UNITED REPUBLIC OF TANZANIA

MINISTRY OF WATER DEVELOPMENT, ENERGY AND MINERALS

RURAL WATER QUALITY PROGRAMME IN TANZANIA

FINAL REPORT

MAIN TEXT

BROKONSULT AB
ENGINEERS – ECONOMISTS – PLANNERS
PER SUNDBERGS VAG 1-3, S-18363 TABY
SWEDEN

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BROKONSULT AB

August 8, 1979

The Principal Secretary
Ministry of Water, Energy and Minerals
P.O. Box 9153
Dar es Salaam

Dear Sir:

We are pleased to forward the Final Report of the Rural Water Quality Programme. This report sets out a detailed set of recommendations on action, organisation, legislation, training and engineering relevant to raising the quality of domestic water supplies in rural Tanzania. This report was prepared by a joint team from Ross Institute of Tropical Hygiene and Brokonsult AB.

The report is based upon extensive field investigations in Tanzania; water quality testing and surveys of rural water schemes on the whole of Tanzania; review of available medical statistics; and interviews with many officials and doctors concerned with health and rural water supplies. In addition, we have reviewed the literature on the relationship between water and health.

We are grateful to the many officials in the Ministry, as well as RWEs and AFYA officials who have contributed much time and assistance to us. In particular, Mr. F.J. Gumbo was the liason officer between the Ministry and the Consultant and exerted great efforts to support the project. We are much indebted to him for his assistance.

Sincerely yours,
BROKONSULT AB

Folke Alkbrant
Project Coordinator

UNITED REPUBLIC OF TANZANIA

MINISTRY OF WATER DEVELOPMENT, ENERGY AND MINERALS

SWEDISH INTERNATIONAL DEVELOPMENT AUTHORITY

RURAL WATER QUALITY PROGRAMME IN TANZANIA

COVER PICTURE

One traditional water treatment method. Water passes through a layer of sand in the upper pot through holes down to the lower pot. Matema at Lake Nyasa.

Final, August, 1979

BROKONSULT AB
ENGINEERS – ECONOMISTS – PLANNERS
PER SUNDBERGS VAG 1-3, S-18363 TABY
SWEDEN

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

LIST OF MAPS

SUMMARY

INTRODUCTION

The goal of the Government of Tanzania and Ministry of Water, Energy and Minerals is to provide the people of Tanzania with an ample supply of safe and wholesome domestic water. Since this is an enormous task and available resources of funds and manpower are limited it must be a very long-term undertaking. The task of MAJI is to improve people's domestic water supplies; this is not an all-nothing procedure but rather a stepwise or incremental process.

The way in which the terms of reference closely juxtapose monitoring and remedial action is central to problems of water quality in Tanzania, and this has dictated the structure of this report. As information on water quality without action is futile, it is necessary to consider possible types of action to improve water quality first, in order to decide upon the structure of a surveillance organisation.

This report contains a complete programme for the improvement of rural domestic water quality in Tanzania. The basis is an action prograame implying an active sequential improvement of the water quality. The recommendations include proposals on engineering solutions, surveillance organisation and supporting legislation. Also included are recommendations on manpower and training, research, schistosomiasis, public education, water source protection, and excreta disposal.

The report is divided into three parts giving information on present situation, a discussion of a rational water quality policy, both serving as a basis for the third part giving the recommendations.

PART ONE: PRESENT SITUATION

This part is a review of the present situation covering existing water quality conditions, existing water supplies including treatment plants, and present laboratories dealing with water testing.

2. Present Water Quality and Use

The effects of water on health are a function both of the quality of the water, the quantity used and the use to which it is put. This latter is difficult to quantify, and most of what is known about water is confined to the total volume used by a person during a day. This information indicates that when water from improved water supplies still has to be carried to the home this

does not lead to an increased water usage and thus, no matter how good the water quality, the significant proportion of faecal oral disease related to hygienic practices cannot be affected by this kind of supply.

The potentially waterborne infectious diseases are all transmitted by the ingestion of minute quantities of faecal material. This is generally of human origin, although certain of the salmonelloses, and probably some other diseases, can be spread by animal excreta. These diseases are caused by agents, ranging from viruses and bacteria to parasitic cysts and eggs. Even in epidemic circumstances only a small proportion of the population is infected by, and therefore excreting, a particular pathogenic organism. This great diversity and sporadic occurrence of pathogens has two implications for water quality monitoring. First, if all pathogens are to be monitored, a large number of different tests must be performed on each sample. Secondly, owing to their sporadic occurrence, extremely large volumes of water from very frequent samplings has to be processed. The approach to be adopted must thus be indirect, monitoring of the likelihood of their presence. This may be achieved by the use of indicator organisms. The most commonly used indicators at present are faecal coliforms and faecal streptococci. The potentials and limitations of these and other indicators are discussed. The membrane filtration technique is proposed as suitable for the monitoring under the circumstances prevailing in Tanzania.

The bacteriological water quality is held to be the most important from a health point of view, thus emphasis was put upon sampling and interpretation of this. By pooling all the results for the same type of water source a good description of their qualities was obtained. The results for twelve types of sources are given.

Boreholes are clearly the best sources. Rainwater collection systems and protected wells are the next best sources and treated water comes off as the fourth, mainly due to poor opration of treatment plants. This is especially the case with chlorine dosage. Springs and piped impoundments are next in quality, while the lowest quality (and the most variable) piped sources are streams and rivers. The worst traditional sources are pits and open wells. This is because pollution introduced during water collection is not able to disperse. These types of sources must be thoroughly suspect during epidemics.

It is inevitable that water carried to the home from a standpipe or traditional source and then dispersed with a scoop or a mug will become polluted on its way. Perhaps the surprising fact is that the extent of this pollution is often rather small.

Domestic water quality standards are set for several chemical parameters by WHO and national authorities. Only few of these, secially fluoride and nitrate, are at present of real importance for the health in Tanzania. Both these constituents are found in high concentrations only in ground water. Areas with high concentrations of these are shown in maps. For fluoride the most severe situation is found in Arusha region where the Consultant's evaluation indicate 23% of sampled sources fail the Tanzanian domestic water standard. Also Singida and Mwanza have high percentages of non-compliance sources. Even Shinyanga is a problem area. In the case of nitrate the most severe conditions are found in Singida, other regions having frequent relatively high concentrations are Dodoma, Mwanza, and Mtwara. The situation regarding conductivity, iron and colour are also reported.

Industries within Tanzania already pollutes and deteriorate the quality of inland waters. The scarcity of receiving fresh water amplifies the problem. At present this is a serious problem only locally.

3. Present Water Supplies and Treatment

The present situation of water supplies operated by MAJI was reported in a SIDA inventory for 1975. From this it can be found that half of the existing schemes supply villages with less than 2,000 persons and two thirds less than 3,000. Stream and rivers are the most common sources (41%), with boreholes next (36%) and lakes and reservoirs third (16%). Shallow wells only represented 7% of all sources.

The Consultant reports data on 43 existing treatment plants, many of which out of order or improperly operated. The most common type of treatment is disinfection with chlorine agents, followed by flocculation with aluminium sulphate (43%). Sand filters come third (35%), about half of which were out of order.

4. Present Water Laboratories

Present laboratories are evaluated in this chapter. The MAJI laboratory at Ubungo is evaluated together with laboratories set up by Water Master Plans. The Ubungo laboratory has a staff of 20 persons and an estimated budget of 435,000/- per year. Based on maximum number of samples handled, the sample cost would be approximately 270/-. A comparable cost in Sweden is 260/-. Based on number of staff and space available it can be concluded that the laboratory is underutilised.

The laboratories established by Water Master Plans in Mtwara, Mwanza, and Shinyanga are evaluated. At present only Mwanza is in a working condition, both staffed and equipped. All these laboratories are equipped with HACH units for physical-chemical and two with Millipore equipment for bacteriological testing. Also MADINI and AFYA laboratories have been visited.

PART TWO: TOWARDS A RATIONAL WATER QUALITY POLICY

The basis for sound policy must be an examination of the goals of improving water quality and the costs of achieving the improvements. The primary goal is improved human health. Although some may try to substitute arbitrary water quality standards for this goal, we are clear that when funds are limited, such an approach can and usually does lead to an unfair distribution of resources to benefit only a limited part of the population. It is, therefore, the objective of this part of the analysis to determine a water quality policy which is justified in terms of the benefits it generates and which can be implemented taking account of the resources available to the Government of Tanzania. First we estimate the relationship between water quality and health, then analyse methods and costs for water quality improvement and finally consider the costs and benefits of three possible levels of improvements.

5. Water Quality and Health

We set out here the general relations between water quality (mainly microbial but also to some extent chemical) and disease and then examine the detailed data collected in Tanzania. This leads to estimates of the morbidity and mortality from faecal-oral diseases.

Water and Disease

Water affects the spread of infections in four ways; by acting as the vehicle for carrying microbes from one infected person to others (as when cholera enters a well), by providing a habitat for snails in which schistosome worms must develop before they can infect people, by enabling people to keep clean and avoid spreading of microbes or allowing them to grow on the skin, and providing a breeding ground for mosquitoes and other disease-carrying insects that develop in water or live near it. The first two of these (faecal-oral and water-based diseases) depend on water quality. Successful provision of clean water should affect both faecal-oral and water washed (third group) diseases.

At persistently high intake of fluoride the condition known as skeletal fluorosis may occur. The difficulty lies in defining the level at which these changes begin to occur. Skeletal deformations have been observed on several occasions in areas around Mount Meru. The present Tanzanian standard should be checked in a study on the presence of osteosclerosis within the country. High nitrate concentrations may cause methaemoglobinaemia in bottle fed babies. The precise levels at which hazards are appreciable is again unclear, however high frequencies are found at concentrations above 23 mg/l of nitrate nitrogen (100 mg/l NO_3). The problem of nitrate is not too serious in rural Tanzania.

The Amount of Disease Related to Water Quality

To assess the importance of water quality disease in Tanzania data on the prevalence and incidence of faecal-oral and other water-related diseases are required. We collected available information on the health status of the population from many sources. All such data are to some extent defective, however, analysis of the data yields some revealing results on the different patterns of disease across the country, which can in turn be related to broad climatic, environmental and hydrological differences. Eight zones have been arranged in an order corresponding roughly to decreasing water availability. Faecal-oral diseases proportionally fall in importance from the highland regions through the hills to the coastal regions, and then, again reaches a maximum in the dry central plateau. This may reflect a decrease in waterborne disease as the water sources change from swift streams, where pollution is washed from one village to another, to more protected wells. The increase in the dry areas represents the effects of lack of water.

In summary it appears that the problem of water quality is more acute in the highland areas dependent on streams and rivers for drinking water. In the drier areas of the country, the main problem is low water availability. The provision of piped water would allow an increase in personal hygiene also, people would no longer have to aggregate to draw water from a few water sources. Both these effects should diminish faecal-oral disease. It is also clear that any attempt to address the problems of water quality and availability must also take into account excreta disposal, or else it may well be found that little benefits accrue from the programme.

The National Perspective

When appraising the importance of improved water supplies, the actual numbers of people affected by the diseases which better water supplies could reduce is required. It was felt that dispensary records would give a much better estimate of this as dispensaries are close enough to the rural population. The diarrhoeal disease rate was estimated to be 3.27 times the number of cases reported among hospital outpatients, giving an attack rate for the whole country of 40% per year. With an average duration of illness of 4 days this means a loss of 1.6 per days per person per year.

Long-term trends were found only for water-washed diseases, for which a steady fall could be observed.

Water quality improvements is only one of complementary inputs affecting health. One very obvious complement is the provision of excreta disposal facilities on a wide scale. A second is a public campaign for health education and a fuller use of health officers and auxilliaries, who although well trained accomplish little. Drawing on all available experience, we can put a ceiling of about a 50% reduction in faecal-oral disease from the very best water quality attainable in absence of these complementary activities. For more practical methods of treatment and hence lower (but substantially improved) levels of water quality, a reduction by 10-20% is considered realistic.

