (viii) w.r.t.Le the size of Le to produce the minimum t_T can be determined as

$$Le = \frac{b}{Y.k.} + \left(\frac{X_f.L_f}{Y}\right)^{\frac{1}{2}} \qquad \text{(ix)}$$

One has to beware of expressions giving the BOD of the pond effluent Le. Le is only the so-called soluble fraction of the remaining BOD which, in addition, possesses a fraction due to the concentration of active solids in the effluent.

Hence total BOD of effluent = Le + 0.54X. In addition for a facultative pond there will also be a major contribution to the effluent BOD from any algal cells involved.

LAGOON LINING

Unlike stabilization ponds aerated lagoons are frequently lined. The necessity to prevent seepage maybe one of the reasons that lagoons have been selected, or the lining may, more usually, be employed to prevent erosion.

Polyethylene sheeting, PVC sheeting or butyl-rubber sheeting have all been widely employed. With these materials it is essential that the lagoon bed be cushioned with a layer of sand before the membrane is installed. Lagoon walls have to be stable and can be strengthened by polyester or fibre-glass underlays. The membrane itself is vulcanised or welded together from broad strips of the material and is loaded with a layer of gravel to prevent uplift. The edges are usually anchored into a trench and secured with concrete slabs.

Soil cement lining has been extensively employed in some parts of the world (17). For this the soil is loosened to a depth of 50 mm and allowed to dry. Then portland cement is added at about 8 kg/m^2, thoroughly mixed, then compacted with a light roller before the addition of the minimum required amount of water.

Asphalt-crumb rubber water-proofing has also been successfully experimented with (18). This is a mixture of asphalt-cement mixed with crumb-rubber (granulated from old tyres) which is sprayed onto the prepared lagoon. This is a tough, relatively homogenous mixture with excellent elastic and impact resistant properties. Its additional advantages include the elimination of seams, simple repairs by hand-spraying, ease of application, conformation with any slight subgrade irregularities and the fact that it adheres to the subgrade.

SYMBOLS

- Y - Yield coefficient (kg cells produced per kg BOD destroyed) - 0.6 to 0.8 kg/kg
- Li - Influent BOD concentration (g/m^3)
- Le - Lagoon and effluent BOD concentration (g/m^3)
- tr - Nominal retention period (days)
- V - Lagoon volume (m^3)
- Q - Flow rate (m^3/d)
- A - Surface area (m^2)
- D - Lagoon depth (m)
- k - Reaction rate constant ($l.mg^{-1}.d^{-1}$) - about 0.015 $l\ mg^{-1}.d^{-1}$ at 20°C for domestic wastes. This rate constant increases with temperature, up to a maximum of about 35°C, according to $k_{(T)} = k_{(20)}(1.097)^{T-20}$

X - Concentration of micro-organisms in lagoon (g/m^3). Although a measurement of ATP is perhaps more realistic this is commonly accepted as being the MLVSS.

b - Endogenous respiration rate (d^{-1}) - 0.18 to 0.24 d^{-1}

REFERENCES

1. Benjes H. Theory of aerated lagoons 210-217

2. Berthet B. Facteurs influant sur l'oxygénation de basins de lagunage de stations d'épuration - advantages et inconvénients d'aérateurs. Téchniques et Sciences Municipales, 74 (8/9), 463-470, 1979

3. White S C and Rich L G. How to design aerated lagoon systems to meet 1977 effluent standards - soluble substrate relationships. Water and Sewage Wks, 82-83, April 1976

4. Lardine R C and Viraraghavan T. Experience with floating aerators in aerated lagoons in New Brunswick. Paper presented at Atlantic Canada AWWA Annual Meeting, Sept 1978

5. Lumbers J F P. Waste stabilization ponds: design considerations and methods. J Inst Pub Hlth Engnrs 7 (2), 70-78, 1979

6. Kormanik R A. Design of two-stage aerated lagoons. J Wat Pollut Control Fed 44 (3), 451-458, 1972

7. Ostwald W J, Basis for waste stabilization pond design. In 'Advances in Water Quality Improvement'. Ed Gloyna and Eckenfelder University of Texas, Austin

8. Mara D. Sewage Treatment in Hot Climates. publ Wiley-Interscience, 1976.

9. Rich L G and White S C. BOD_5 removal from aerated lagoon systems, Water and Sewage Wks R21-R23, 1977

10. Hess M L. Pond installations and equipment Paper presented at WHO (EMR) seminar on Waste Stabilization Ponds, Lahore, Pakistan January 1980

11. Marais G v R and Capri M J. A simplified kinetic theory for aerated lagoons 299-310

12. Mckinney R E. Mathematics of complete mixing activated sludge. J ASCE SED, 88, SA3, 87-113, 1962

13. Thirumurthi D. Design criteria for aerobic, aerated lagoons. J Environmental Engineering Division, ASCE 105, EEI, 135-148, 1979

14. Eckenfelder W W. Aerated lagoons, Manual or Treatment Processes, Vol 1, Environmental Science Corp, 1968

15. Rich L G and White S C. How to design aerated lagoon systems to meet 1977 effluent standards - system design. Water and Sewage Wks, 88-89, May 1976

16. Tikhe M L. Aerofac aerated lagoons, J Wat Pollut Control Fed, 47 (3), 626-629 1975

17. Hess M L. Pond construction: lining and construction details. Paper presented at WHO (EMR) seminar on Waste Stabilization Ponds, Lahore, Pakistan, Jan 1980

18. Frobel R K, Jimenez R A, Cluff C B and Morris G R. Asphalt-crumb rubber waterproofing membrane. J Irrigation and Drainage Division ASCE, 104, IRI, 43-58, 1978

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WASTEWATER FOR REUSE

INTRODUCTION

A crucial problem facing most countries in the 20th century is the acute shortage of adequate quantity and quality of water supply to meet the basic and various requirements of man. This is particularly very serious in semi-arid and arid regions of Africa and also in countries with temperate climate where communities are constantly in search of alternative sources to meet their demands. This problem has been aggravated in the savanna belt of West Africa by the recent drought which has devastated the region. The effects of the drought has been felt along the coasts of Senegal and Mauritania across Mali and Niger to the heart of Chad Republic, even into Sudan and Ethiopia. The significant aspects of the incidents of the drought are the crop failures, scarcity of water for drinking, irrigation and watering cattle. The people were forced to migrate across the states and international boundaries on their sourthward journey in search of water and food.

On the global level, the World Health Organisation (WHO) has recognised the urgency of acute water shortage and in its recent 6-year global environmental health promotion programme (1978-83), priority has been given to two major issues - the provision of safe water and sanitation. This is in line with the United National Drinking Water Supply and Sanitation Decade (1980 - 1990).

Wastewater reclamation is becoming an ever more attractive method of increasing the available water resources in order to meet the present and the future needs. This has been the case in Israel where, for example, the conventional water resources are so limited that sewage is being utilized as part of the natural water potential. It has been estimated that about 10% of the total water potential of Israel is sewage water (ref.1).

Direct use of raw wastewater is not generally recommended. The discharge of raw wastewater into water courses may cause massive pollution of the water courses with far-reaching economic and health consequences. However, when adequately treated, sewage effluents may permit repeated uses in a planned way for some beneficial purposes. Treated wastewater are normally returned to water cycle to be used indirectly in diluted forms. In periods of prolonged drought and low flows, the treated effluents may supplement the river flows. Sewage effluents can be used economically and safely in industry as cooling water for towers and boilers at power stations. Cotton textile mills, steel, chemical and pharmaceutical industries may use considerable amount of sewage effluents as cooling waters. Treated sewage effluents can also be put into other uses such as in fish breeding ponds and for irrigation of crops.

The emphasis in this paper is to highlight the potential uses of wastewater as means of boosting agricultural production especially in some parts of Africa where there is widespread drought and where chemical fertilizer is not easily available.

WASTEWATER FOR IRRIGATION

The exploitation of domestic sewage for irrigation is a common practice in some parts of the world especially in countries with insufficient rainfall. But in other countries with adequate rainfall, disposal of sewage by irrigation is practised primarily to protect the water courses against pollution and a secondary effect of slightly increasing the crop yields. In India, for example, it is reported that there are over 132 sewage farms covering approximately 12,000 hectares and utilizing about one million cubic meters of sewage daily (ref. 2). In South Africa and Namibia, it is also reported that about one-half of the released wastewater effluent is used for irrigation and that one-quarter is used for industrial purposes (ref. 3.). Similar operations are practised in Israel, France, U.S.A. etc.

SOME FACTORS AFFECTING THE SUITABILITY OF IRRIGATION WASTEWATER:

Plant Nutrient Value:

The suitability of wastewater for irrigation is based on its considerable fertilizing constituents and soil conditioning values. Besides containing water which maintains proper moisture levels in the soil, sewage effluent is a valuable source of plants fertilizing nutrients such as nitrogen, phosphorus and potassium. In addition to these manurial values sewage effluent contains a considerable amount of organic matters which when applied to light soils of low humus, can enrich the soil structure by increasing its humus content which may result in significant improvement in crop yields.

Salt Content:

The salt contents of sewage are contributed by such factors as the salt content of original water supply, the rate of water consumption per head and the kind and quantity of salts released into the sewage by local industries and domestic activities. Sewage contains such cations as calcium, magnesium, sodium and anions such as carbonate, bicarbonate, sulphate, chloride and nitrates which are generally essential for plants' growth and which may be toxic to plants only in very high concentrations. Injuries to plants occur as a result of the following identifiable hazards:

Salinity hazard:

Serious salt injury to crops occurs when a high salinity as measured by electrical conductivity or high total dissolved salts wastewater is used for irrigation. In soils which do not transmit irrigation water rapidly enough to keep salts moving downwards through the root zone, salt injury to sensitive crops can occur if wastewater containing more than 1250 ppm dissolved salts (electrical conductivity 2.0 μmhos/cm) is applied regularly.

The U.S. Salinity Laboratory has classified the effects of salinity as follows:

Low salinity water (0-250 μmhos/cm)
Moderate salinity water (250-750 μmhos/cm)
Medium to High salinity water (750-2500 μ)

The degree of tolerance to soluble salts varies from plant to plant and is dependent on contact period and the ambient temperature. For example, fruit crops, such as date palm show a high salt tolerance while grape and orange show medium and low salt tolerance respectively.