The benefits from a reduction of faecal-oral diseases may be split up in disability, mortality and expenditures by health services. The disability is estimated to 1.6 days per person and year. The estimate is made that 19,821 deaths per year are caused by faecal-oral disease in the over five age groups. The average productive time lost is 20.5 years per death.

Schistosomiasis

Schistosomiasis is a group of two diseases which are vey prevalent in Tanzania and likely to increase. Although responsible for rather little mortality they give rise to a variety of disabilities and much misery.

In practice, the chief way in which improved domestic water supplies reduce the risk of schistosomiasis is by reducing contact with surface water sources, so that access is even more important than quality as such in reducing schistosomiasis. In rural development programmes, and especiaaly water development projects, adequate thought has to be given to providing accessible water without schistosomal risk.

6. Engineering Cost Estimates

In this chapter we discuss in detail the cost estimates for various treatment methods and then cost alternative strategies of water treatment. We cover increased storage, chlorination, flocculation-sedimentation, and slow sand filter. The detailed costings are then used to estimate strategy costs for three different water quality levels.

The preparation of engineering cost estimates requires first the provision of appropriate bills of quantity; then costing these to estimate the financial construction cost. Finally, the financial costs are adjusted to economic costs. The detailed costing for water quality improvement appropriate to Tanzanian conditions have a wider set of uses than as inputs for the strategy cost calculations. These costs are available for assessing the financial and economic costs for alternative treatment plants of sizes up to 200 m^3/day.

Water Treatment Methods

It is assumed that the design and construction of a water scheme is done in such a way that the quality of the raw water will not be lowered on its way from the source to the delivery point. The treatment processes dealt with are those required to provide water to maintain or improve health conditions among the water consumers.

If water is stored in a covered tank certain advantageous effects will occur; reduction of bacteria and other pathogens and sedimentation of particles. The cost for this kind of treatment is defined as the increased cost for total storage over the present design balancing storage.

Treatment of water with chlorine is used for disinfection of water and as a safeguard against possible bacterial pollution in the distribution system. Disinfection by chlorine will not take place until the organic content is low enough. Therefore, the amount of chlorine required for treatment will vary with the quality of the raw water. The alternative chlorine agents considered for use are: chlorine gas manufactured in Tanzania, calcium hypochlorite from India and sodium chlorite made in Tanzania. Sodium hypochlorite is slightly cheaper than calcium hypochlorite (chlorinated lime).

The biological filtration taking place in a slow sand filter is an appropriate treatment method for surface water having a low turbidity.

For a more polluted and turbid water it is not possible to use slow sand filters as they clog quickly. Instead a chemical treatment consisting of addition of aluminium sulphate (alum) and sodium carbonate (soda ash, normally needed for pH-adjustment) is required. After coagulation and flocculation the flocs are allowed to settle in a sedimentation tank. Remaining flocs are eliminated in an upward flow sand filter and finally the water is chlorinated.

The acceptable limit for turbidity is proposed to be set at 30 units; at higher levels clogging will occur too frequently and make utilisation of this treatment method too awkward. Apart from proper design, construction as well as maintenance, good operation of slow sand filters is believed to be the factor on which the result of this treatment depends.

Engineering for Three Different Levels of Water Quality

Water treatment may include one or several treatment processes. The treatment required depends upon:

(a) the quality of the raw water;
(b) the quality level required of the treated water.

The cost estimates for treatment to be included in the rural water supplies have been carried out for three levels of the treated water quality; low, medium and high. The water sources have been divided in four classes depending on the quality of the raw water; degree of pollution and turbidity.

For each of the twelve combinations an appropriate treatment is assumed (see Table 1) and it also is specified which level of staff is needed.

For each region we have estimated the total cost (operations, maintenance, and capital) for each treatment level and raw water quality. The results are presented as present values of the economic costs based on a construction rate of 5% per year and 18% interest rate. For the whole nation the low level treatment a sum of TSh. 47 million is required. It must be remembered that this is a present value using 18% discount rate. For the middle level treatment, we have a total of TSh. 192 million and for the high level 937 million.

For the different treatment methods at daily capacities ranging from 20 to 200 m^3 are capital, economic and financial costs given. From these data it can be seen that storage is the cheapest method of providing treatment. For a 100 m^3/day scheme the financial cost at 9% interest is TSh.0/17 per m^3. Chlorination costs 0/31, sedimentation 0/62 and slow sand filters, 1/40 shillings per m^3.

7. A Cost/Benefit Approach to Improving Water Quality

Central to the choice of a future policy is the comparison of alternative actions in such a manner as to permit the decision-maker to choose the best policy. In this chapter we present estimates of the beneficial aspects of improving water quality and compare this to the cost estimates.

Out of this comparison we identify the recommended approach to water quality treatment. The method we use is known as benefit-cost analysis. The decision-maker is assumed to have an objective function which he aims to maximise. This objective function is the net social benefits defined in a way so as to incorporate all things which contribute to the social welfare. In this project

TABLE 1

REQUIRED TREATMENT FOR DIFFERENT COMBINATIONS
OF WATER SOURCE VERSUS QUALITY LEVEL TO BE REACHED

Quality Level	Water Source			
	(1) Groundwater	(2) Turbidity <30 Low Pollution	(3) Turbidity 30-100 Slight Pollution	(4) Turbidity > 100 Moderate Pollution
Low	No treatment	No treatment	Storage	Storage
Medium	No treatment	Storage	Chlorination	Flocculation, Settling and Fillration. Chlorination.
High	Chlorination	Slow Sand Filtration	Flocculation, Settling and Chlorination	Source Recommended to be Rejected.

under analysis it is assumed that the society's welfare increases if the social benefits (additional resources to the society) of the treatment of water exceed the social costs (resources used up). In order to obtain an estimate of benefits from improvement in health and prolonged life we will estimate averted costs for medical care and increase in production. We never ask if people want the results obtained from potential increase in resources and who benefits from the improvements. The problem of valuation can be avoided by turning to cost-effectiveness analysis, which only tells us how to reach a well defined goal at least cost.

Our problem is to choose between three strategies (low, medium, and high levels) of water treatment. For each higher level of treatment the costs will rise and it is assumed that the corresponding benefits also will rise. We assume that, independence of treatment level, the water treatment programme will be finished after 20 years. In order to evaluate and compare the different levels we calculate a present value of all costs and benefits for each level.

The total benefits include those due to faecal-oral diseases avoided and benefits from deaths avoided. The first group included reductions in hospital costs, disease costs evaluated as lost earnings, costs for transportation and waiting time in connection with attendance at hospital. The hospital cost per person for faecal-oral disease is estimated to 7/05. Based on a daily production value of TSh.3/42 is the total cost for transport and waiting 1/45, resulting in a total treatment cost of 8/50 per attack. The time lost from illness is estimated to 4 days. The benefits of reduced deaths are based on a loss of 8.3 productive years per 100 persons, 0.275 deaths per 100 persons per year, and a annual surplus production over minimum subsistence of 600/- per year. The total benefits are calculated as present values for a period of 40 years at interest rates from 2 to 21%. At a discount rate of 18% total benefits are estimated at 300-350 million shillings. That is, the present value of the total benefits from hospital cost savings, reduced diseases, and longer lifetimes. Of this only 3% comes from hospital costs, 25% from reduced diseases and 72% from longer lives.

After a comparison of costs and benefits at a wide range of different assumptions we can conclude that the low level treatment is justified on the basis benefit-cost analysis and expert judgement as to the faecal-oral disease cure rate to be expected.

8. Legislation and Regulation of the Water Quality Programme

In this chapter we review the legislation dealing with water quality and make recommendations on the legislation and regulation. We give an introduction to the legal technical issues on water quality, review alternative approaches to water quality legislation, review existing legislation and present recommendations.

Two existing laws dealing with water quality are reviewed; the Water Utilisation Act (1974) and the Fisheries Act (1970).

A programme for water quality implies that there are one or many goals of the society relating to the quality of water which are to be achieved. Legal instruments must be created to enforce an implementation programme. The choice of instruments is important in order to achieve the highest possible efficiency. The following two legal technical aspects are of basic importance; formulating the standards and constructing the enforcement instruments. It is necessary to formulate standards so that they are understandable and enforceable. Standards must not necessarily be laid down numerically. Another method is what is called "narrative" standards. The narrative rule specifies the real purpose of the water quality standards but permits precise formulation to be adjusted to the circumstances and the knowledge of for example the relationship between water quality and health. An efficient enforcement system must include procedural rules, economic rules, rules on supervision and rules on sanctions. Procedural rules are those which require specific actions, applications, documentation etc. Economic rules lay down who shall bear the costs or suffer the losses arising from implementation of a programme. To ensure efficiency in legislation concerning water, supervision is important. It must be made clear, not only who is to supervise water quality but also how the supervisor shall proceed to make offenders comply with the law. Even if it would be desirable to achieve an understanding for the necessity of complying with the law, there must always be fallbacks to protect society from offenders by means of sanctions.

Several different approaches to water quality legislation are discussed. The proposed approach includes three sets of standards; drinking water quality standards, effluent standards and receiving water quality standards. This eliminates most disadvantages of other discussed approaches, but gives high administrative costs.

Our legislative recommendations are thus aimed at the immediate problems of raising water quality though appropriate surveillance and follow-up action as well as provide the basis for handling the macro-regulation problems which are certain to arise in the future.

Four major recommendations are made: (1) immediate acceptance of the Tanzanian Temporary Water Quality Standards as now formulated, with some slight changes and promulgation of the enforcing regulations suggested here; (2) amendments on the Water Utilisation Act and successive establishment of Water Basin Boards; (3) extension of the surveillance programme to cover sewage and industrial wastes and receiving waters and (4) recommendations on a national resolution to reduce schistosomiasis.

It is important that water quality standards are real - that there is a system for enforcing the standards. After all, the objective is to protect the health of the population by raising the quality of water consumed. The fact that it is impossible to reach the ultimate standards immediately does not mean that action should not be taken to improve the situation. The approach that we follow is to specify action standards (non-compliance levels) for bacteria, fluoride and nitrate and chemical contamination. These proposed rules specify exactly what is to be done at what levels of non-compliance. The objective is to successively improve the water quality on the basis of a plan for phasing the action programme. A period for three years is given for elimination of sources with very high bacterial pollution after which six years is allowed for the improvement of sources within next non-compliance level.

A detailed proposal for the amendment of the Water Utilisation Act is given. The organisation is proposed to be based on Project Preparation Division establishing Water Basin Boards and simultaneous deletion of Regional Water Officers. Should these recommendations be accepted then we feel that at the start only a few Water Basin Boards should be designated.

PART THREE: A PROPOSAL FOR A WATER QUALITY PROGRAMME

9. Recommendations

This chapter presents the detailed recommendations arising from the analysis presented in the report. It sets out the organisation for a Water Quality Programme, reviews engineering recommendations, presents the detail programme for the water hygiene division and summarises legislative recommendations, reviews manpower and training programmes, and presents four research programmes. It also deals with a schistosomiasis recommendation and public education campaign.

The recommendations include two alternative schedules (A and B) for the Organisation of the Rural Water Quality Programme. Also two alternatives are given for the construction of tanks for increased storage (20 and 30 years implementation periods). A summary of the budgetary costs is given in Table 2.

The Water Quality Programme Organisation and the budgetary costs are set out. For Alternative A the annual budgetary cost is around 6 million shillings and for Alternative B around 4.5 million shillings. The first six years total budgets are 36 and 29 million shillings respectively out of which about half and one third respectively are foreign exchange. The surveillance organisation will cost approximately 3 million and 2 million shillings a year respectively. The research programme would cost 4 million shillings.

TABLE 2

SUMMARY OF COSTS FOR THE WATER QUALITY PROGRAMME
(Thousand TSh.)

	80/81	81/82	82/83	83/84	84/85	85/86
Water Quality Programme						
Alternative A	2,594	10,683	6,003	5,456	5,486	5,696
Alternative B	2,502	9,353	4,833	4,143	4,616	3,693
Total Cost for Treatment						
20 year programme	-	7,377	8,191	8,470	8,757	9,052
30 year programme	-	4,918	5,461	5,667	5,838	6,034

The Emergency Fund which is another channel for water treatment or source improvement comes to 5,000,000. It is however included in the organisation cost as revolving fund and actual expenditure on emergency water quality improvements would be considerably larger.

Organisation

The proposal for organisation includes three authorities: (1) National Water Quality Committee; (2) Regional Water Hygiene Committee; and (3) Water Hygiene Division. The responsibilities for these three authorities are outlined.

The National Water Quality Committee is to be the high level coordination point for implementation of the water quality programme and resolve issue that may arise. Membership is at Principal Secretary level comprising Ministry of Water, Energy and Minerals, Ministry of Health, Ministry of Housing and Urban Development, Ministry of Agriculture, Prime Minister's Office and Ministry of Industries.

The Water Hygiene Division is the key organisation for implementation of the water quality programme and its formation is the central recommendation of the study. The organisation is outlined in Figure 1.

The Regional Water Hygiene Committee comprises regional representatives for the same Ministries as the National Committee. We anticipate that in a properly run programme there should be considerable difference of view, especially on actions. This committee should solve these problems.

Engineering Solutions

The benefit-cost analysis was carried out for three levels of quality. The conclusion was that low level treatment was justified under the existing economic conditions. In the Consultant's view there is a strong case for pegging treatment at provision of extra storage for surface sources. Although this method has not been widely used in the past, it has many advantages which should not be overlooked. Current knowledge on the precise efficiency of the process is limited, but the following effects can be assured after 48 hours storage; bacterial removal in excess of 90%, removal of suspended matter, variable according to the layout of the tank and, death of schistosome cercariae. The technical performance of storage systems is fully discussed. Although we are confident in substantial water quality improvement from storage, we believe that additional research is necessary to permit the determination of an optimal design for storage tanks. The research programme sets out how we recommend this should be done. We recommend that for supplies for more than 20,000 persons chlorination should be used.

Recommendations are also made for flocculation-sedimentation treatment. We did not find any of the constructed slow sand filters operating successfully in Tanzania. Although this is a good treatment method we believe that there are several points which condition proper operation.

In brief reviewing the three existing treatment methods of treatment; chlorination, flocculation-sedimentation and slow sand filters, we find similar problems in each. When we add to this the list of actually observed problems in operation conditions, there certainly is a case for shifting to increased storage requiring little operations and maintenance.

There is a great deal that can be done to protect sources from becoming polluted. We give detailed recommendations on the protection of all sources. Design recommendations dealing with water quality are also given together with recommendations on large schemes and supplies for rural institutions.

Water Quality Surveillance Programme

In this section we present detailed recommendations on the organisation, manpower, and finance of the surveillance programme. The organisation should guide the relevant authorities so that the health of people is not endangered by unsafe water. This is accomplished by; advising on improvements of water quality, checking, and initiating actions when the required quality is not met. The elements of a surveillance programme include engineering and the physical, biological, chemical, and institutional examination of water supplies. For the organisation to be able to perform its duties in an effective and active way several requirements must be met; independent organisation and budget, skilled manpower staffing the organisation, and legislation and administrative regulation supporting necessary action to enforce remedial actions.

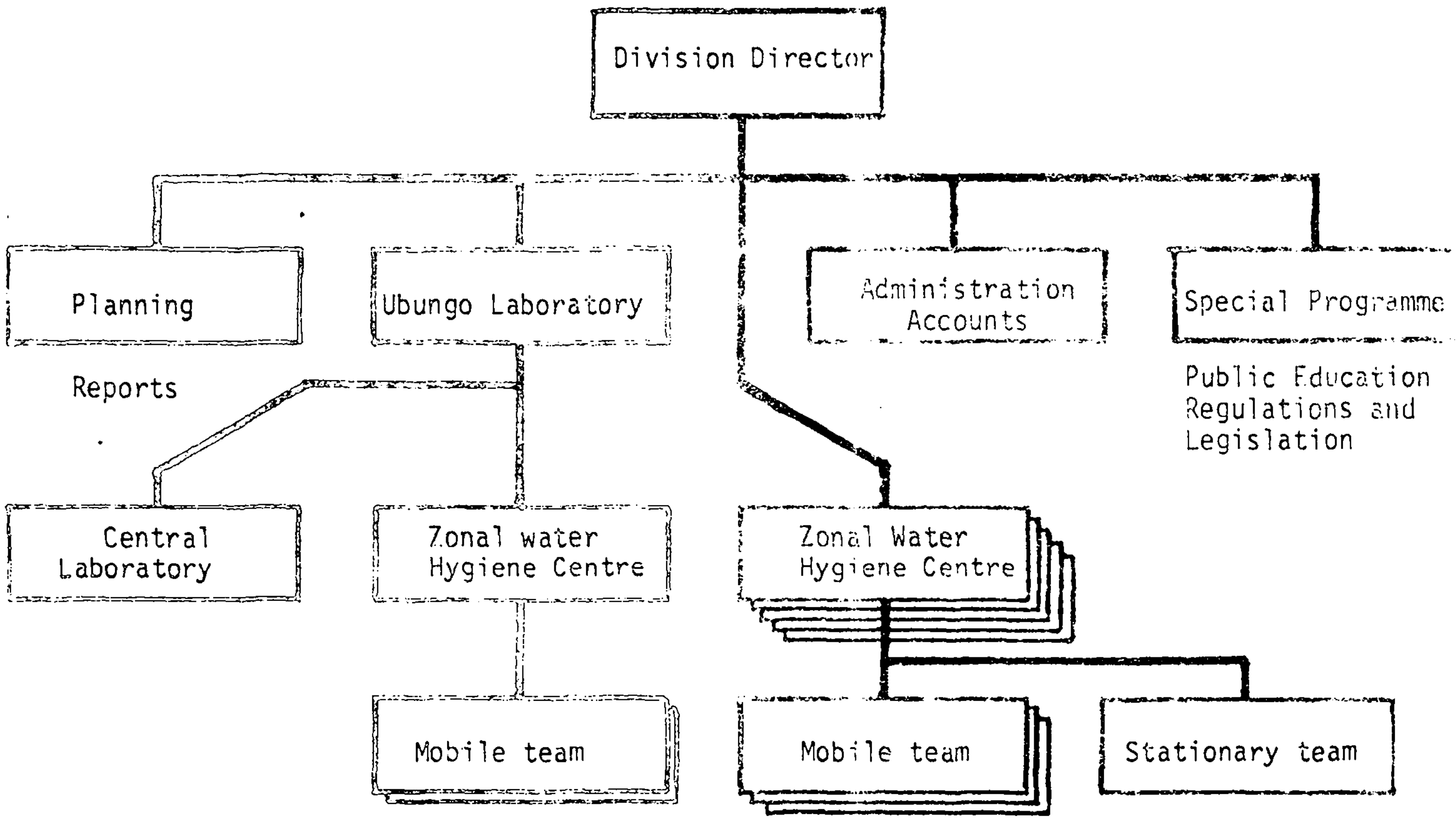
Based on these requirements a Water Hygiene Division is proposed and organised according to Figure 1.

The Central Administration has the control and management responsibility for the Water Quality Programme. The Ubungo Laboratory should function as supervisor for the Zonal Water Hygiene Centres, central laboratory and participate in training.

The Zonal Water Hygiene Centres form the core of the surveillance organisation. These are composed of one stationery and one to three mobile units. The stationery unit will function as a base for the mobile unit and carry out physical-chemical testing. The mobile unit performs the surveys and samplings required. It is also equipped with facilities for bacteriological testing. The mobile team, headed by a water hygiene engineer, constitutes the core of the zonal water hygiene centre.

FIGURE 1

ORGANISATION CHART FOR PROPOSED WATER HYGIENE DIVISION



The engineer is responsible for all parts of the surveillance; planning, survey, testing, and evaluation. A job description and an outline for working procedures is given.

According to Alternative A we propose that initially six zonal water hygiene centres are set up in Dar es Salaam, Mbeya, Moshi, Mtwara, Mwanza, and Shinyanga. We also propose a successive expansion that ultimately will lead to 11 zonal centres each with three mobile units. Alternative B starts with four centres in Dar es Salaam, Mtwara, Mwanza and Shinyanga.

Recommendations are also given on timing and frequency of sampling, and analysis procedures, record-keeping and dissemination of results.

15 year budgets for the two alternative Water Hygiene Divisions are given. To enable a full effect of the non-compliance rules outlined in Chapter 8 we propose the creation of an Emergency Water Quality Fund. This fund would be appropriate to the control of the Principal Secretary MAJI for use to solve water quality problems for water schemes that are near closure or are closed under the proposed compliance regulations. We propose an initial appropriation of TSh.3 million, serving as a revolving fund and be drawn by the RDDs to solve emergency water quality programmes but be repaid.

Manpower requirements are set out and discussed in detail together with a recruitment including expatriates and training programme. It should be noted that the recruitment has to be started ahead of the main programme. In discussing the training programme we cover the different levels and functions that must be provided to training.

Special emphasis is put on the training of zonal water hygiene engineers. This person will not be a laboratory scientist but an engineer by basic training. In addition three areas of specialised knowledge is required; water-related disease and its control, rural water treatment and supply engineering and, laboratory procedures for bacteriological and chemical water analysis including laboratory management and quality control. The recommended programme is to assign ten of the group of graduate engineers returning from India. The training is commenced with a four month period at MAJI. The health training can probably be obtained at the School of Hygiene, Muhimbili Medical Centre. The course is presently being reconstructed and will be organised in a "block" form. Specialised training in rural water supply is hard to come by. The University of Dar es Salaam and the Chuo cha Maji might be able to offer a short course. An additional possibility would be the organisation of a three month study tour to institutes of public health engineering such as Nagpur, Bangkok, and Bandung. This tour would also be of assistance in teaching the principles of laboratory management.

Research Programme

To establish and maintain water quality requires not only resources and organisation but also a constant effort at improving the technology of water quality and of deeping the understanding of health consequencies of water quality. Four proposals are set out; indicator bacteria, fluorosis, treatment of water with high fluoride concentrations, and optimal storage tank design.

. The key conclusion in the economical analysis of the justified treatment level is to increase storage so that the retention time of water is two days storage. It is essential that the design of the storage is optimised. For this purpose we propose an investigation, which is outlined in detail.

The problem of accurate and sensitive tests of bacteriological contamination in water is not really solved for tropical conditions. We believe it is possible to significantly improve the reliability of the tests.

The estimated cost of the four research proposals is 4 million shillings over a four year period.

CHAPTER 1
INTRODUCTION

It is clearly the goal of the Tanzania Government, and of the Ministry of Water, Energy and Minerals (hereafter referred to as MAJI) in particular, to provide the people of Tanzania with ample supplies of safe and wholesome water for domestic use. Since this is an enormous task and resources of funds and manpower are limited, it must be a very long-term undertaking. For people to remain alive at all, they must have some form of domestic water source even if it be a muddy well far from where they live. The task of MAJI is thus rightly conceived of as to improve people's domestic water supplies: this is not an all-nothing procedure but rather a stepwise or incremental process.

It is not that people have to be provided with an expensive ideal water supply and that, if funds are inadequate for this, nothing can be done. Rather, there are improvements that can be made to any person's water supply and, even when funds are scarce, something can almost always be done to make that supply better than it was previously. These are positive and realistic concepts aimed at improving conditions for the majority of the people.