Sodium hazard:

The quality of an irrigation water depends not only on the total concentrations of soluble salts but also on the relative proportion of sodium (Na^+) to other cations, calcium (Ca^{++}) and magnessium (Mg^{++}). This is usually expressed as Sodium Absorption Ratio (SAR) defined as: (ref. 4)

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Where Na^+, Ca^{++} and Mg^{++} are expressed in milliequivalent per liter. The U.S. Salinity Laboratory classified SAR as follows:

Low Sodium water (SAR 0 - 10)
Medium Sodium water (SAR 10 - 18)
High Sodium water (SAR 18 - 26)
Very high Sodium water (SAR $>$ 26)

Generally, wastewater with SAR $>$15 should be avoided because of the detrimental effect on soil structure and ultimate reduction in the infiltration rate of the soil.

Bicarbonate hazard:

Using "residual sodium carbonate" as a basis of computing for the bicarbonate hazard the U.S. Salinity Laboratory conclude that waters containing "residual bicarbonate" of

1. less than 1.25 meq/l are proably safe
2. 1.25 - 2.5 meq/l are marginal and
3. more than 2.5meq/l are unsuitable for irrigation.

Boron hazard:

Boron content of irrigation water is of great importance to many crops. Boron in trace quantity is essential for the growth of all plants. However, some crops can tolerate a large quantity of boron while others are very sensitive to it. The crops most sensitive are citrus, nuts and deciduous fruits; semi-tolerant are lettuce, alfalfa, beet, asparagus and date-palms. In general, boron concentration of more than 2.0 mg/l in irrigation water will seriously affect many crops.

PUBLIC HEALTH AND NUISANCE CONSIDERATION

Wastewater may be generated by municipal industrial and agricultural activities. Because of its nature and origin, wastewater is quite variable in its physical, chemical and biological compositions. Municipal sewage usually contains a full range of pathogenic bacteria, viruses, protozoa and helminths which are excreted in large number by the carriers of a community and which are associated with enteric diseases such as cholera, typhoid, hepatitis and poliomyelitis endemic in the community. Industrial and agricultural wastewater may contain a considerable amount of complex inorganic and organic compounds which may be toxic to plants and animals. Recently, there is an increasing concern about the largely unknown health effects of heavy metals such as mercury and lead which may be present in wastewater.

Conventional wastewater treatment is a well established process for the removal of organic contaminants and pathogens. But while a considerable amount of organic contaminants are removed by the various physical, chemical and biological treatment processes, the bacteria including pathogens and viruses are partially removed.

It is therefore evident that from the public health consideration, the use of raw wastewater is generally not considered desirable for agricultural purposes. Even, the partially treated effluent has to be used with caution.

In addition to the contamination of the crops irrigated with wastewater, there is the potential health risk to the agricultural workers from direct contact with sewage, and the health risks to animals grazing on sewage irrigated pasture. Such direct contamination has been reported in India where there is a high incidence of helminthic infection among the sewage farm population as compared to that of the farming population in general. Sewage irrigation by flooding may encourage the breeding of disease vectors while spray irrigation may result in wide dispersion of pathogens within the aerial sprays. In addition to the microbial and chemical problems associated with sewage irrigation, aesthetic factors such as taste, odour and appearance of sewage water are usually undesirable.

ELIMINATION OF PUBLIC HEALTH HAZARD:

In order to minimize or eliminate possible health risk associated with the wastewater irrigation, the following measures are desirable.

Additional treatment of wastewater effluent:

If wastewater effluent is to be used for unrestricted irrigation of all agricultural crops, a high degree of disinfection is necessary to inactivate the pathogens and viruses. It has been recommended by WHO meeting of experts (ref.5) that crops eaten raw should be irrigated only with biologically treated effluent that has been sufficiently disinfected to achieve a coliform level of not more than 100 organisms per 100ml. in 80% of the samples. Studies by Kott (ref.6) have shown that 20mg/l of chlorine applied to primary effluent for 6 hours achieved a coliform count of not more than 100 per 100ml, while 8mg/l of chlorine achieved the same results in 2 hours when applied to the effluent from a high-rate trickling filter effluent. It was also reported that the treatment was effective in activation of amoebic cysts. Studies by Shuval (ref. 7) have shown that it is quite feasible to achieve a coliform count of around 100/100ml by applying as little as 5mg/l chlorine to the effluent of a high-rate biological filter plant. However, it was shown that with 1-hr contact time, about 10 times as much chlorine is required to achieve the same degree of disinfection for poliovirus as is required for coliforms. Recent Studies by Ogunrombi (ref. 8) shows that a 15 - 25 mg/l of chlorine concentrations applied to Oxigest Plant Effluent for 1 hour consistently inactivate fecal coliform by 99.999%. A higher reduction can be achieved by simply increasing the contact time beyong 1 hour.

There is a trend in many countries to chlorinate wastewater effluents for controlling water-borne diseases. However, wastewater chlorination has become an issue of controversy. There is an increasing concern about the effects of chlorinated-induced toxicity of chlorinated wastewater. A high level of chlorine is usually required to satisfy inorganic constitutents of wastewater and to maintain an adequate degree of disinfection. Consequently, the residual chlorine may be sufficiently high to have a detrimental effect on aquatic environments. Chlorination of wastewater is further complicated by the possibility of aftergrowth of coliforms and pathogens in chlorinated effluent. Such aftergrowth has been observed by some investigators (refs. 9, 10, 11). When the effluent is to be used for irrigation of food crops, the health hazard of aftergrowth of coliforms and pathogens become apparent. However, in spite of the possible harmful side effects and in spite of the occurrence of aftergrowth, controlled chlorination of sewage effluent is still a desirable process. Disinfection by zone is not widely practised. However, studies by Katzenelson et al (ref. 12) indicate that ozone inactivates viruses many times more rapidly than chlorine. More research is needed in this area.

Restrictive Utilization for certain Crops:

The threat to health associated with wastewater irrigation can be minimized by restricting the effluent irrigation to certain crops not used for human consumption or to crops consumed only after cooking or processing. It is generally considered that only a limited health risk would result from using wastewater effluent for restricted crops. It is usually advisable to restrict the use of wastewater effluent to the following crops:

1. Industrial crops such as cotton
2. Grass grown for hay
3. Vegetable which are only consumed after cooking such as potato
4. Ornamental shrubs, plants and flowers
5. Plants grow for seed

Experiments conducted in India (ref. 13) over a period of 1 - 2 years with essential oil bearing plants citronella and Mentha (Peppermint) as test plants showed that the plants can be grown on sewage and their yield as well as oil percentage are higher than with plain water. Also, the experiments conducted at Ahmadu Bello University, Zaria over a period of 3 years with varieties of barley, maize and wheat as crop tests indicate better grains yield with sewage effluent than with plain water.

SUMMARY AND CONCLUSION

Irrigation with wastewater effluent is widely practised in many countries of the world. Besides containing water, wastewater has manurial and soil conditioning values. Utilization of wastewater effluents for crop irrigation not only aids the agricultural economy but also helps in the control of water pollution. Wastewater irrigation may involve hazards to the soil and a potential health risk to a community. However, with adequate treatment to restore the effluent to high-level quality and with proper management, the health hazards can be minimized or eliminated. The advantages of wastewater irrigation, nevertheless, outweigh the disadvantages particularly in the light of food production in the more arid areas where there is widespread droughts. However, more research is required in order to identify the full spectrum and concentrations of the chemical and microbial contaminants in the waste water effluent, in as much as they affect the safety or public health. *Also, many psychological problems* remain to be solved to win public acceptance for the widespread use of wastewater effluent for irrigation. This is more so in the arid and semi-arid zones of West Africa where wastewater irrigation is relatively unknown. Experimental farms can be organised to educate both the farmers and the general public.

REFERENCES

1. A. Feinmesser, (1963), *Survey of Sewage* utilization in Israel. Published by the Water Commission, Ministry of Agriculture, Israel.

2. Central Public Health Engineering Research Institute Nagpur, India. Health Status of Sewage Farm Workers. Technical Digest No. 17. (1971).

3. Notes on water pollution, No. 31, Water Pollution Research Laboraotyr, Ministry of Technology, London, (1965).

4. Agriculture Handbook No 60 United States Department of Agriculture (1954). Diagonis and Improvement of Saline and alkali soils.

5. WHO, Reuse of effluents: Methods of wastewater treatment and health safeguards, Technical Report Series No 517 Geneval.

6. Kott, Y. (1966). The treatment of sewage effluents for unlimited sewage irrigation. Haifa, Technion Sanitary Engineering Laboratories (Research Report CV-210).

7. Shuval, H.I. Disinfection of Wastewater for agricultural utilization. In advances in Water Pollution Research (Ed. S.H. Jenkins) Oxford: Pergamon Press.

8. Ogunrombi J. A. (1979). Chlorination of Wastewater for Reuse. Nigerian Journal of Engineering.

9. Shuval, H.I., Cohen, J. and Kolodney R. (1973), Regrowth of Colfiroms and fecal coliforms in chlorinated wastewater effluent. Water Research Journal of the International Association on Water Pollution Research, Vol. 7, No. 4.

10. Eliasson, R. (1968) Coliform aftergrowth in chlorinated stream overflows. Journal of Sanitary Engineering Division, A.S.C.E 94.

11. Rudolfs W., and Gehm H.W., (1936) Sewage chlorination studies. Bulletin 601, New Jersey Agric. Expt. St. New Brunswick, N.J.

12. Katzenelson, E., Kletter, B., and Shuval, H.I. (1974). Inactivation kinetics of viruses and bacteria in water by use of ozone. Journal of the American Water Works Association Vol. 66.

13. Central Public Health Engineering Research Institute Nagpur, India. Sewage Farming. Technical Digest No. 3. (1970).

6th WEDC Conference: March 1980: Water and waste engineering in Africa

RICHARD J OTIS

LESSONS LEARNED FROM U.S. EXPERIENCE WITH SEPTIC TANK SYSTEMS

INTRODUCTION

In the United States, many small communities are facing extreme financial hardships in providing adequate sanitation for their citizens. Conventional water borne sewerage consisting of gravity collection sewers and a central treatment plant that discharges to a surface body of water is the commonly accepted approach to sanitation. However, small communities often do not have the financial resources to construct and operate such a facility, nor do they have the skilled personnel necessary to maintain them. This has forced communities to investigate alternative technologies that provide the same reliable service at a lower cost. Some of the lessons learned may be useful in solving similar problems faced by small communities in developing countries.

SEPTIC TANK SYSTEMS AS COMMUNITY FACILITIES

Conventional sewerage has become to be considered the ultimate design of any public wastewater facility. If improved sanitation is to be realized in most small communities this notion must be overcome. In an analysis of costs of all public facilities constructed in the U.S., construction and maintenance of the collection system accounted for more than 65 percent of the average total annual costs (1). In small communities, sewers can be even more costly because housing is typically scattered (2). Therefore reduction or elimination of the collection system could provide substantial savings in the costs of small community facilities.