It follows that, in the area of general policy, MAJI has two difficult tasks. The first is to decide on which water improvements will make the best use of available resources to give the greatest benefits to the Tanzanian people and the second is to ensure that such improvements as are made to the supply of domestic water are maintained, so that the result is steady and sustained progress. We believe that this report can contribute to both these key tasks.

The improvements that can be made affect two main aspects of domestic water supplies. One is access to water and consequently the volume of water used by each person. The other is water quality. The Tanzania government, particularly in its rural water programme, has so far concentrated its efforts on improved access to water; on bringing water to communities that previously had to walk to more distant sources. We are clear that the Tanzania government was completely right in this policy. A water supply of the most ideal quality, if it be inaccessible, will not be used and therefore the priority had to be given to making water more readily available.

It is now timely to consider the other aspect, water quality, which is the subject of this report. An essential dimension to considering both availability and quality of water supplies is the second task referred to above; operation and maintenance of the improved facilities, and this cannot be over-emphasised.

This report therefore considers domestic water quality in Tanzania: the present situation; how it may be improved; and how that improvement may be maintained. The detailed terms of reference are set out in Annex I. They give particular emphasis to a programme of water quality surveillance. It is therefore necessary to consider at the outset the meaning of the term 'surveillance'. Essentially, it is the collection of information, or monitoring, leading to remedial action. Surveillance can therefore fail in two ways. Either the necessary data may not be collected - an 'information gap' - or else the information may be collected and available but not result, for a variety of reasons, in remedial action being taken - an 'implementation gap'.

The way in which the terms of reference closely juxtapose monitoring and remedial action is central to problems of water quality in Tanzania, and has dictated the structure of this report. For if information without action is futile, it is necessary to consider possible types of action to improve water quality first, in order to decide what information can be used and therefore what is worth collecting.

If the first guiding principle in our approach has been to relate information to action, the second has been to make realistic proposals for organisations and facilities than can be maintained in the medium and long term. It is notorious that in all developing countries it is far easier to obtain development capital than recurrent finance. The temptation to build up what cannot feasibly be maintained is therefore very great. Such erratic progress cannot be the basis of sound socio-economic development and our proposals are therefore intended to be on a modest but viable scale. A small organisation with adequate recurrent finance to operate efficiently is far preferable to a large and elaborately housed unit with inadequate funds for proper functioning.

Since the terms of reference allow of some latitude of interpretation we have considered it helpful to set out above the basic philosophy of the approach in this report, which may be summarised as: The objective of a water quality programme to improve the quality of the domestic water supplies of the Tanzanian people. Any surveillance system must be designed as part of the mean towards this objective.

This report is divided in three parts: present situation, towards a rational water quality policy, and recommendations. The present situation on water quality has been evaluated during field studies and by collection of available data. Since bacteriological pollution is the most important and best known, this has been emphasised. Also the present situation of water treatment plants has been established, together with a general review of water schemes. The existing surveillance organisation has been reviewed, especially its use as a base for a more complete organisation.

Part II develops the issues leading to a water quality policy. The prevalence and distribution of diseases related to water quality in Tanzania are set out and discussed in relation to their ill effects on the population and the possible benefits from water improvements. Schistosomiasis is considered as a rather separate case. Health is thus set out as a benefit of improved water quality. Feasible methods of rural water quality improvement are assessed and their costs calculated. Three possible levels of water quality programme are costed, and comparison with the potential benefits is found to favour the lowest cost programme.

In Part III an action programme on this basis is developed together with a system of assessing priorities. A detailed proposal on treatment based on prolonged storage is made. A supporting Water Hygiene Division based on zonal water hygiene centres closely integrated with regional authorities is proposed. The manpower implications are set out and educational programmes are described. The necessary legislative basis and research needs for the programme are described.

PART ONE

PRESENT SITUATION

This part of the Rural Water Quality Project is a review of the existing situation. It covers existing water quality conditions, existing water supplies including treatment facilities, and the present surveillance system.

CHAPTER 2
PRESENT WATER QUALITY AND USE

2.1 Water Use

The effects of water on health are a function both of the quality of the water the quantity used and the type of use to which it is put. This latter aspect is very difficult to quantify and, indeed, most of what is known about water use is confined to the total volume used by a person during the day. These measurements do, however, serve two purposes. The first is simply to put the discussion of water quality in perspective. The second is to indicate that improved water supplies which still have to be carried to the home do not lead to markedly increased water usage and thus, no matter how good the water quality, the significant proportion of faecal-oral disease related to hygienic practices cannot be affected by this kind of supply. This underlines the fact that the water quality issue is only a part of the public health implications of water supplies.

Various studies of water use in Tanzania are summarized in Table 2.1. The average quantity of water taken from the source is 12 liters/person/day. An additional set of investigations carried out during the Tri-Region Water Master Plan gave a range of consumption of the range 8-17 liters/person/day. Volumes of water used are difficult to measure since only part of the water is gathered and taken to the home in vessels so that the volume can be estimated. Laundry and bathing are often performed at the source so that water used cannot really be measured.

The conclusion is that water extracted for use in rural areas is in the range 10-15 liters/person/day. This corresponds to 2-3 debe (tins) per household per day.

TABLE 2.1
WATER USE STUDIES IN TANZANIA - SUMMARY

Water Supply Type		Average [1] Person/Day	Minimum	Maximum
Standpipe (a)	Moshi	13.3	4.2	35.0
Standpipe (a)	Dodoma	20.8	13.7	36.5
Pit (a)	Kipanga	12.7	5.0	48.5
Very Distant (b)	Pare District	4.3	3.6	5.2
Stream (b)	Kilimanjaro Dist.	8.9	8.4	10.8
N.R. x (b)	Morogoro District	13.2	N.R.	N.R.
N.R. (b)	Nzega	12.6	3.5	20.0
Standpipe (c)	Mbezi	11.4	4.0	33.0
N.R. (d)	Shinyanga Region	12.7	8.0	17.0
Average		12.2	7.1	24.4
Range			3.5-13.7	5.2-48.5

x N.R. = Not recorded
(a) White, Bradley, White "Drawers of Water" University of Chicago Press 1972
(b) Warner, Presented at conference on Rural Water Supply in E.Africa 1971
(c) Coast Region Water Master Plan
(d) Shinyanga Water Master Plan

2.2 Bacteriological Water Quality

Bacteriological Indicators of Water Quality

The potentially waterborne infectious diseases are all transmitted by the ingestion of minute quantities of faecal material. This is generally of human origin, although certain of the salmonelloses, and probably some others, can be spread by animal excreta. These diseases are caused by a plethora of different agents, ranging from viruses and bacteria to parasitic cysts and eggs. It is also likely even in epidemic circumstances (and certainly in conditions of endemic diseases) that only a small proportion of the population is infected by, and therefore excreting, a particular pathogenic organism. This great diversity and sporadic occurrence of pathogens has two implications for water quality monitoring. First, if all pathogens are to be monitored, a large number of different tests must be performed on each sample. These must be, by their very nature, hazardous for the laboratory staff involved. In addition, there are simply no tests available for the large group of viral agents. Second, owing to their sporadic occurrence, extremely large volumes of water would have to be processed, which has practical limitations.

One of the few cases when it may be useful to monitor pathogens is during an epidemic. Practically, this is possible as there is only one, already identified, pathogen under scrutiny. Given this possibility, the results are obviously more meaningful than those from indicator monitoring. However, as stated above, this is not the case during routine monitoring.

The approach to be adopted must thus be indirect. If it is impractical to monitor pathogens, then the next best approach is to monitor the potential likelihood of their being present. As they are all faecal in origin, this reduces to estimating the extent of faecal pollution of a water source. The ideal indicator would thus have the following properties:

(i) Consistently and exclusively present in the intestines and hence faeces of people and, ideally not in animals.

(ii) Present whenever pathogens are present, and absent when there is no possibility of pathogens being present. Present in higher number than pathogens.

(iii) Easily isolated from water samples and non-pathogenic.

(iv) Unable to grow outside the intestine and with a die-off rate slightly less than that of pathogens.

Because of historical and practical considerations related to (iii) above, bacteria are almost universally used for this purpose. With this condition satisfied, the choice of a suitable bacterial species not easy.

Condition (i) is at present the focus of much research work. There are many exclusively faecal bacteria but in general they occur in both humans and animals. Interest has been recently expressed in using anaerobes, as their more fastidious habits make them more species specific in their habitats than the facultative bacteria (such as the widely used E. coli and faecal streptococcus).

Condition (ii) is hard to satisfy. The great variety of pathogens means that some processes which have a lethal effect on the indicator bacteria may not have the same effect on the pathogens, and vice versa. A similar argument applies to condition (iv) - it may be possible to find a species of bacteria with a slower death rate than all bacterial pathogens, but the long persistence (week or even months) of some viral pathogens makes all the nonspore-forming bacteria unsuitable. Further, the behaviour of spore-formers in the environment is different to that of the long-lived viruses and thus makes them unsuitable.

The other part of condition (ii), that the indicator should be present in higher numbers than pathogens, is the case for the average of a human population. Some infections (particularly bacterial) will cause the sufferer to excrete the infective organisms in essentially pure culture, but taking the population as a whole, the large number of bacteria in the faeces of healthy people (about 30 % of the wet weight) provides more than enough non-pathogenic bacteria to outweigh the excretion of pathogens by (typically few) infected individuals in the population.

Thus, the question remains as to which species of bacteria to use as faecal indicators. The ones most commonly used at present are faecal coliforms and faecal (group D) streptococci. Their drawbacks are twofold. First, they are not exclusively human in origin and tend to occur in equally high numbers in human and animal faeces.

Secondly, they are relatively short-lived, and thus do not present a picture of the potential risk from viral pathogens. This is partly mitigated by the fact that in an endemic situation, the water pollution is also "endemic". Thus, although bacteria in a faecally polluted water source are constantly dying off, they may also be constantly increased in number by further pollution. This allows the source to be identified as faecally polluted and hence points out the potential risk from all excreted pathogens. This would not always be true, however, such as in a protected well which experiences a single pollution episode. In this case, faecal coliforms and faecal streptococci could well have died away when there were still some longer-lived pathogens present.

Faecal streptococci suffer from the further disadvantage that they are not exclusively faecal in origin, as some of the group are also associated with plants and insects. Thus, of these two well-tested indicator systems, the faecal coliforms are the better of the two. The anaerobic bacteria, particularly the genera Bacteroides and Bifidobacteria, have been suggested as alternative indicator bacteria. As mentioned above, they have the advantage that certain species are much more common in man than other animals. It is quite possible, however, that they could be even shorter-lived than faecal coliforms and faecal streptococci. The practical experience with these bacteria is limited, and the use of these little-tried methods in this project gave results of limited significance.

In summary, faecal coliforms and faecal streptococci have been adopted as indicators of possibly dangerous faecal pollution. They have some limitations as described above, but are the best available tools for the job. Faecal coliforms are better indicators than the faecal streptococci.

Methods

(i) Membrane Filtration

In recent years the simple, compact membrane filtration system for water bacteriology has taken over from the older, multiple tube technique. This has been largely for three reasons:

First of all is speed and simplicity. The multiple tube (MPN) analysis for faecal coliforms is a two-stage process involving many sterile dilution steps and two successive incubations in different broths. The first incubation is for 24 or 48 hours, and the second, a further 24 hours. It thus requires more time and skill than the single aseptic filtration and 24 hour incubation of a membrane filter sample.

Secondly, the MPN method cannot be performed in the field, as the equipment is bulky. The portable incubator used in this study could accommodate only two MPN tests as opposed to 12-15 membrane filtration tests. The confirmatory second MPN incubation could not be carried out at all in the field incubator. In a country where communications are slow the travel times to a laboratory often exceed the 8-12 hours maximum which can be allowed for bacteriological samples. Hence, techniques that can be carried out in the field are essential.

Thirdly, the membrane filtration method offers greater precision. As table 2.2 shows the 3-dilution series used in comparative tests has far wider confidence limits than the membrane filtration test.

However, there are some disadvantages of the membrane filtration technique. One is the possibility that recovery of bacteria is less complete in the more unfavourable growing conditions of the filter surface. This would lead to lower counts on the membrane filters than from MPN tests. Table 2.2 shows that, at least under the conditions where it was tried, this objection is not upheld.

TABLE 2.2
MEMBRANE FILTRATION AND MULTIPLE TUBE TECHNIQUES COMPARED FOR ENUMERATION OF FAECAL COLIFORMS

Membrane Filtration		Multiple Tube	
Estimate	95% Confidence Limits	Estimate	95% Confidence Limits
500	361-639	1100	150-4800
7	2-12	4	0.5-20
28	18-38	23	4-120
36	24-48	93	25-380
14	7-21	9	1-36

NOTE

These tests were performed in parallel on the same water samples.

The confidence limits are defined by statistical theory. For the membrane filters, a Poisson distribution is assumed, and the 95% confidence limits are $n \pm 1.96\sqrt{n}$ where n is the number of colonies counted. The MPN (Multiple Tube) tests were using 3 tubes of each of 3 dilutions (the 3x3 test) and the confidence limits read directly from specially prepared tables.

A more serious disadvantage of membrane filtration in all tropical countries is the inability of the method to deal with turbid waters. The filter becomes clogged, meaning that the volume filtered is limited, and also that diffusion of nutrients to the growing bacteria is reduced. However, from the experience of around 250 filtration tests made during the study, this is only important in a few cases.

The membrane filtration technique is thus held to be suitable for this type of work.

(ii) Selective Media

a. m-FC Medium

The m-FC medium is used for enumerating faecal coliforms. It was prepared from one of the standard dehydrated formulations commercially available. It should be noted that during long periods of fieldwork, with no access to a refrigerator, all media are best kept in the dehydrated form until needed. This includes both the m-FC broth base and the rosalic acid.

There were, however, some difficulties in colony enumeration. This medium gives fairly large, irregular, bright blue colonies of faecal coliforms, which are to be counted. In some cases there were some colonies which were grey-blue but hard to differentiate from the bright blue ones. It is likely that these were of the genus *Klebsiella* although some were also undoubtedly *E. coli*. Very small, bright blue colonies of *Bacillus* species were also encountered, and again, could lead to confusion. This is an indication of a more general problem with tropical water bacteriology - namely, that due to the higher water temperatures, other faecal and non-faecal bacteria may mimic the thermal tolerance which is the main selective test for faecal coliforms. A more reliable test for *E. coli* in tropical waters is urgently required.

A second observation was the common occurrence of white colonies, particularly in samples of boiled or chlorinated water. It is of particular concern to locate pollution in such 'safe' water if it exists. It was found that the white colonies appeared less frequently if the petri dishes were well sealed with adhesive tape before incubation, to retain water. Nevertheless, they still appeared in boiled water samples. It is not clear whether these were typical, stressed faecal coliforms or another type of bacteria. This should be investigated.

Some tests were made to compare the dehydrated media with that supplied in liquid form in ampoules. This consisted of filtering aliquots from the filters on the two different media. The results are presented in Table 2.3. Although they indicate a slightly higher recovery on the dehydrated broth the difference, as evalued using the "t" test (see footnote) is not significant ($0.4 < P < 0.5$). It is therefore recommended that the dehydrated broth be used in preference to the ampoules, as it is much cheaper.

b. KF Medium

The KF medium is used for enumerating faecal streptococci. By using the dehydrated broth and preparing it as needed, satisfactory results were obtained.

The medium as a broth was compared (in a similar manner as above) to the same medium in an agar formulation. It became apparent that the agar medium has a disadvantage in that it tends to produce a fine 'dust' of microscopic red colonies in addition to the larger, pinhead red colonies, characteristic of faecal streptococci. This "dust" was analysed and did not contain any faecal streptococci. This phenomenon will thus lead to overestimation of the actual count. This is clearly brought out in Table 2.4.

Two comparisons using the "t" test (see footnote) were made, using the counts made on broth by the study team as a reference (i.e. those designated "B" in Table 2.4.). The counts designated "A" in Table 2.4. were made using agar, by the study team, who were aware of the 'dust' problem, and the results do not differ significantly from the broth count ($0.05 < P < 0.1$). However, an independant worker, the technician for the Pwani Coast region master plan, found consistently higher counts (designated "AK" in Table 2.4) using agar as opposed to the study team's counts on broth ($0.02 < P < 0.05$). This indicates that it may be very hard to obtain good inter-observer comparability using the KF agar, and it is thus recommended that the KF broth be used for enumerating faecal streptococci, to promote standardised and comparable results.

Footnote

The "t" test tests the null hypothesis that the ratios D/A, B/A, B/AK are equal to 1, i.e. that the two counts are identical. Bacterial counts tend, however, to be logarithmically distributed. It is thus more accurate to test the hypothesis that the logarithms of the ratios are equal to zero.

The t statistic is calculted as

$$t = \frac{\Sigma\chi}{\eta} \sqrt{\frac{\eta\ (\eta-1)}{\Sigma\chi^2 - \frac{(\Sigma\chi)^2}{\eta}}}$$

Where χ = logarithm of ratio.

η = number of ratios excluding those where both counts are zero

There are η-1 of freedom for the test.

The probability that the null hypothesis is true (i.e., that the ratios would have an average value of 1 in an infinite series of tests) is then read from tables based on t and the number of degrees of freedom. In most cases (including this one) the null hypothesis will be rejected if its probability (P) is less than 0.05 or 5 %.

TABLE 2.3

COMPARISON OF MEDIA
M-FC BROTH FROM DEHYDRATED INGREDIENTS VS AMPOULES

D*	A*	D/A	D	A	D/A	D	A	D/A
52000	24800	2.10	63	37	1.70	750	980	0.77
186	134	1.39	255	238	1.07	0	0	1.00
7	10	0.70	950	1550	0.61	20	50	0.40
114	80	1.43	0	0	1.00	40	70	0.57
48	90	0.53	3	4	0.75	3	3	1.00
6	6	1.00	30	20	1.50	6	11	0.55
28	34	0.82	600	400	1.50	6	2	3.00
36	80	0.45	22	19	1.16	10	2	5.00
14	15	0.93	20	3	6.67	0	0	1.00

* D = count per 100 ml from dehydrated medium
A = count per 100 ml from ampoules
Average ratio D/A = 1.43, range = 0.40 - 6.67

TABLE 2.4

KF MEDIUM AS AGAR VS BROTH

B*	A*	B/A	B	A	B/A	B	AK	B/AK
101600	126800	0.80	90800	159600	0.57	10	412	0.02
20300	16000	1.27	41700	32000	1.30	128	300	0.43
2460	5380	0.46	21200	16800	1.26	123	800	0.15
760	1200	0.63	8800	12600	0.70	5	60	0.08
84	194	0.43	5060	7000	0.72	50	50	1.00
14	14	1.00				56	130	0.43
						15	29	0.52

* B = count per 100 ml from broth
A = count per 100 ml from agar
AK = count per 100 ml from agar, made by another worker

Average ratio B/A = 0.83, range = 0.43 - 1.30
Average ratio B/AK = 0.38, range = 0.02 - 1.00

c. Kanamycin Bile Agar

This medium was used, with anaerobic incubation at room (or Land Rover) temperature, for enumeration of Bacteroides fragilis. This was the first time attempts have been made to use it in field experiments, and unfortunately the results were not good.

Initial experience indicated that the system was working: the colonial appearance (round and white with a central depression) and smell of the organisms were characteristic. However, as the study progressed it became clear that the system had for some reason ceased to work, and samples sent to England for identification proved to be mainly coliforms. The reason for this change is not clear. It could be in degradation of the medium over time, or the lack of stringently anaerobic conditions. This latter factor was checked at a later stage and appeared to be satisfactory, so it is probably the medium which was causing trouble.

It is felt that the early success of this technique could be made more reproducible if further work was carried out to make it suitable for field use.

Survival of Indicator Bacteria

This was investigated for two reasons. One was to confirm the usefulness of faecal coliforms and faecal streptococci as indicators under Tanzanian conditions. The other was in connection with the possible use of water storage to improve quality.

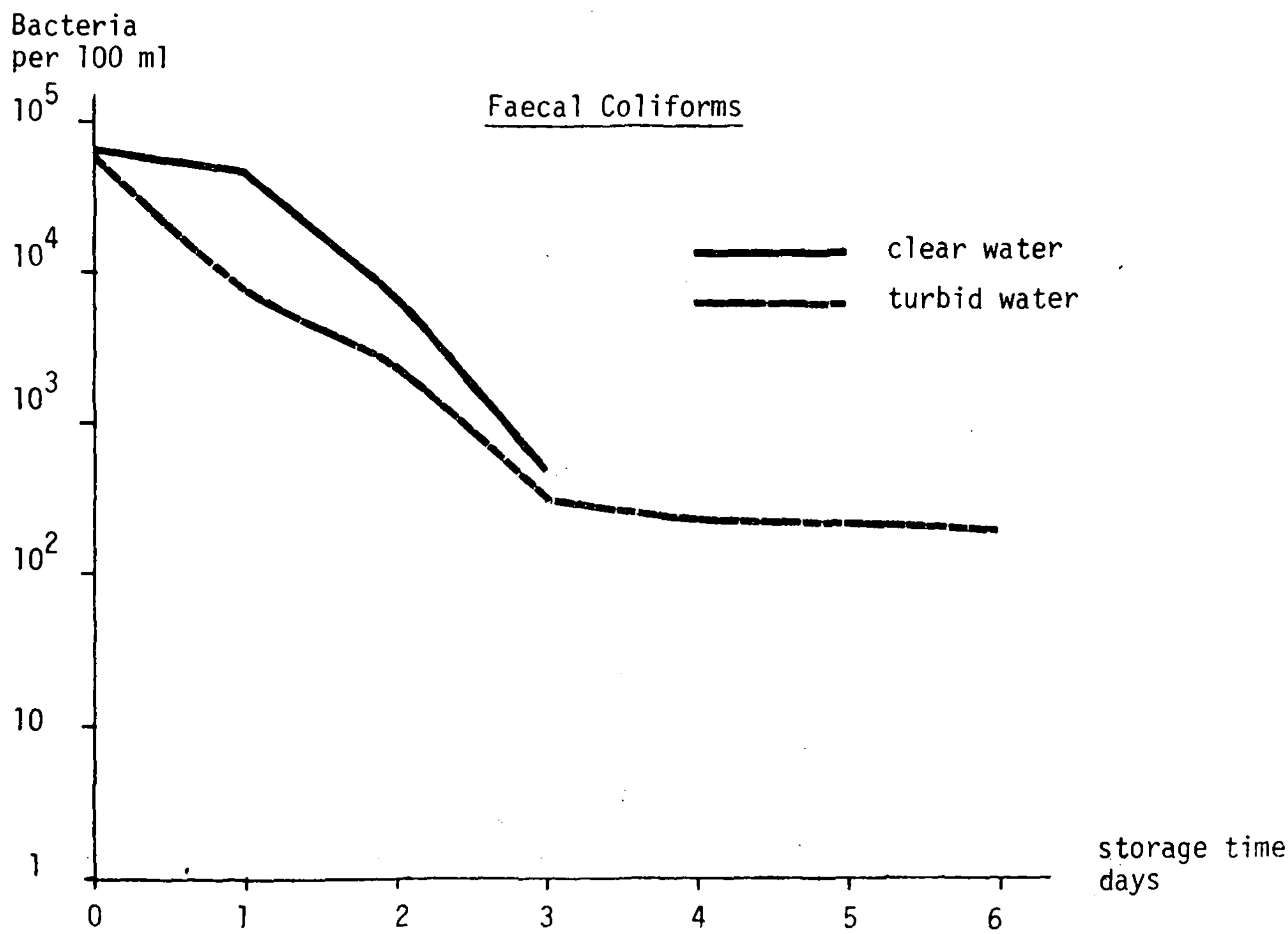
Two rather heavily polluted samples were collected near the Ubungo laboratory. One was highly turbid and collected from the muddy stream behind the laboratory. The clear water sample was collected from a small pond nearby. They were stored in the dark in identical large glass bottles and examined daily. The turbid water sample was not shaken on abstracting samples to be filtered, to ascertain the effect of sedimentation on bacterial removal.