However, probably the greatest savings to the communities can be made by reducing the operation and maintenance costs. These costs can account for nearly 30 percent of the total annual costs (2).

Septic tank systems or other "onsite" systems offer a low cost alternative to conventional sewerage. Several treatment and disposal sites could be located within the community to keep costs of collection to a minimum by decentralizing the facility and treating and disposing of the wastes near where they are generated. This also can reduce treatment costs because the wastes would not be concentrated in one spot but dispersed over larger areas so that the environmental impact would not be as great.

The most extreme decentralized wastewater facility is one where each building is served by an individual onsite disposal system. Unfortunately, it is the failure of these systems to function properly which forces most communities into constructing conventional wastewater facilities in the first place. The cause of the failures can usually be traced to poor siting, design, construction and maintenance. Since regular and timely maintenance is a key element to the success of these systems, public management of the systems paid for through user charges would be necessary. Some communities could completely solve their problem by forming a public onsite system management district to rehabilitate and maintain all the individual systems within their jurisdiction at a very reasonable cost.

In many cases, though, the site and soil conditions on each lot preclude the upgrading of the existing onsite systems. Alternatives to the conventional septic tank system could be installed, but they are usually more complex and costly. In such cases, it may be more cost effective to serve a group of homes on a common or "cluster" system. Cluster systems have the advantage of economy of scale as well as the possibility of locating the system on a nearby site with site conditions suitable for a less costly treatment system. Again, public management would be necessary as an integral part of the system.

PUBLIC MANAGEMENT OF SEPTIC TANK SYSTEMS

Sound management of wastewater facilities is an essential component of an effective sanitation program. If community facilities are to be properly administered, operated and maintained, a public or private management institution must be established. This is common practice for central sewerage, but is a relatively new concept for managing onsite systems that may be located on private property. With sufficient powers, however, public management of onsite systems can be very effective.

Management institutions that are to provide sewerage services must have the authority and power to perform the following functions (3):

1. Plan, design, construct, inspect, operate, maintain and own all wastewater systems within its jurisdiction.
2. Enter into contracts, sue and be sued, and undertake debt obligations either by borrowing or issuing bonds for purposes of acquiring necessary property, equipment and supplies.
3. Raise revenue by fixing and collecting users charges and levying special assessments and/or taxes.
4. Plan and control how and at what time

wastewater facilities will be extended to those within its jurisdiction.

5. Make rules and regulations regarding the use of the system or systems under its jurisdiction and to provide for the enforcement of those rules.

FACILITIES PLANNING IN SMALL COMMUNITIES

Planning wastewater facilities that will meet water quality and public health goals at a cost small communities can afford requires a proportionately greater effort than is customary for larger communities. Each community can be quite different and no single solution will work for all. Individual onsite systems, clusters and alternative collection systems must be investigated to keep costs down. Maximum use must be made of the existing facilities and the natural resources of the community. This increases the need for detailed field work and public involvement. A systematic four step procedure outlined below is offered as a guide (4).

Preliminary Assessment

- Define scope of problem.
- Identify sources of information.
- Meet with community officials.
- Discuss potential alternatives.

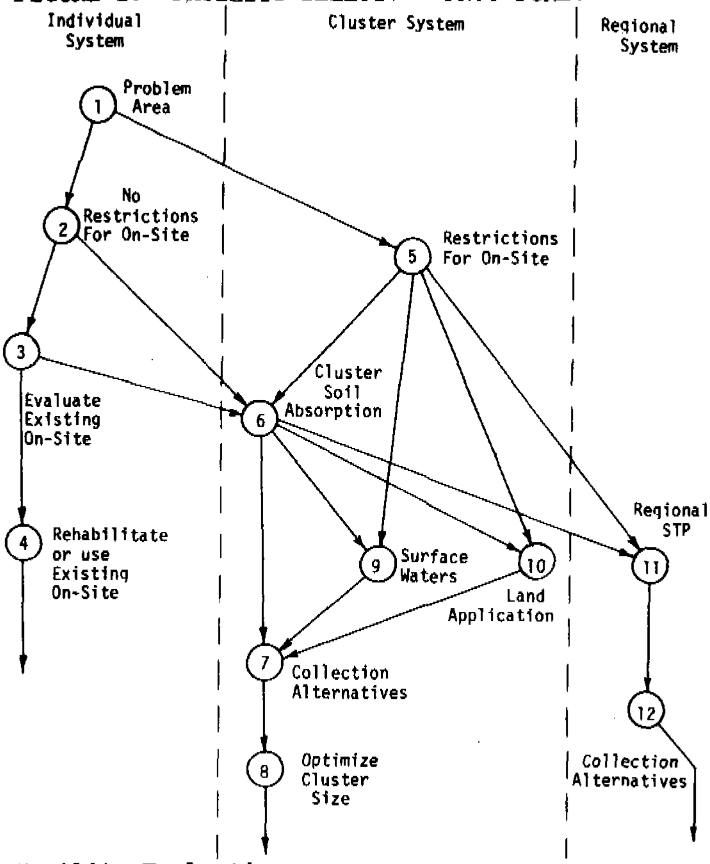
Problem Area Identification

- Identify areas requiring improved or new facilities.
- Evaluate existing private facilities.
- Distinguish between areas where off lot is only alternative and those that are feasible with rehabilitation.

Facility Selection

- Select alternatives for each area.
- Employ procedure (Table 1, Figure 1) to eliminate alternatives.
- Assumptions for Table 1:
  - Where no restrictions exist, subsurface soil absorption of septic tank effluent is the least expensive alternative.
  - Maximizing the use of existing septic tank systems minimizes the total costs.
  - Cluster soil absorption fields are less costly than individual fields where new construction or reconstruction is necessary for a number of lots unless collection costs are excessive because of economies of scale.

FIGURE 1. FACILITY SELECTION PROCEDURE.



Facility Evaluation

- Estimate costs for selected alternatives: construction, operation, maintenance, monitoring.
- Compare present worth of alternatives.
- Review local cost share based on funding available.
- Estimate assessment and user charges.

CASE STUDY

To determine if onsite technology could be employed under central management to significantly reduce the total annual costs of public wastewater facilities, a small rural community was sought for a demonstration study (5). The unincorporated community of Westboro, Wisconsin was selected because it is typical of hundreds of small rural communities that are in need of improved wastewater facilities but are unable

TABLE 1. FACILITY SELECTION DECISIONS CORRESPONDING TO FIGURE 1.

NODE	DECISION	ACTION
1	Do the developed lots have soil and site characteristics suitable for onsite subsurface soil absorption?	Yes - Proceed to Node 2 No - Proceed to Node 5
2	Do the undeveloped lots have soil and site characteristics suitable for onsite subsurface disposal? (If not, can the area be replatted to make each lot suitable?)	Yes - Proceed to Node 3 No - Proceed to Node 6
3	Are the existing onsite systems functioning properly? (If not, can they be rehabilitated easily?)	Yes - Proceed to Node 4 No - Proceed to Node 6
4		Determine costs of rehabilitation
5	Is a suitable area available for a cluster soil absorption system within a reasonable distance?	Yes - Proceed to Node 6 No - Proceed to Nodes 9,10,11
6	Does it appear collection costs will not be excessive?	Yes - Proceed to Node 7 No - Proceed to Nodes 9,10,11
7		Layout collection options and proceed to Node 8
8		Compare costs of various cluster sizes
9		Design low maintenance treatment works to meet water quality standards
10		Design low maintenance land application system to meet local design requirements
11		Investigate feasibility and local cost share of conveying wastes to a regional treatment plant
12		Layout collection options

to afford conventional sewerage.

Westboro has a population of about 200 people. Until 1977, the community of Westboro had no public wastewater facility. All the buildings were served by private septic tank systems. A survey by the Wisconsin Department of Natural Resources (DNR) showed that 80 percent of these systems were discharging wastes above ground. Consequently, DNR issued an order to the Town of Westboro to upgrade the existing septic tank systems or construct a public wastewater facility.

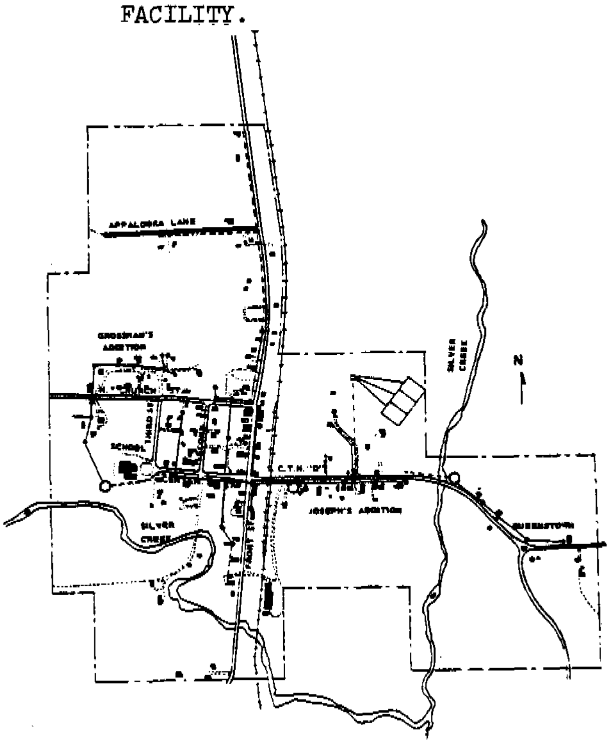
Because the soils and small lot sizes prevented the replacement of most of the failing septic tank systems, public sewerage was necessary. The Town Sanitary District #1 of the Town of Westboro was formed to incorporate all the buildings with failing systems which were endangering the water quality of Silver Creek. An engineering firm was hired to complete a facilities plan in cooperation with staff at the University of Wisconsin.

Selected Alternatives

In addition to conventional sewerage, six alternative facility plans utilizing individual and clustered onsite systems and alternative collection systems were felt to be viable. These alternatives are described elsewhere (5). Each of the alternatives was evaluated on the basis of reliability, cost and environmental impact. Following this analysis, the facility design recommended was a system of small diameter gravity sewers collecting the wastes from each cluster and conveying them to a single area for soil absorption northeast of town (Fig. 2). Homes not in the sewered area would be served by individual onsite systems, owned and operated by the sanitary district.