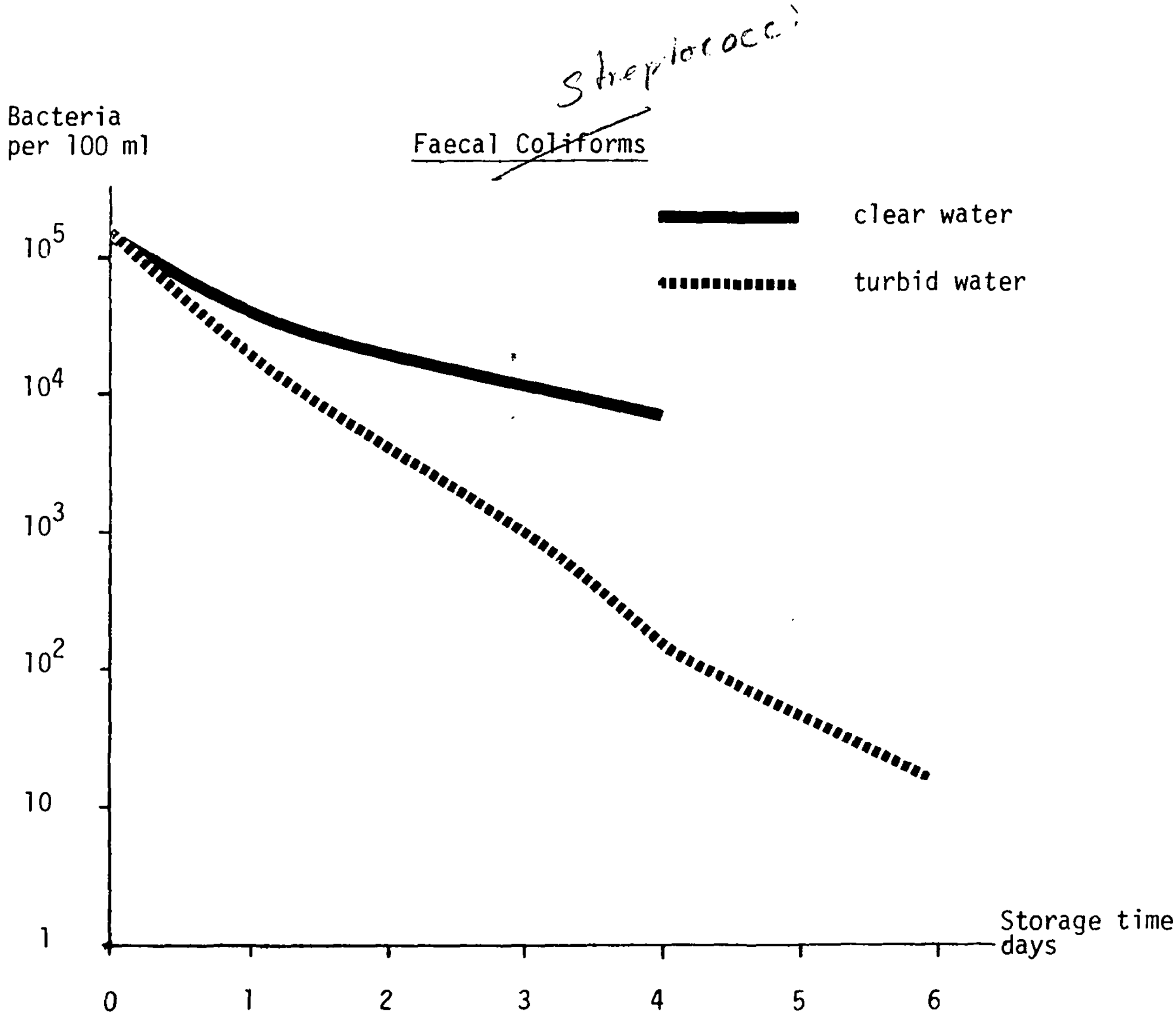
The results are presented in Table 2.5 and Figure 2.1. The conclusions are as follows:

i. The death-rates observed are around the expected value and thus indicate the suitability of these bacteria as indicators under these conditions.

FIGURE 2.1

DIE-OFF RATES DURING STORAGE





ii. The faecal coliforms in both types of water, and the faecal streptococci in turbid water are reduced by about 95% after 2 days' storage. The faecal streptococci are reduced by around 85 % after 2 days' storage in clear water. This indicates that this length of time will be sufficient to ensure about 90% die-off for most bacteria (see Annex 9).

TABLE 2.5

DIE-OFF RATES DURING STORAGE

The die-off coefficient μ is defined by:

$$\frac{dn}{dt} = -\mu n$$ where n = concentration of bacteria
t = time in days

$$\mu = \frac{\ln 2}{t\ 1/2} = \frac{\ln 10}{t_{90}}\ \text{day}^{-1}$$

The following were calculated from a linear least squares fit of $\log_{10} n$ against t.

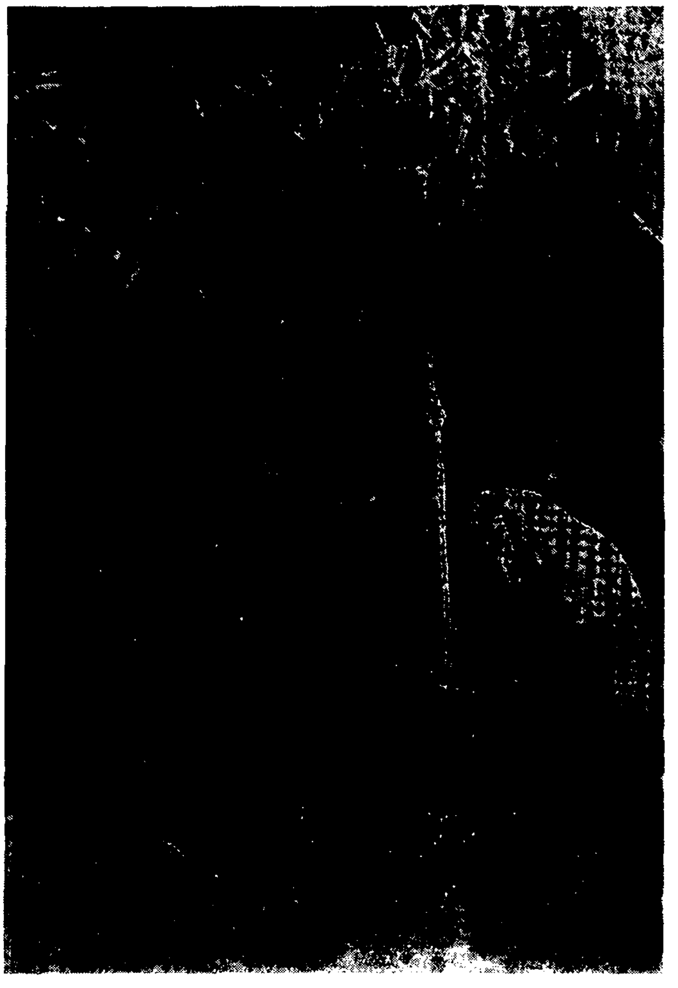
Water Sample	Bacteria	t 1/2	t_{90}	μ	r
Turbid	Faecal coliform	0.72	2.39	0.96	0.91
Turbid (days 0-3)	Faecal coliform	0.42	1.40	1.66	0.97
Clear	Faecal coliform	0.42	1.40	1.67	0.95
Turbid	Faecal streptococci	0.45	1.51	1.51	0.99
Clear	Faecal streptococci	0.95	3.17	0.73	0.97

r = coefficient of correlation
t 1/2 = time in days for 50% death
t_{90} = time in days for 90% death

Experimental Results (number per 100 ml)

Storage Time Days	Turbid Sample FC	Turbid Sample FS	Clear Sample FC	Clear Sample FS
0	52 000	114 200	66 000	125 200
1	7 180	18 150	47 000	36 850
2	2 460	3 920	7 000	19 000
3	300	980	480	10 700
4	220	139	-	6 030
6	186	14	-	-

FC = Faecal coliforms
FS = Faecal streptococci



SHALLOW PIT. OPEN TO POLLUTION. RUKWA REGION

SHALLOW WELL. WELL PROTECTED WITH APRON. SHINYANGA REGION

Water Quality in the Country

The map (Map 2.1) shows the location of sampling points, and in Annex 2.2 a catalogue of all bacteriological samples is found. These results together with results from Water Master Plans have been sorted into twelve different kinds of water source. The water quality has not been examined on a geographical basis. This is because a single sample or few samples from the same source do not characterise it - there are random variations within the body of water and over time. By pooling all the results for the same type of water source this difficulty can be overcome to some extent. The pooled results show the pollution pattern for the different source types quite accurately. This is more useful than uncertain measurements of pollution at specified locations.

The twelve source types considered are described in Table 2.6. The pooled results of tests for faecal streptococci and faecal coliforms are presented in Tables 2.7 and 2.8 and Figures 2.2 and 2.3. A scoring system has been devised to attach a figure to the overall quality of each type of source, running from 0 in very poor sources to 100 in sources meeting WHO standards. The full results are presented in the Annex 2.1.

Boreholes are clearly the best sources. Those cases where there is appreciable pollution can be ascribed to the distribution system, since samples were taken at the taps. This would indicate that around one fifth of distribution systems are subject to pollution of a greater or lesser amount, and should give cause for concern.

Rainwater collection systems and protected wells are the next best sources. They should be seriously considered for untreated supplies as the quality is fairly consistent.

Treated water comes off the fourth best type of water. This is largely due to poor operation of treatment plants, especially poor control of chlorine dosage. Nearly one half of all the samples contained more than ten faecal coliforms per 100 ml of water. If allowance is made for faulty distribution systems this still means that fully one third of all treatment plants are not being properly operated. This represents both a health risk and a great wastage of the resources devoted to building and running the plants.