The District would be responsible for the operation and maintenance of all components of the facility, including those located on private land commencing from the inlet of the septic tank. The property owner would be responsible for providing and maintaining the lateral drain from his home or establishment to the septic tank and any power costs associated with lifting his effluent into the collection sewer if necessary.

FIGURE 2. PLAN OF THE CONSTRUCTED WASTEWATER FACILITY.



Design

Effluent Sewers: Experience with small diameter gravity sewers has been limited to Australia. Guidelines used for their design were ones developed by the South Australia Department of Public Health. These guidelines are summarized in Table 2.

Ten cm diameter mains were specified, set at a minimum gradient of 0.67 percent. Assuming a peak flow of 11.3 L/h per capita (6) this size sewer can serve approximately 600 persons flowing half full. Half full conditions are recommended by South Australia to maintain ventilation of the sewers. This is a very conservative design because peak flows are dramatically attenuated through the septic tank (6). Peak flows of 3.8 L/h per capita are more likely, which increases the design capacity of each sewer line to 1800 persons.

Manholes were placed at the upstream end of each line at junctions and at spacings up to 18 meters. Because settleable and floatable solids are excluded from the sewers, curvilinear alignments both in the horizontal and vertical plans were permissible.

TABLE 2. SOUTH AUSTRALIA GUIDELINES FOR SMALL DIAMETER GRAVITY SEWERS

Minimum Pipe Diameter	10 cm
Minimum Velocity (1/2 Full)	0.46 mps
Minimum Gradient	
10 cm Conduit	0.67%
15 cm Conduit	0.40%
20 cm Conduit	0.33%

Soil Absorption Fields: The soil absorption field was divided into three beds. Two are in service at any one time with the third acting as standby. Every Spring, the standby bed is rotated into service so that each bed receives wastewater for 2 years and rests for 1 year. The resting period allows the bed's infiltrative surface to dry out and rejuvenate (6).

Operating in this manner, the field should last indefinitely if not overloaded. However, if one of the beds unexpectedly fail, the standby bed would be rotated in immediately. The failed bed could then be chemically treated with hydrogen peroxide for immediate rejuvenation (6) or rested.

The total design capacity selected for the absorption field was 113.4 m^3/d. Each bed was designed to absorb half of this or 57 m^3/d. The design flow was estimated by assuming 0.94 m^3/d per home plus commercial flow. These estimates include infiltration. Undeveloped lots and vacant buildings were included in this estimate.

The application rate chosen for the absorption beds was selected based on a soil type which was sand and loamy sand. Long term infiltration rates into such soils loaded with septic tank wastes have been determined to be approximately .049 m^3/m^2d (7). Therefore, each bed required 1160 m^2. This was provided by 30 m by 46 m beds. Pressure distribution networks were designed to distribute the wastewater uniformly over the infiltrative surface to prevent local overloading and premature failure (8).

Three 25 cm siphons were installed, one for each bed. They are capable of discharging an average of 3.78 m^3/d at the design head. Two siphons are operating at any one time. They automatically alternate operation discharging approximately 30.2 m^3 per dose. At design capacity each bed will receive 2 doses per day. The third siphon is taken out of service by closing a ball valve installed in the siphon blow off vent.

Facility Construction

Construction began in April, 1977 and was completed in September, 1977. The soil absorption fields were constructed first. After they were completed, house connections were made and the wastes discharged into the fields as the sewers were installed. Before each connection, however, the septic tank was carefully inspected. All inadequate tanks were properly abandoned and new ones installed. To facilitate pumping of the tanks, some homeowners chose to relocate their tanks near the road. This usually meant reversing the plumbing in the home which was at the owner's expense.

Total project costs were Ƀ 181,960 (1977). This represented about a 13 percent savings per connection over a conventional facility (see Table 3). This was not as great as hoped but the constructed facility serves every home in the district while the conventional facili ity would not have been able to serve 13 of the homes because of excessive costs.

TABLE 3. COMPARATIVE COSTS OF CONSTRUCTION FOR CONVENTIONAL AND ALTERNATIVE FACILITIES.

	Actual Costs of Alternative	Estimated Costs[1] of Conventional
Collection	Ƀ 109,170[2]	Ƀ 80,585[3]
Treatment	40,345	77,400
TOTAL	Ƀ 149,515	Ƀ 157,985
Cost/Connection	Ƀ 1,800	Ƀ 2,080
Number of Homes Served	83	76
Unserved	0	13

[1]Gravity collection/stabilization facility serving 75 connections.
[2]Includes septic tanks and house laterals.
[3]Includes customer hookup charges of Ƀ 215.

Operation and Maintenance

The facility requires very little attention by the operator. All duties can be performed by an unskilled laborer within 2 to 4 hours weekly. The maintenance schedule is summarized in Table 4.

Design Modifications

The facility in Westboro is operating successfully after over 2 years of operation.

TABLE 4. FACILITY MAINTENANCE SCHEDULE

Daily

1. Check lift station alarm lights.

Weekly

1. Open lift stations for visual inspection of pump operation float control operation and debris.
2. Record total weekly flow from pump running time meters as per permit requirement.

Monthly

1. Sample lift station wastewater for BOD_5, suspended solids and pH as per permit requirement.
2. Inspect observation vents in each bed for ponded water. If the ponding is greater than 12 inches, take the ponded bed out of service.

Annually

1. Each Spring alternate resting bed into service and drain manifold of bed taken out of service.
2. Inspect the surface of the absorption field for holes and depressions. Fill in any that are found.
3. Pump 1/3 of septic tanks each year according to schedule.
4. Pump lift stations and siphon chamber to remove any sludge.
5. Jet any of the sewer lines which have a history of clogging problems.

The savings over conventional sewerage were not as great as hoped but experience gained thus far indicates that design changes that can be made which would substantially increase the savings in future facilities of this type. For example, it appears that small diameter gravity sewers do not need to be laid on a uniform grade. Since solids are not accumulating in the system, non-gradient alignments would permit simple trenching procedures reducing excavation and labor significantly. Other suggested modifications are discussed elsewhere (5).

DISCUSSION

The facility constructed in Westboro may not be directly applicable in many developing countries where water borne sewage does not exist. However, several aspects of the Westboro project may provide lower cost alternatives to conventional sewerage. First, public management of onsite systems whether latrines or septic tank systems may solve many of the existing problems without new construction. Second, small diameter sewers can be effectively used in staging public facilities. The lower cost sewers can be used to collect aqua privy wastes for soil absorption fields used for septic tank wastes where public water supplies are constructed. No further upgrading would be necessary. Finally, the planning methodology described can be employed to select the most appropriate sanitation facility for a given community regardless of the technologies considered.

References

(1) Smith, R. and R.G. Eilers, "Cost to the Consumer for Collection and Treatment of Wastewater", Water Pollution Control Research Series No. 17090, U.S. EPA, Washington, D.C. (July, 1970).

(2) Sloggett, G.R. and D.D. Badger, "Economics of Constructing and Operating Sewer Systems in Small Oklahoma Communities", Bulletin B-718, Agricultural Experiment Station, Oklahoma State University (April, 1975).

(3) Otis, R.J. and D.E. Stewart, "Alternative Wastewater Facilities for Small Unsewered Communities in Rural America", Small Scale Waste Management Demonstration, Phase III, Annual Report to the Upper Great Lakes Regional Commission, University of Wisconsin, Madison (July, 1976).

(4) Otis, R.J. and J.E. Kleinschmidt, "Guide to Wastewater Facilities Planning in Small Unsewered Communities", Small Scale Waste Management Project, University of Wisconsin, Madison(1980).

(5) Otis, R.J., "An Alternative Public Wastewater Facility for a Small Rural Community", Small Scale Waste Management Project, University of Wisconsin, Madison (1978).

(6) "Management of Small Waste Flows", University of Wisconsin, U.S. EPA, EPA-600/2-78-173, Cincinnati, Ohio (1978).

(7) Otis, R.J., G.D. Plews and D.H. Patterson, "Design of Conventional Soil Absorption Trenches and Beds", in Home Sewage Treatment, American Society of Agricultural Engineers Publication 5-77, St. Joseph, Michigan, 86-99 (1978).

(8) Otis, R.J., J.C. Converse, B.L. Carlile and J.E. Witty, "Effluent Distribution", in Home Sewage Treatment, American Society of Agricultural Engineers, Publication 5-77, St. Joseph, Michigan, 61-85 (1978).

J I FRASER

THE DESIGN OF WASTE STABILISATION PONDS

INTRODUCTION

Waste Stabilization ponds (WSP) have been used for over 20 years, particularly in hot climates, as an effective, low-cost and easily maintained alternative to conventional systems for the treatment of domestic sewage, agricultural wastewaters and mixtures of sewage and industrial effluents. In addition, ponds have been used to treat night-soil collections, the contents of conservancy tanks, the effluents from septic tanks and aqua privies, and as a tertiary treatment at conventional works to enhance pathogen removal.

The natural processes taking place within a WSP system are controlled essentially by temperature, light intensity and detention time. WSPs are very effective therefore in the tropics where ambient temperatures are high, solar radiation is at a global maximum and the large areas of land required are often freely available. Where waterborne sewage disposal is economically and hydraulically feasible the WSP should be the preferred method of waste-watertreatment in Africa.

Despite the world wide use of ponds and the extensive literature on their design and performance, misconceptions still persist regarding their utility. Their potential for disease transmission control - especially important in most developing countries is often not fully exploited, and difficulty in choosing suitable design criteria inevitably occurs when ponds are being planned for the first time in a distinct climatic region.

POND SYSTEMS

A WSP system should contain at least a relatively large facultative pond for the removal of BOD, followed in series by two smaller maturation ponds for the destruction of pathogens. In the case of high strength agricultural wastewaters (for example, coffee processing and sugar refining wastes) anaerobic pretreatment units should be provided to reduce the BOD to a level (500 mg/l) that the succeeding facultative pond can cope with. To facilitate maintenance and flexibility of operation, the total area required for a pond system can be provided by parallel replicates.

Anaerobic Ponds

An anaerobic pond functions as an open, unmixed, unheated, single-stage anaerobic digester, and to conserve heat and maintain anaerobic conditions such ponds are constructed with depths from 2 to 4M. Like septic tanks, anaerobic ponds require desludging periodically, and should be used for domestic sewage only at the larger installations when the resulting saving in land will be appreciable and where thorough maintenance can be assured.

FIG. 1 WASTE STABILISATION POND SYSTEM

Facultative Ponds

A facultative pond is usually the primary unit in a system treating wastewater of moderate strength. The depth should be in the range 1.0 to 1.6M, and the upper region is maintained in an aerobic condition by the photosynthetic production of oxygen from naturally occurring algae. Anaerobic conditions prevail towards the bottom of the pond due to the fermentation of settled sludge. The conversion of organic carbon to methane in the benthal deposits contributes significantly to the removal of BOD in a facultative pond.

A pond depth of at least 1 M. is necessary to prevent the mergence of vegetation from the pond bottom, and the depths in excess of 1.6M would lead to predominantly anaerobic conditions in the pond contents. Since a pond approximates to a completely mixed reactor, and as part of the influent organic matter is converted to algae, it is neither possible nor desirable to reduce the effluent BOD_5 to values less than about 60 mg/l. Indeed, the design objective should be to obtain a relatively high degree of BOD removal, while maintaining a stable balance between the aerobic and anaerobic zones during all seasons of the year.

Maturation Ponds

In most developing countries waterborne and faecally-transmitted diseases are prevalent, and cause high morbidity and mortality rates, particularly amongst children. The principal function of maturation ponds is to extend the detention time of the pond system, and take advantage of series reactor kinetics, in order to destroy faecal pathogens. The presence of two or more maturation ponds will also reduce the BOD, and suspended solids content, to the values normally obtained from conventional works.

The sanitarily superior effluent obtained by the proper use of maturation ponds is vitally important in semi-arid regions, where many receiving streams are seasonal, such that the dry weather flow may be predominantly or entirely composed of wastewater (treated or otherwise). These same streams are frequently used for laundering clothes, growing vegetables water cattle, and may even be the only source of domestic water.

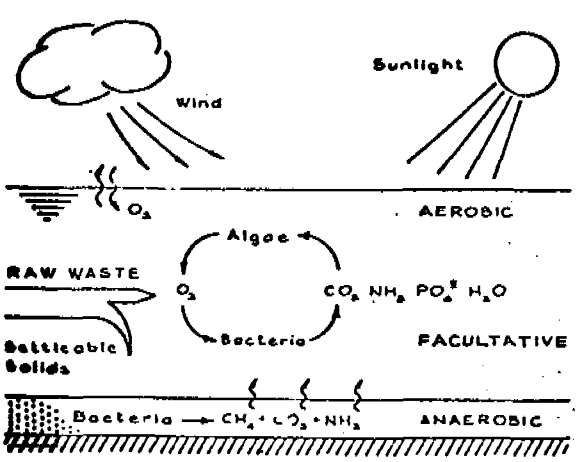


FIG. 2 FACULTATIVE POND MECHANISMS

Standards

In a developed country where waterborne diseases have been virtually eradicated, the main aim of sewage treatment is to prevent environmental nuisance, and treatment systems are designed to minimize space utilisation and accelerate the overall purification process. Pathogens are removed only partially and incidentally.

Consequently, even where ponds are chosen for cost and maintenance advantages, the effluent standard to be achieved is often expressed solely in terms of the BOD and suspended solids removals that commonly occur in conventional works; the British Royal Commission "20/30" standard is frequently quoted in Commonwealth countries. However, this standard applies only to an effluent which can be diluted with 8 volumes of "clean" (BOD_5 = 2mg/l) river water. As pointed out above, tropical rivers often provide zero dilution in the dry season; in the rainy season the superabundant flow may be carrying an enormous load of silt and organic matter, rendering conventional river standards meaningless.

Waste Stabilization Pond in Kenya

The experience of Kenya in the field of sanitation is a common one in developing countries. In the colonial period sewage systems and conventional treatment works were installed in the major urban centres and at government institutions such as hospitals, prisons and military establishments. Since independence in 1963 the ageing of plant, the lack of trained staff and the foreign exchange cost of obtaining spare parts has made it increasingly difficult to maintain such facilities.

In 1972 the Kenya Government carried out a survey of its water supply and sanitation services (Ref. 1) with a view to providing the whole population with a safe piped water supply by the year 2000, together with the concomitant sewerage facilities. The survey revealed that waterborne sewage collection was available to about 43 percent of the urban population. However, since 90 percent of the people lived in dispersed rural settlements, only 2 percent of the population outside the capital Nairobi enjoyed waterborne sanitation; 40 percent were using pit latrines, while over 50 percent of the population had no sanitation whatsoever. Furthermore, outside of Nairobi all facilities using mechanical and electrical equipment were not working properly, or had been abandoned.

Fortunately, the first WSP in Kenya was built in 1959 to replace an overloaded activated sludge plant serving Embakasi Airport, Nairobi (Ref. 2). The success of thisexperiment indicated the way forward.

National Survey

From 1972 to 1974, the author (Ref. 3) carried out a comprehensive survey into the design, construction and performance of the existing and proposed WSP's in Kenya. In the 15 years since the Embakasi ponds were commissioned, over 35 ponds had been built to serve municipalities and government institutions in the several climatic zones of Kenya. Also, crude holding lagoons were used for treating process wastewater from a variety of agricultural industries.

From this experience it should have been possible to formulate, with confidence, empirical design criteria for future ponds in Kenya. However, the only location where measurements of effluent quality had been taken with any regularity were the ponds under the control of Nairobi City Council.

Unfortunately, no regular measurements had been taken of volumetric flow rates and influent quality, so that actual pond loadings and removal efficiencies, in terms of BOD, suspended solids and faecal bacteria, were largely unknown.

Process design of ponds had been pre-occupied solely with BOD removal based upon empirical surface loading rates, chosen arbitrarily from published performance figures from India, the Americas and Southern Africa. Design loading rates for facultative ponds ranged from 100 to 500 kg. BOD_5/ha d. This range is equivalent to a population served per hectare of about 2500 to 12500, representing detention times of approximately 40 to 8 days respectively.

The higher loading rates, which had led to anaerobism and failure in facultative ponds, indicates the danger of applying unthinkingly, empirical loading rates in the design of pond systems. A loading rate suitable for a facultative pond had been used to calculate the total area of a pond system (facultative plus maturation ponds), leading to the immediate overloading of the primary pond.

Since no mechanical or electrical equipment is required in pond systems, and if appurtenances are kept as simple as possible, the only regular maintenance required is that the grass is cut to prevent it from growing down the embankment into the water, and the ponds surfaces should be kept free of floating solids. Maintenance is facilitated, and embankments protected, by placing precast concrete slabs at the waterline or down the whole of the submerged slope. In Kenya, odours and mosquitoes were invariably present at ponds where weeds had been allowed to grow down the embankments into the pond contents, and scum allowed to build up on the liquid surface. Well maintained ponds, unless overloaded, were free from odours and insect nuisance.

The following table summarises contemporary comparative costs (20 K shs = 1£S) for treatment works built by contract in East Africa :

One Mgal/d Unit	Conv. Filter	Ox. Ditch	Fac+Mat Pond	An+Fac+ Mat Pond
Acres	10.0	7.75	45	35
Cap. Cost sh.	6M	4M	3.7M	3.03M
Run. Cost sh.	150000	180000	50000	50000
Cap. Cost/gal.	6.0	4.0	3.7	2.03
Run Cost/gal.	0.15	0.18	0.05	0.05

In India at that time, the cost of WSPS was reported to be less than 25 percent of that for conventional systems. The very low comparative costs for ponds in India is believed to be the result of highly labour intensive construction methods.

Embakasi Ponds

More information is available about the performance of these ponds than any other in Kenya. They originally consisted of a facultative pond, designed for a surface loading of 225 kg BOD_5/ha d, followed by a maturation pond with approximately half the surface area. As the quantity of sewage supplied to the ponds increased, the surface loading rose to about 315 kg BOD_5/ha d and the facultative pond became completely anaerobic. Consequently a new, larger facultative pond was installed, creating a 3-pond series system and reducing the surface loading on the new primary pond back to about 225 kg BOD_5/ha d. This empirical loading cam e to be adopted as the MOW design criteria for facultative ponds in Kenya.

With an influent BOD_5 concentration of 400mg/1, the total BOD reduction through the 3-pond system was consistantly around 95 percent, with a final effluent concentration from 14 to 25 mg/1. By 1972 the influent BOD had risen to values between 450 and 500 mg/1 with a surface loading of about 300 kg BOD_5/ha d. The pond system was again close to failure, but measurements of BOD and faecal coliform (Ref. 4) removals gave the following results :

Sample	BOD_5 mg/1	Faecal Coliforms no/ml
Influent	450	210×10^3
Pond 1 effluent	110	5.5×10^3
Pond 2 effluent	70	190
Final effluent	55	12
Total Removal %	88	99.99

The BOD_5 of the receiving stream at this time was about 100 mg/1.

Design Criteria

The author's survey examined critically the methods available for the design of anaerobic, facultative and maturation ponds in relation to the environmental and socio-economic conditions pertaining in Kenya. The following recommendations are based on this analysis, together with the author's field observations and the performance data from the Embakasi ponds.

1. Anaerobic ponds should be used for wastewaters with strengths in excess of 500 mg BOD_5/1 and maximum permissible pond loadings should not exceed 400g.BOD_5/M3 d. The following minimum BOD_5 removals may be expected in anaerobic ponds in Kenya :

2 day retention	50 percent
3 day retention	60 percent
5 day retention	70 percent

2. The Marais and Shaw equation (Ref 5) based on first order kinetics, and developed for southern African conditions, should be used for the design of facultative ponds :

$$L_e = \frac{700}{2H+8} = \frac{L_0}{(1+Kt)}$$

Where L_o and L_e are the influent and effluent BOD_5 values (mg/l) respectively, H is the depth of the pond in metres, K is the first order BOD removal rate constant (Day - 1), and t is the hydraulic retention time in days from which the dimensions of the pond can be found. The most appropriate form of the Arrhenius equation for the variation of K with temperature is that proposed by Arceivala (Ref. 6) :

$$K_T = 0.30 (1.05)^{T-20}$$

where 0.30 is the value of K at 20°C, and K_T is the value at any other temperature T. 1.05 is the temperature co-oefficient applicable to the treatment of domestic sewage in WSPs.

3. Marais and Shaw found that in order to obtain a satisfactory final effluent BOD it was necessary to provide two maturation ponds in series, each with a detention time of 7 days. They also found that the removal of faecal bacteria follows first order kinetics :

$$\frac{Ne}{No} = \frac{1}{(1+Kt_a)\ (1+Kt_f)\ (1+Kt_m)^n}$$

where N_o and N_e are the influent and effluent bacterial concentrations respectively, and K is the bacterial decay rate (Day-1), t_a t_f and t_m are the detention times in the anaerobic, facultative and maturation ponds respectively, while n is the number of maturation ponds. While K will vary with temperature (Ref. 7), it is advisable to adopt a conservative constant value of 2.0 for sanitary safety. N_e should be less than 5000/100 ml. If this is not achieved with two 7 - day maturation ponds, or if a higher standard is required, then 3 maturation ponds in series each with a detention time of 5 days should be provided. Pond depths should be the same as the preceeding facultative pond.