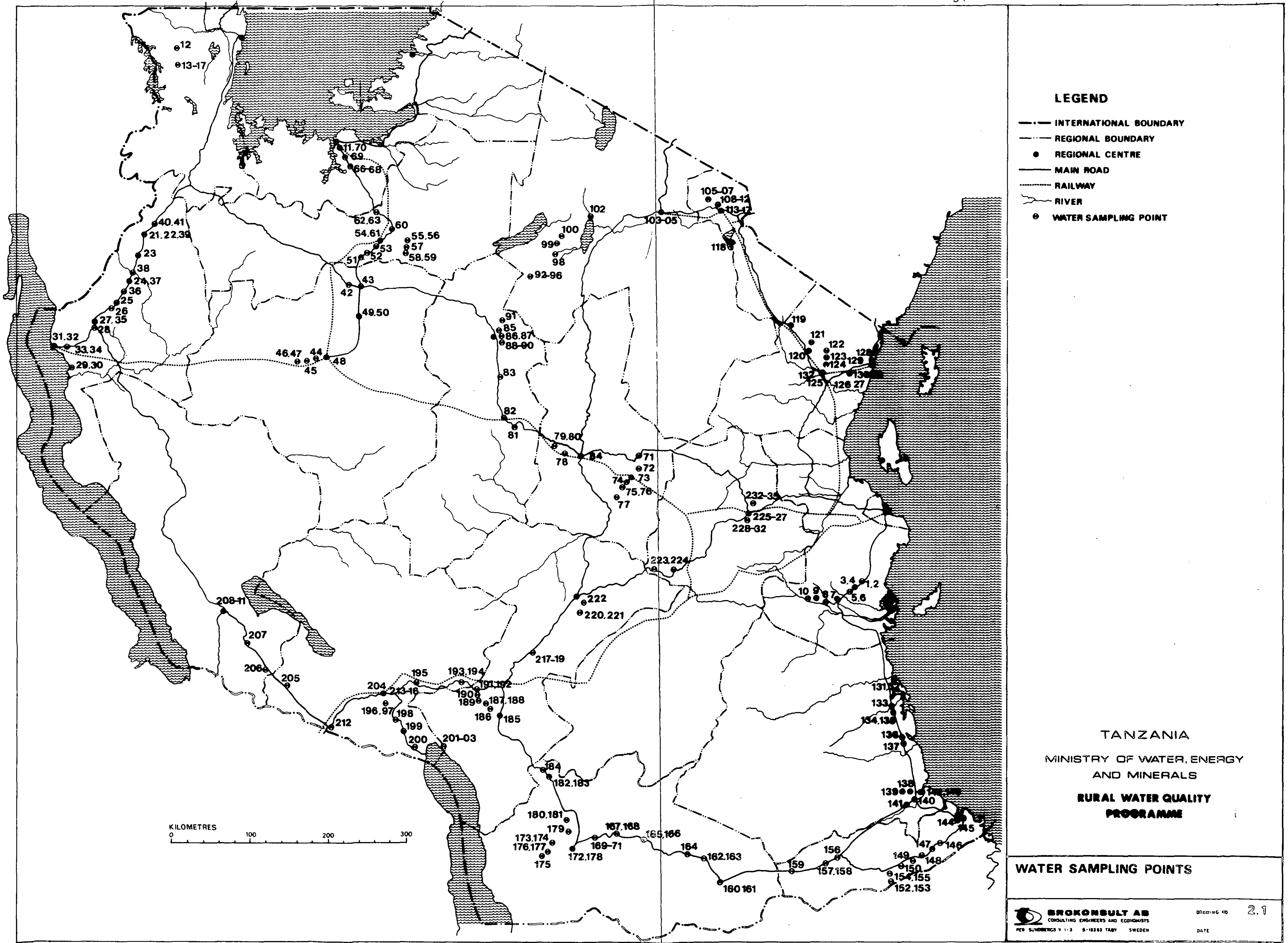

LEGEND
INTERNATIONAL BOUNDARY
REGIONAL BOUNDARY
REGIONAL CENTRE
MAIN ROAD
RAILWAY
RIVER
WATER SAMPLING POINT
KILOMETRES
0
100
200
300
TANZANIA
MINISTRY OF WATER, ENERGY AND MINERALS
RURAL WATER QUALITY PROGRAMME
WATER SAMPLING POINTS
BROKONSULT AB
CONSULTING ENGINEERS AND ECONOMISTS
DRAWING NO
2.1
DATE

TABLE 2.6

WATER SOURCE TYPES

Borehole	Deep bored well with motor or hand pump.
Well-protected	Dug well lined with concrete or masonry, surrounded by concrete apron, completely covered. Water removed by pump.
Well-open	Dug well lined with concrete or masonry. Water removed in buckets.
Spring - protected	Spring enclosed in a concrete or masonry box. Water removed through a pipe.
Spring - open	Spring discharging into a pool or stream.
Stream - piped	Any running surface water, with water removed through a proper intake, by pump or gravity.
Stream - unpiped	Any running surface water.
Impoundment - piped	Any lake, charco, dam, pond or reservoir of still water, removed by a proper intake by pump.
Impoundment - unpiped	Any lake, charco, dam, pond or reservoir.
Pit	Waterholes, unlined wells and similar traditional sources.
Treated water	Water which has been treated in any way.*
Rainwater	Rainwater collected from roofs and stored.

* This means either flocculation or chlorination, separately or together, or slow sand filtration.

TABLE 2.7

OCCURRENCE OF FAECAL COLIFORMS
RESULTS FROM WATER MASTER PLANS AND THIS STUDY

Source Type	% Sources with given No./100 ml					No. Sources	No. Samples	S	GM
	<1	1-10	11-100	101-1000	>1000				
Borehole	62	20	14	4	-	53	99	85	1
Well-protected	30	33	26	11	-	67	133	71	7
Well-open	0	9	19	32	40	44	58	24	343
Spring-protected	16	38	36	10	-	29	42	65	15
Spring-open	15	22	39	24	-	42	46	57	20
stream-piped	7	22	37	32	2	55	75	50	32
Stream-unpiped	5	6	25	42	21	64	110	33	128
Impoundment-piped	17	30	37	16	-	30	95	62	10
Impoundment-unpiped	4	19	47	28	2	79	122	49	163
Pit	-	11	23	40	26	37	73	30	61
Treated water	30	24	40	3	3	28	33	69	7
Rainwater	25	38	37	-	-	8	8	72	3
TOTAL						536	894		

$$S = \frac{4 \times (\% <1) + 3 \times (\%1\text{-}10) + 2 \times (\%11\text{-}100) + (\%101\text{-}1000)}{4}$$

S = 100 if all sources have <1 faecal coliform per 100 ml.

S = 0 if all sources have >1000 faecal coliforms per 100 ml.

GM = Geometric mean count per 100 ml.

TABLE 2.8

OCCURRENCE OF FAECAL STREPTOCOCCI
RESULTS FROM COAST REGION MASTER PLAN AND THIS STUDY

Source Type	% Samples with given No./100 ml					No. Sources	No. Samples	S	GM
	<1	1-10	11-100	101-1000	>1000				
Borehole	72	12	12	-	4	13	25	87	11
Well-protected	1	19	44	31	5	35	70	45	33
Well-open	-	-	11	28	61	17	18	13	1761
Spring-protected	8	8	68	8	8	13	13	50	40
Spring-open	6	6	56	32	-	16	16	47	58
Stream-piped	5	5	60	20	10	18	20	44	64
Stream-unpiped	-	2	14	62	22	40	42	24	293
Impoundment - piped	5	16	28	42	9	26	64	42	17
Impoundment-unpiped	-	-	24	40	36	23	25	22	590
Pit	-	-	15	30	55	27	27	15	974
Treated water	21	21	48	10	-	26	29	63	12
Rainwater	-	50	25	25	-	4	4	56	13
TOTAL						258	353		

For explanation see Table 2.7.

FIGURE 2.2
OCCURRENCE OF FAECAL COLIFORMS AND FAECAL STREPTOCOCCI
BY SOURCE TYPE

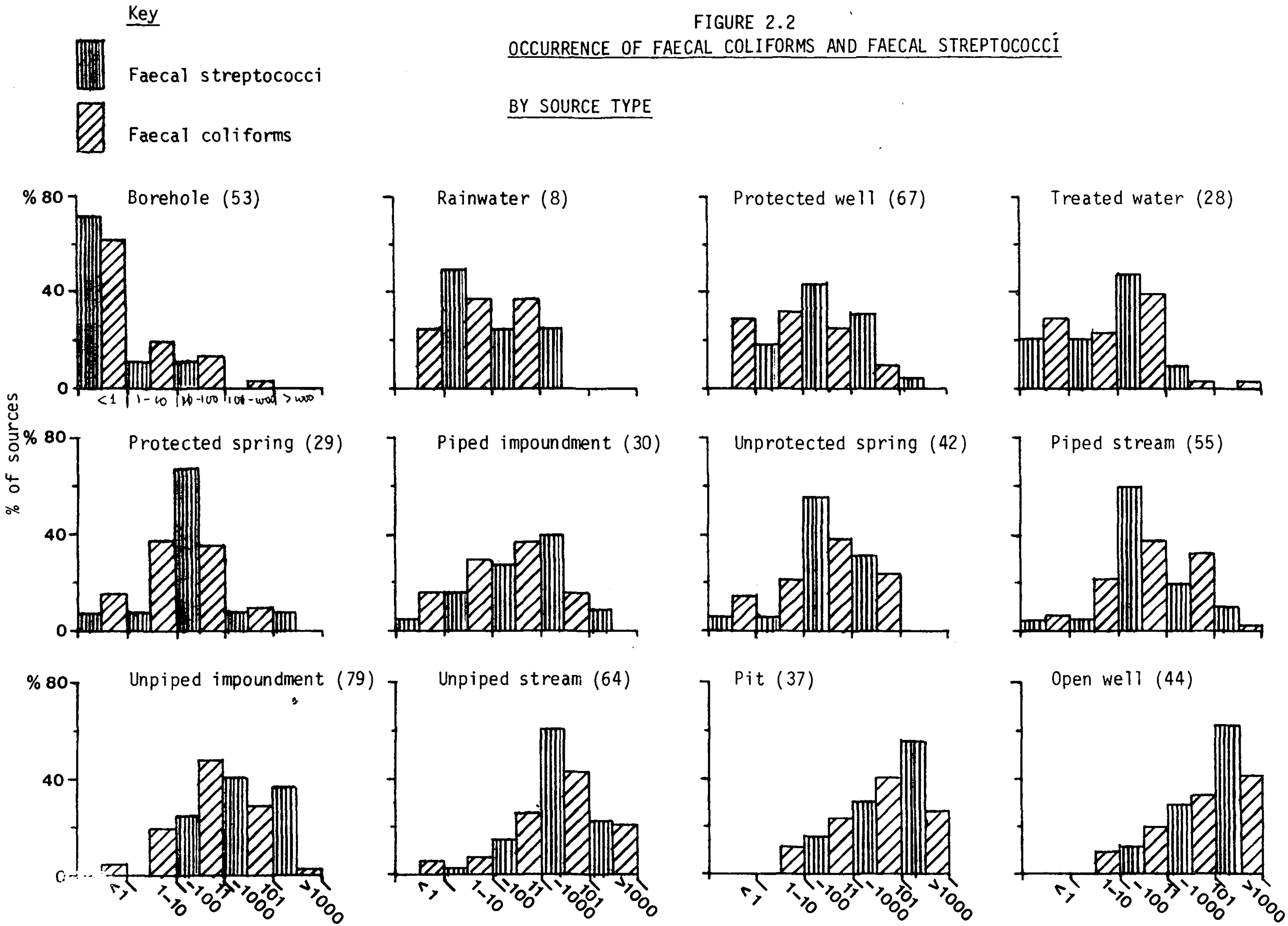
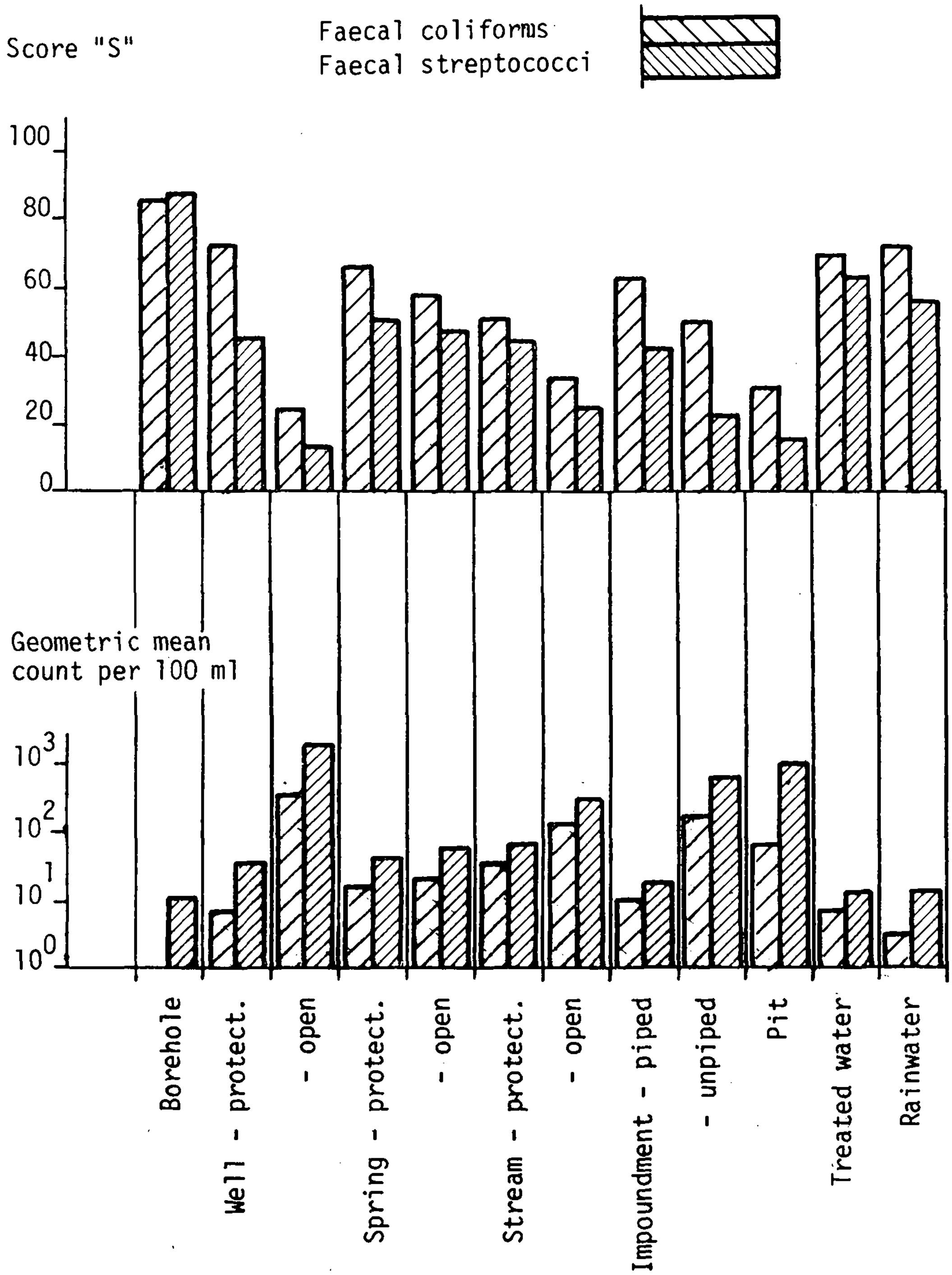