KANO, NOTHERN NIGERIA

The Kenya experience in sanitation is being repeated in Kano, and again the WSP will play an important part in the solution. The following quotations are taken from the recent Master Plan Report of the UNDP Sewerage and Drainage Survey of Kano (Ref. 8) :

> The lack of experience and skilled labour for operating a waterborne sewage disposal system, the frequent power failures and the foreign currency shortage and restrictions forbid highly sophisticated technical solutions and facilities. This applies mainly to wastewater treatment plants. Existing plants in Kano with artificial treatment processes either do not work or are kept running only with great difficulties. Therefore natural treatment will be proposed in the study.

and

> The tropic climate favours natural sewage treatment processes. Since the availability and cost of land is still not a limiting factor, wastewater treatment in ponds is the most economical solution.

Already a WSP is under construction to serve one of the new housing estates in Kano, ponds have been proposed for the new Bayero University and the UNDP consultants have proposed ponds in conjunction with afforestation irrigation, for the treatment of mixed domestic and industrial wastewaters.

Again the difficulty arises of selecting suitable design criteria in an area with a complete lack of empirical data. Here the Kenya experience is instructive. While the climate of Kano is generally much hotter and less humid than Kenya there are nevertheless many similarities :

a. Seasonal rivers with highly polluted dry weather flows

b. High strength (BOD and faecal pathogen) domestic sewage;

c. A large rural riparian population; and

d. A distinct cool season with temperatures similar to those in Nairobi.

Recommendations

1. The above design criteria found appropriate for Kenya are recommended as a guide to the design of ponds in Northern Nigeria. However, these should be used in conjunction with an experimental programme to check the efficacy of the design, and the suitability and seasonal variation of the biological rate constants assumed.

2. Flow measuring devices should be installed at all major ponds. Without influent flow measurements it is difficult to determine actual loading rates and detention times, and without effluent flow measurements it is impossible to assess the combined losses due to evaporation and seepage in the pond system.

3. Ideally, a regular testing programme of both influents and effluents should be instituted at several ponds in different climatic zones, so that a body of performance data can be built up as an aid to future design in Northern Nigeria.

REFERENCES

1. KENYA GOVERNMENT. Sectorial Study and National Programme for Community and Rural Water Supply Sewerage and Water Pollution Control. WHO. Brazzaville, 1972.

2. HUNT MA. and RESTONBERG HJW. Oxidation Ponds in Kenya. J.I.S.P., (3) 230, 1964.

3. FRASER JI. The Design of Waste Stabilization Ponds in Kenya. MSc Thesis, University of Newcastle Upon Tyne, 1975.

4. MARA DD. The use of Agar Dip-Slides for Estimates of Bacterial Numbers in Polluted Waters. Water Research, 6, 1605. 1972.

5. MARAIS GvR and SHAW VA. A Rational Theory for Design of Sewage Stabilization ponds in Central and South Africa. Trans. S. Afr. Instn. Civ. Engrs., 3, 205, 1961.

6. ARCEIVALA SJ et al. Waste Stabilization Ponds: Design, Construction and Operation in India, CPHERI, Nagpur, 1970.

7. MARAIS GvR. Faecal Bacterial Kinetics in Stabilization Ponds. J.E.E. Div., ASCE, 100 (EEI), 119, 1974.

8. KANO STATE GOVERNMENT, NIGERIA. Kano Sewerage and Drainage Project: Master Plan Report. UNDP, New York, 1978.

Session 8: WASTEWATER AND ITS TREATMENT

Discussion

T M Aluko

Waterborne Sanitation in Nigerian Cities

Dr ALUKO said that for large towns and cities there was no doubt that the central sewerage system was the most effective method of dealing with sewage, but there were problems common to most African urban areas. These problems were described in the paper. The most important was cost. Studies have indicated that pipe costs rise logarithmitically with pipe diameter, resulting in high sewerage costs in large urban areas where large size sewers will inevitably be used. The conclusion was that while it was almost impossible to provide sewerage systems for large urban areas due to the cost of big size sewers, it was possible to provide sewerage in small pockets of development where pipe size and therefore pipe cost will not be too high.

2. Dr E A ANYAHURU commented that the high cost of sewerage for the whole of Lagos was surely related to other factors as well as pipe diameter, such as existing facilities, and the cost of excavating flat areas. Dr ALUKO replied That he was attempting to show that the more extensive the project area the larger the main sewer and the bigger the diameter of inlet pipes needed to be. Where a small suitable area could be identified, the chances were that smaller pipes could be used and the cost would be so much less.

3. Professor A M WRIGHT asked if Dr Aluko had comparative costs for providing water, sewerage and electricity. Dr ALUKO had no such information, but he would look into it.

W C Boyle and R J Otis

Treatment of Small Flows Wastewater-on-Site with Intermittent Sand Filtration

4. Professor BOYLE explained that the work had all been done in the United States of America and they had no experience of Africa at all, but they believed that the Conference would be interested in some of the low-cost technology now being used in the USA for treatment of wastewater in rural areas. Over the past ten years the University of Wisconsin had been working on several alternatives to the conventional septic tank where this was not suitable. All the alternatives tested had been found to be satisfactory, providing low-cost and low operation units for individual homes and small communities.

5. Mr G H READ asked whether any consideration had been given in the United States to the limitation of water consumption at domestic levels, or to treating sewage and sullage separately. This might have a reducing effect on costs.

6. Professor BOYLE said that a typical rural home in the United States used 40 gallons per person per day. The large figure of 247 gallons was for large cities and included other things such as fire services etc. For areas where water supply was short, low flush devices had been recommended. Separation of sewage and sullage and their separate treatments was being investigated. In Wisconsin there were eight demonstration sites. A report would be made to the Office of Water Research at the end of 1980 on the separation question, together withthe effectiveness and acceptance of low-flow systems.

R J Otis

Lessons Learned from U S Experience with Septic Tank Systems

7. Mr OTIS said that as a guide, a sanitation system must satisfy needs; be reliable; and be low cost. Often as a small community grew, its sanitation system could be staged, ie pits first then septic tanks and finally sewerage. Again emphasis was placed on planning and public participation in schemes.

8. Mr J C NDUPUECHI asked how groundwater pollution was prevented when disposing of treated sewage by percolation into the ground, and how was clogging of the surface of percolation basins dealt with.

9. Mr OTIS said that it was important to do a site evaluation before proposing soil absorption of wastewater. Special soil conditions were needed and over half the soils in the US were unsuitable without further modification. The soil should have a depth of at least 900mm of unsaturated soil below the infiltrative surface. This would adequately purify the percolating water, given a suitable percolation rate. This rate was defined using the percolation test, which was not very good. It involved digging a hole of

about 100-200mm diameter, filling it with water and timing the drop of the water level in the hole. If the rate was found to be faster than about 25mm per half minute, the soil was too coarse. For individual homes the rate would be up to 25mm per sixty minutes, while the rate for a large community system would be up to 25mm per thirty minutes. With regard to clogging, a three year cycle was used for the system. Also a pressurised syphon could be used to distribute the water over a larger area, thus giving a life of over twenty years to the system. If failure did occur then a hydrogen peroxide solution would oxidise the clogging mat.

10. Dr ALUKO observed that in Lagos the soil was very good for soaking away water, but the water table was very high. Sometimes in the wet season it came up to ground level. Even in good soils there must be minimum distance of the water table below the outlet.

Dr J I Fraser

The Design of Waste Stabilisation Ponds

11. Dr FRASER explained that waste stabilisation ponds had been known and used for twenty years especially in hot climates, as an effective, low cost and easily maintained alternative for sewage and agricultural wastewater treatment. In his opinion this should be the preferred method of treatment in Africa where waterborne sewage was practical, providing that sufficient land was available. Slides were used to help explain the purpose and working of a waste stabilisation pond, putting the emphasis on their great ability to destroy pathogens.

12. Mr J N GITONGA commented that in Kenya one of the biggest problems with older conventional wastewater treatment systems was that of overloading. How well did the waste stabilisation ponds adapt to overloading? Dr FRASER answered that if overloading occurred, extra pond space was needed. For example, the first pond could be used as an anaerobic pond, adding new maturation ponds to complete the pond system. Or a parallel system could be used to divide the load.

13. Dr K O IWUGO thought that although land was available now for waste stabilisation ponds, this might not be the case in the next ten to twenty years. Dr FRASER answered that in most African countries sufficient land was readily available. Because ponds have no massive structures the land can be reclaimed for an alternative purpose, or a more compact treatment works in the future. Consequently the land could be considered as a long-term investment.

14. Professor WRIGHT asked whether with a change of type of pond as described, the depth of the original ponds would still be suitable for the new use. Dr FRASER said that the depth in all the ponds must be sufficient (from 1.0 to 1.5m) to prevent weed growth, but the depth of an anaerobic pond can be much greater in order to preserve heat and maintain anaerobic conditions. However, anaerobic ponds are not normally recommended for domestic sewage because of maintenance problems.

Ken Ellis

Aerated Lagoons for the Treatment of Industrial Wastewaters in Developing Countries

15. Mr John PICKFORD apologised for the absence of his colleague and showed the slides which illustrated the paper, showing linings and aerators for the aerated lagoons. He emphasised the importance of proper maintenance by skilled people.

Professor J O Ogunrombi

Wastewater for Reuse

16. Professor OGUNROMBI commented that in recent years drought had devastated Africa, and now alternative sources of water were urgently needed. Work had been done on the suitability of wastewater, and this could be especially important in areas where few fertilisers were used and food crops were failing through lack of water. The great problem was the psychological one of how to convince the farmers that the water was suitable.

17. Professor B Z DIAMANT asked whether, in view of the dangers of spreading enteric diseases in the wastewater used on food crops it might be better only to recommend its use on non-food crops, such as sisal for ropes.

18. Dr IWUGO noted that Dr Fraser had mentioned destruction of pathogens in maturation ponds. Could this be used instead of chlorination of the wastewater for reuse?

19. Professor OGUNROMBI replied that maturation ponds alone were not enough. Additional treatments had to be used. Chlorination, provided it was controlled, was quite good enough.

20. Dr M UKAYLI said that in Saudi Arabia, secondary treated sewage was used for agricultural irrigation and for household supplies. The psychological problems had been overcome by the intervention of the religious leaders, the 'Mufti', who had declared it 'Halal' to use tertiary treated sewage for drinking water provided it was under a closely watched monitoring system.

21. Mr J O OYENNGA referred to the desirability of chlorination, and said that in Festac village the final effluent from the

sewage works was hlorinated before discharge into the lag on in order to protect fish and plant life.

22. Professor DIAMANT suggested that everyone seemed to have forgotten that some years ago it was found that the combination of chlorine with certain organisms produced new organisms which were cancer-forming. We should therefore take great care when using chlorine and consider replacing it with something else,

RESOLUTION BY PARTICIPANTS

The participants at this Conference resolve as follows:

1. In order to make even minimal progress in low cost sanitation in both urban and rural Africa, it will be essential to train a large cadre of technicians in current thinking and sanitation programme development.

2. There is in particular a shortage in the manpower categories of: sub-professional health workers (Category A), and mid-level construction technicians of the artisan/ foreman level (Category B).
Very few in these categories have had exposure to current thinking in sanitation programme implementation.

3. The participants request that the Universities of Ahmadu Bello, (Zaria,Nigeria) Kumasi, (Accra, Ghana) and Loughborough, (Loughborough, UK), prepare proposals for meeting this need, considering each category separately.

4. It is suggested that existing cadres of Category A, health workers, would make a highly effective contribution to sanitation development if given further training in programme design, financing, technology and construction management. This could best be done through existing Institutions, such as the Universities at Kumasi, Zaria and Loughborough.

5. It is suggested that for Category B, short in-service technician training programmes in sanitation could be rapidly developed in conjunction with a number of on-going water supply training programmes, (such as the Cameroon Rural Water Programme, the Tanzanian Rural Well Programme or the Ghanain Rural Water Programme).

6. It is felt important that personnel in both categories see such training as part of a career structure in the sector.

7. The participants recommend that this be given a high priority by the Universities of Ahmadu Bello, Kumasi and Loughborough, and that early consideration be given to funding the programme.

R F CARROLL

IMPROVING THE PIT LATRINE

1 INTRODUCTION

The main expectation of a sanitation system is the disposal of excreta without contact with or nuisance to members of the community. A fundamental criterion necessary to preserve public health and comfort is the isolation of human excreta from other people, insects and animals until it is rendered harmless and inoffensive.

The pit latrine is the most widely used excreta disposal system in developing countries today, although still secondary to defaecation in fields or bush. Badly constructed pit latrines can become offensive due to odours and fly and mosquite nuisance. Also health hazards exist with some installations, resulting from access to the pit contents by insects and animals. If disease organisms are present then they can easily be transmitted over a wide area by these carriers. Pit collapse is a common problem, particularly where heavy superstructures are built and the supporting ground is unstable.

Shortcomings of pit latrines are frequently reported, and the purpose of this paper is to consider improvements in design and construction to improve the comfort, safety and effectiveness while at the same time achieving an economical unit cost.

2 POLLUTION FROM PIT LATRINES

There is some recent evidence(1) that groundwater pollution can occur from pit latrines installed in certain ground situations. In areas with fissured rock or other types of highly permeable ground or where pits penetrate the groundwater, high nitrate levels and high bacterial counts can occur and could present dangers to human health. In areas where hazards exist, it is important that a safe water supply is made available from an uncontaminated source if pit latrines are the only affordable method of excreta disposal.

It has however been shown by such authorities as Baars(2) that the passage of contaminated water through soil generally has a filter effect in removing harmful organisms that may contaminate boreholes and wells.

Possible sources of groundwater pollution, such as pit latrines, should be sited with care in relation to water sources and recommended safe distances should be observed(3).

3 A NEW APPROACH TO PIT LATRINE TECHNOLOGY

As new housing plots tend to be smaller as time goes on, due to a growing shortage of land, particularly in the semi-urban areas created by development of land for 'site and services' schemes, the traditional practice of digging a new pit when the first one is full may not be practicable. Also if standards of design and construction improve, giving greater comfort conditions with improved stability of pit and superstructure, then the rebuilding of the latrine every few years is wasteful of effort and material resources.

One approach could be to empty pits for re-use rather than excavate new ones. The practice of emptying pits for re-use is not entirely new; in some countries single pits have been emptied by first flooding the 'full' pit with water and then extracting the diluted contents by cesspit emptier (vacuum tanker). There are considerable health hazards in this practice, since the top layers of the pit contents will not be decomposed and are likely to contain viable organisms harmful to health.

By sealing off a pit after a period of use and retaining the contents long enough for pathogens to die off, the material then excavated would be harmless and inoffensive.

To achieve this it is proposed that double pits be employed, used in turn for a period before sealing off, the contents then left for a further maturing period before emptying.

If double pits that can be emptied are used, excavations smaller than traditional pits will suffice, with correspondingly reduced labour and material costs for the supporting structure. For example, at a designed capacity of 1.5 m^3 effective volume, a compartment should last a family of five persons for around three years. This calculation is based on two thirds of 'actual' pit volume being used as 'effective' volume(4).

Pit emptying should be carried out without the addition of water, since water is normally a scarce resource and its addition will also increase the volume of material to be extracted and transported to disposal.

By constructing shallower pits there will be less risk of penetrating the groundwater, less side area for percolation of contaminated liquids into the ground and indeed less stored material that is possibly a pollution source.

4 EXPERIMENTAL DOUBLE PIT LATRINE

To develop the concept of permanent and emptyable pit latrines, prototype designs have been prepared, designated the 'PIP latrine' (Permanent Improved Pit latrine). The basic design is the PIP type A, illustrated. A prototype has been constructed at the Building Research Establishment to verify constructional details and to investigate the effectiveness of alternative pit ventilation arrangements.

The main features of the PIP latrines are:

- (i) Small double pits, each 1.5 m^3 effective volume.
- (ii) Pit tops and superstructure supported.
- (iii) Pits ventilated, to reduce odour and insect nuisance.
- (iv) Mechanised or manual emptying.
- (v) Two year retention period.
- (vi) Three year emptying cycle.
- (vii) Pit contents decomposed, harmless, inoffensive and useful as a fertiliser.

A major departure from traditional pit latrine practice is that PIP latrines are designed to be emptied. Double pits are used so that a period of 2 years can elapse before the last deposited material is excavated. If the average pit is filled in 3 years, this retention period means that the bottom layer of pit contents will be at least 5 years old, reducing through the depth of material to the topmost layer which will be at least 2 years old.

The human gut is the ideal host environment for survival and breeding of many pathogenic bacteria and parasites that are the cause of much poor health, particularly in the developing countries. Pathogens that may contaminate fresh human excreta will die-off during a retention period exceeding 9 months in a pit latrine(3) due to the unsuitable environment. It is proposed that a retention period of around 2 years be adopted, as an added safeguard to health.

The construction sequence for a PIP type A latrine is illustrated by the figure:

1 Initial shallow excavation, 350 mm deep, with level bottom.
2 Concrete liner, 500 mm deep x 100 mm thick, cast in shutters on undisturbed ground.
3 Pits excavated within liner and partition wall constructed up to the underside of the liner.
4 Precast concrete floor panels (2) and access covers (4) assembled.
5 Superstructure erected on floor panels. Separate ventilation pipe with insect screen to each pit.
6 Mechanised pit emptying or may be manually emptied.

5 PIT EMPTYING

Because of the shallow depth of PIP latrines it is feasible to empty the compartments manually, using long-handled shovels. However, in many cultures this is socially unacceptable even though the decomposed material in the pit should be almost odourless and inoffensive, similar in texture to friable soil if the pit is above the water table. If the pit is wet the resulting slurry should also be harmless and have little offensive odour after two years retention.

Mechanised emptying of pit compartments is planned for an experimental project in Botswana. As part of the research programme an emptying machine will be supplied to provide a three year emptying cycle for these double pit latrines. The machines envisaged will work on a high volume air flow principle, that will draw all types of material, ranging from light dry material to wet sludge, according to the groundwater conditions in the pit at the time of emptying. The suction unit is based on a centrifugal fan, passing only filtered air. No abrasive material will pass through the rotor of the fan, thus ensuring a long life. Trials with such a machine, lorry mounted, will be carried out at BRS, to ascertain maximum horizontal distances over which a simulated pit material can be pulled by the machine. The suction hose is 200 mm dia and will pass all the common materials likely to be deposited in a pit latrine.

6 PIT VENTILATION

So that odour nuisance is a minimum, as well as to reduce the attraction to insects to enter the system, it is desirable to create a flow of air in through the inlet hole and to discharge it together with foul gases through a ventilation pipe at high level.

Experiences reported from tropical countries have suggested that by siting a black painted ventilation pipe on the sunny side of a superstructure, solar heat would warm the air in the pipe, causing an upward flow. This upward movement would then draw air in to the pit through the inlet hole.

Experiments are planned during the collaborative project in Botswana to examine this solar effect, as well as the effects of wind blowing across the open end of a vent pipe. In the meantime however some measurements have been made in the BRE prototype latrine, choosing warm sunny days that gave an appreciable temperature increase of the air in the ventilation pipe.

The results obtained so far do not indicate a significant air flow difference, when comparing the flow in a solar warmed pipe with a cool pipe in shade. However, the wind blowing across the open end of the ventilation pipe, although very light on the days when measurements were made, produced corresponding peaks of air movement in the pipe.

Various venting arrangements will be tried out in the prototype latrine, using different pipe diameters. In addition the ventilation efficiency of a single pipe, shared by both pits, will be compared to that of individual pipes to each pit.

The preliminary results indicate that a pipe diameter of 100 mm gives a good air flow, even when partially obstructed by a flyscreen. This suggests that for a low-cost installation, the pipe could be a single straight length of 100 mm diameter, of any durable material, such as UPVC or asbestos cement, fixed at top and bottom. The pipe can be left self-coloured, but since solar heat absorbed by the pipe could be beneficial in encouraging an upward flow of air and gases, a black external finish to the pipe may be an advantage. This useful effect however may be overrated as already indicated and requires experimental work under tropical conditions to verify.

The outlet end of the pipe may require a terminal fitting if a downward component of the wind is expected. This is only likely if buildings or trees, taller than the ventilation pipe, are in close proximity to cause turbulence. A simple plate terminal located above the outlet should be adequate.

It is important to incorporate an insect screen in the ventilation pipe to prevent disease carrying insects from leaving the latrine. An effective screen can be made from stainless steel woven wire mesh (16 mesh x 28 SWG). This mesh has an aperture of 1.23 mm and should prevent insects such as houseflies and mosquitoes from emerging.

7 RE-USE OF DECOMPOSED EXCRETA

It is hoped that, as a long term benefit, the decomposed pit contents will be used as a fertiliser and soil conditioner, so vitally needed in arid areas with poor soil. In Asia and the Far East generally, raw human excreta has been recycled to the land producing food crops for many hundreds of years. The practice has been accepted as a normal re-use procedure for a waste material even though until recently the health risks were not generally understood. Considerable progress has been made in recent years with composting techniques(5) so that the material being handled is considerably safer for application to land producing crops for direct human consumption.

Pit latrine contents, when properly broken down by bacteria and sufficiently matured to remove pathogens, are ideal for recycling, not least because of their inoffensive nature which it is hoped will encourage their application in gardens and possibly on a larger scale to farmland. Large scale collection would be necessary for farm use, since only small amounts would be available from domestic pit latrines at widely spaced intervals eg for the PIP latrine a three year cycle is planned.

The volume of fertiliser produced from an original 1.5 m^3 compartment would probably be less than one quarter of the original volume. The final amount must depend very much on the nature of materials other than excreta going into the pit. Coarse woody vegetable material will take a lot longer to completely break down than light leafy materials. Other materials such as stones and plastics if they are put in will not reduce at all, but will add to the stored bulk.

8 FURTHER INFORMATION

Final design recommendations and information on construction costs will be reported when the Botswana experiment is completed.

ACKNOWLEDGEMENT

The work described has been carried out as part of the research programme of the Building Research Establishment of the Department of the Environment and this paper is published by permission of the Director.

REFERENCES

1 Lewis, W J, Farr, J L and Foster, S S D. A detailed evaluation of the pollution hazard to village water supply boreholes in Eastern Botswana. Republic of Botswana, Dept of Geological Survey, Project Report GS 10/4, 1978

2 Baars, J K. Travel of pollution, and purification en route, in sandy soils. WHO Bulletin No 16, 727-747, 1957

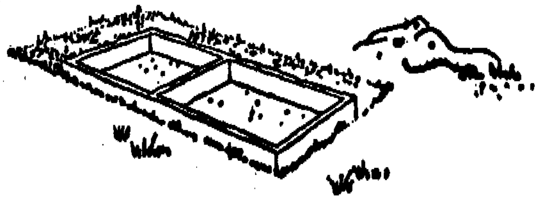
3 Wagner, E G and Lanoix, J N. Excreta disposal for rural areas and small communities. WHO Monograph Series No 39, 1958

4 Feachem, R and Cairncross, A M. Small excreta disposal systems. Ross Institute, London School of Hygiene and Tropical Medicine, Bulletin No 8, 1978

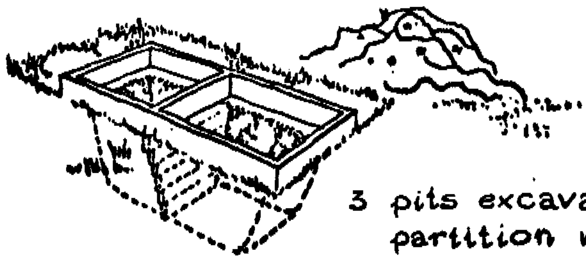
5 Feachem, R, McGarry, M and Mara, D (Editors). Water, wastes and health in hot climates. Wiley, London 1977

PIP

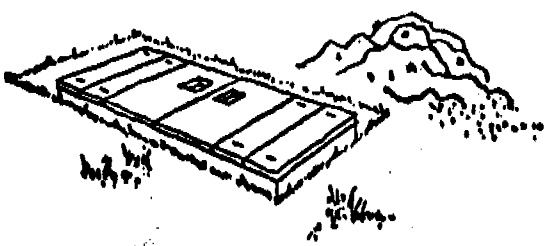
1 shallow excavation - level base



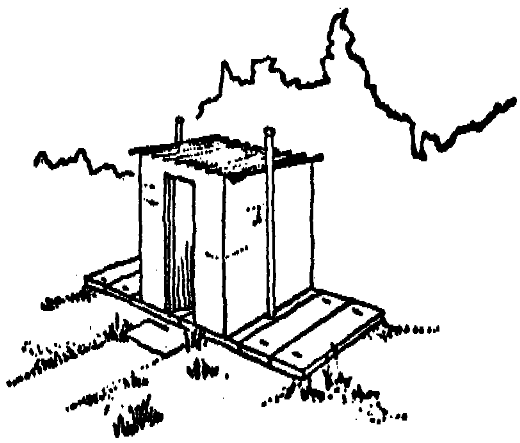
2 concrete liner, cast in shutters on undisturbed ground



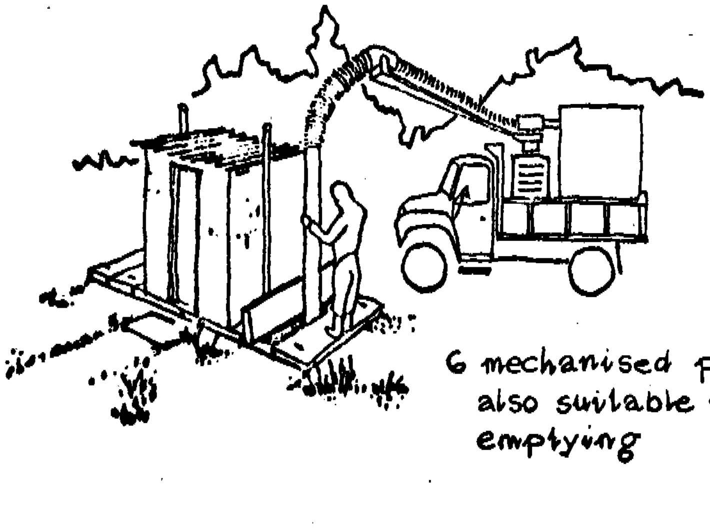
3 pits excavated within liner; partition wall constructed



4 precast concrete floor panels and access covers assembled



5 superstructure on floor panels; separate vent to each pit compartment



6 mechanised pit emptying; also suitable for manual emptying

6th WEDC Conference: March 1980: Water and Waste Engineering in Africa

BILL MOFFAT √

THE SELECTION OF AN APPROPRIATE WELL SCREEN MATERIAL FOR A DEVELOPING COUNTRY

This short paper is an attempt to present in a simple format the important properties of the various materials used in the manufacture of well screens. No attempt is made to describe the size and type of screen openings required for a particular formation or the design of the accompanying gravel pack. These calculations are fully documented in Johnson 1966 and Hunter Blair 1968 and 1970.

The selection of the correct and appropriate well screen is important in any context, but especially so in a developing country where equipment and personnel may not be available to correct any future failure or fault.

An appropriate screen should fulfil the following conditions:

1. The expected life of the screen should be at least similar to the expected life of the rect of the well installation.
2. The material used should not be corroded by the groundwater, and if encrustation is expected the screen material should be unaffected by the chemical or method used to remove the encrustation.
3. The weight and construction of the screen should be such that it can be transported easily and safely by whatever means are readily available.
4. The material should not deteriorate in storage under hot and/or humid conditions.
5. The cost should not be so high that the total number of wells that can be drilled are severely restricted.
6. There is some advantage in having material that can be slotted or constructed in the country of use. Delivery times are frequently so long with imported material that the screen has to be ordered long before the aquifer grading is known, and the correct opening size calculated.

In assessing the benefits of a borehole supply in a developing country some factor should be included for the social and psychological benefit obtained from having a borehole supply working continuously. If frequent screen problems (collapse, blockage) are encountered the users will lose confidence in the new scheme and revert to the old, perhaps polluted source. Cheap first cost and low life materials may thus not be the most satisfactory selection.

Comments on Table

Temperature range - refers only to the temperatures which may be met with in normal working conditions, ie storage in the sun.

Corrosion resistance - this refers only to chemical conditions normally found in ground water and chemicals which may be used to regenerate wells.

Transport problems - includes only those transport problems which can be caused by the properties of the material.

Storage problems - includes only those storage problems which can be caused by the properties of the material.

Production cost - the relative costs at place of production.

Total cost - the relative costs including transport and installation.

Suspended length - the maximum length that can be freely suspended in a water well without causing collapse of the screen or failure of the joints.

Opening types - the types of screen openings which are commonly available.

Coded 1 slots
2 perforations
3 wire wound
4 bridge

Acknowledgements

Thanks are due to the following firms for the supply of information:
Bristol Composite Materials Engineering Ltd, Bristol, UK
DEMCO, Nuneaton Drilling Equipment Manufacturing Co Ltd, Nuneaton, UK
Geotextiles Ltd, Borehamwood, UK
Johnson Screens Europe Ltd, Feltham, UK

Any errors in interpreting the supplied information are however mine.

Material					Cost		Storage problems		Suspended casing length	Notes
					screen	total				
Carbon Steel 1	7.9	No effect	Low unless protected	Weight	High	High	None	1 2 3 4	Unlimited	
Stainless steel 2	7.8	No effect	V good	Weight	Very High	High	None	1 2 3 4	Unlimited	
Glass reinforced plastic 3	1.8	No effect up to 100^{0}C	V good	Medium	High	Medium	Few delaminates	1	1000m	
UPVC 4	1.4	0-60^{0}C	V good	Low	Low	Low	Heat and sunlight	1 2 3	250m +	
Polyolefin 5	0.93	-10 to +110^{0}C	V good	Low	Low	Low	None	1 2	200m	
Brass 6	8.4	No effect	Medium	Weight	Very high	High	None	1	Unlimited	
Bronze 7	8 +	No effect	Good	Weight	Very High	High	None	1	Unlimited	
Bamboo 8	0.4	No effect	Poor	-	Very low	Low	-	1 3	Low	
Terracotta 9	2.3	-	Good	Weight	Low	Low	None	1	Low	
Rainwater PVC 10	1.35	0-60^{0}C	Good	Low	Low	Low	Heat and sunlight	1 3	Low	
Yellow PVC 11	1.3	0-60^{0}C	Good	Low	Low	Medium	Heat and sunlight	1 2	Low	Difficult to to install
Rope 12	-	-	Poor	Low	Low	Very low	-	Random	Depends on former	Wound on former
Polypropylene fabrics 13	low	-	V good	V low	Low	Low	None	2	Depends on former	Wound on former
ABS 14	1.06	-40 to +85^{0}C	Good	Low	Low	Low	Heat and sunlight	1 2	150m +	