FIGURE 2.3
COMPARATIVE WATER SOURCE QUALITY

For explanation of Score "S" see Table 2.7.



Springs and piped impoundments are next in quality. Any treatment would obviously take water from an advantageous place in the impoundment, so these two sources represent those suitable for simple treatment. Quality is fairly consistent which is another advantage.

The lowest quality (and the most variable) piped sources are streams and rivers. These must only be considered as sources when no alternative is available, and facilities for fairly advanced treatment must be installed and operated to achieve the temporary Tanzanian standards.

Of the traditional sources, springs are by far the best, being basically groundwater. Next in line are the various impoundments and lakes. They are better than streams and rivers because the storage in the impoundment, although open to further pollution, allows the death and sedimentation of bacteria. The worst traditional sources are pits and open wells. This is because pollution introduced during water collection is not able to disperse. These types of source must be thoroughly suspect during epidemics.

The information may be summarised thus:

Sources

Boreholes	-	Suitable for use without treatment.
Rainwater & Protected Wells	-	Good quality water which need not be treated unless aspiring to a very high goal of quality.
Springs & Impoundments	-	Moderate quality water suitable for simple treatment.
Streams	-	The worst type of water source for a water supply; to be avoided if possible. If not, it demands substantial treatment.
Pits and Open Wells	-	The worst type of unimproved water source. Always polluted.

Maintenance

Distribution	-	Often faulty. They should be properly constructed and regularly maintained.
Treatment Plants	-	Poor operation and maintenance is very common, and badly needs improving.

It is perhaps also instructive to consider the number of sources exceeding various quality levels. Using the present mix of source types across the country we find 2% above 1000 faecal coliforms per 100 ml, 17% above 100, 43% above 10 and 66% above 1.

Interpretation of the faecal streptococci counts

The counts of faecal streptococci were used for two purposes. These were, firstly, to confirm the plausibility of the faecal coliform counts and secondly, to try and draw tentative conclusions as to the source (human or animal) of the faecal pollution.

Figure 2.4 shows the relationship of faecal coliform and faecal streptococci counts in 150 samples covering all the source types plus sewage. It can be seen that a moderately good positive correlation ($r = 0.74$) exists between the two parameters. That the correlation is not better is due to two factors, namely lack of selectivity of the KF medium used for isolation, and the presence of non-faecal group D streptococci. Some colonies were subcultured and sent to the central public health laboratory in London to be typed and both these factors were demonstrated. Out of 45 strains from a pond near Ubungo, 9 (20%) were not streptococci, whilst out of 22 strains collected from domestic water sources near Kibiti, 5 (23%) were *S. faecalis* var. *liquefaciens*, an organism known to be non-faecal in origin. Given these two effects, the observed correlation of faecal coliform and faecal streptococcus counts is as good as can be expected, and thus supports the faecal coliform data.

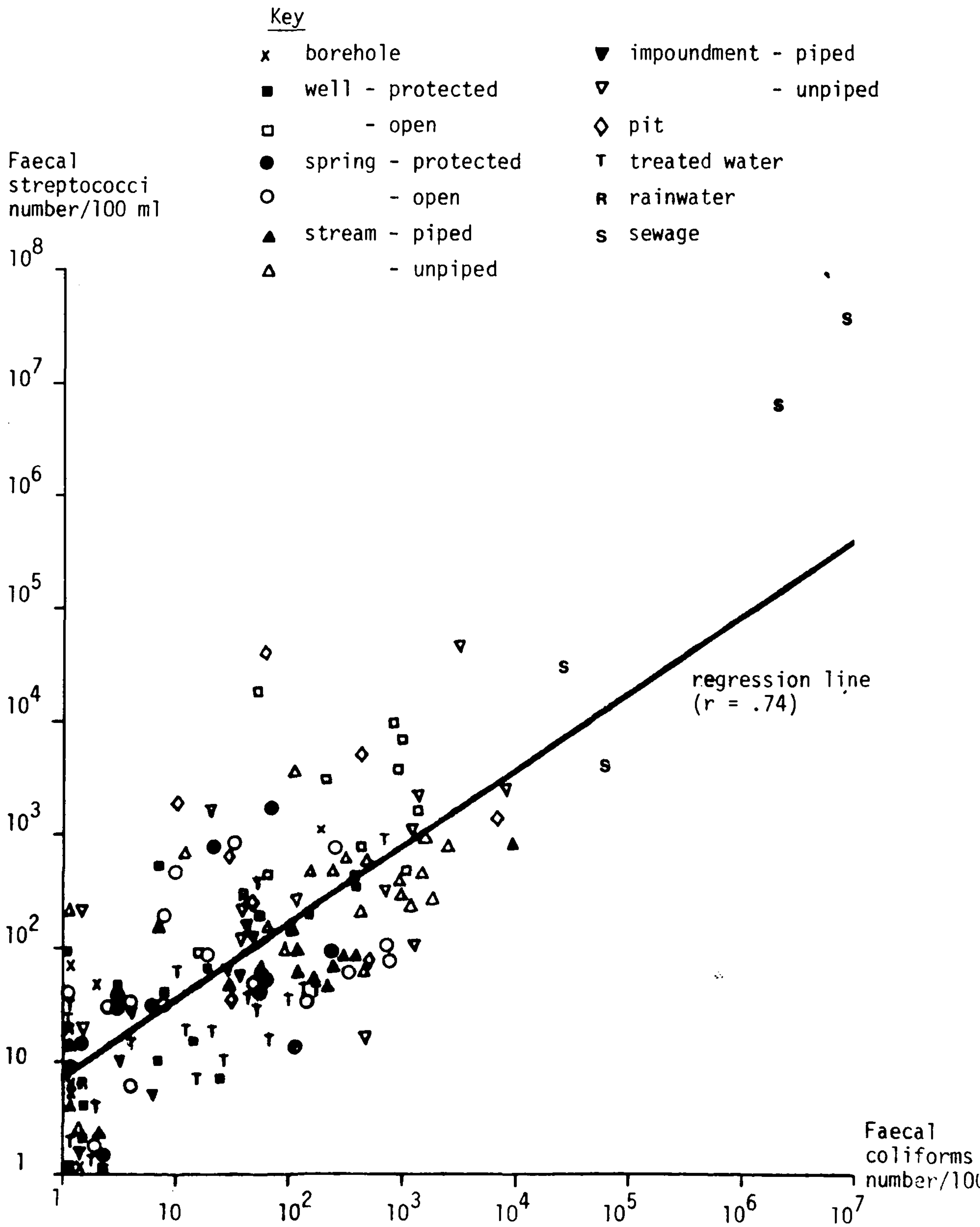
The idea that the ratio of faecal coliforms to faecal streptococci can be used to differentiate human from animal pollution has been in circulation for some time, but it is only recently that it has been thoroughly refuted (e.g., Wheater, Mara and Oragui 1978 - see footnote). Thus any attempt to analyse the data in these terms was abandoned, although this was originally planned.

Footnote

Wheater, D.W.F., Mara, D.D., Oragui, J. "Indicator Systems to Distinguish Sewage from Stormwater Run-off and Human from Animal Faecal Material." Presented at the Symposium on Biological Indicators of Water Quality University of Newcastle-upon-Tyne, U.k., September 1978.

FIGURE 2.4

RELATIVE LEVELS OF FAECAL COLIFORMS AND FAECAL STREPTOCOCCI



Pollution after Collection

It is inevitable that water carried to the home from a standpipe or traditional source and then dispensed with a scoop or mug will become polluted on its way. Before discussing the extent of this pollution it is relevant to consider its nature. Any microbes introduced during the passage from source to mouth will tend to be those being shed by the water collector. This means that they are already within the family group. Thus water must not be seen in this case as the primary vehicle of infection, but rather as one of many different transmission routes for faecal-oral disease which exist within the close contact of a family. Therefore the risk attached to any particular level of contamination will be lower than for the actual water source.

The faecal coliform and faecal streptococci levels for source and consumer containers (buckets and scoops) are presented in Figures 2.5 and 2.6 and Annex 2.3.

The results certainly show pollution after collection. Perhaps the surprising fact is that the extent of this pollution is often rather small. Most of the pollution is less than an extra 50 faecal coliforms per 100 ml. This is very likely of little importance in comparison with the pollution transmitted on food. Nevertheless, there are some points indicating very heavy pollution of water by consumers. This highlights the importance of health education in hygiene to support any efforts to improve health by providing good water.

2.3 Chemical Water Quality

This section reviews the present chemical domestic water quality situation in Tanzania. Domestic water quality standards are set for several parameters by WHO and national authorities. It is, however, not possible to discuss more than a few of these. Little information is available on concentrations of many constituents, mainly due to difficulties in analysing them.

The most important parameters to be discussed are: fluoride, nitrate, conductivity (salinity), and turbidity. Also chemical pollution will be discussed.

FIGURE 2.5
FAECAL COLIFORMS IN WATER SUPPLY AND CONSUMERS' CONTAINERS

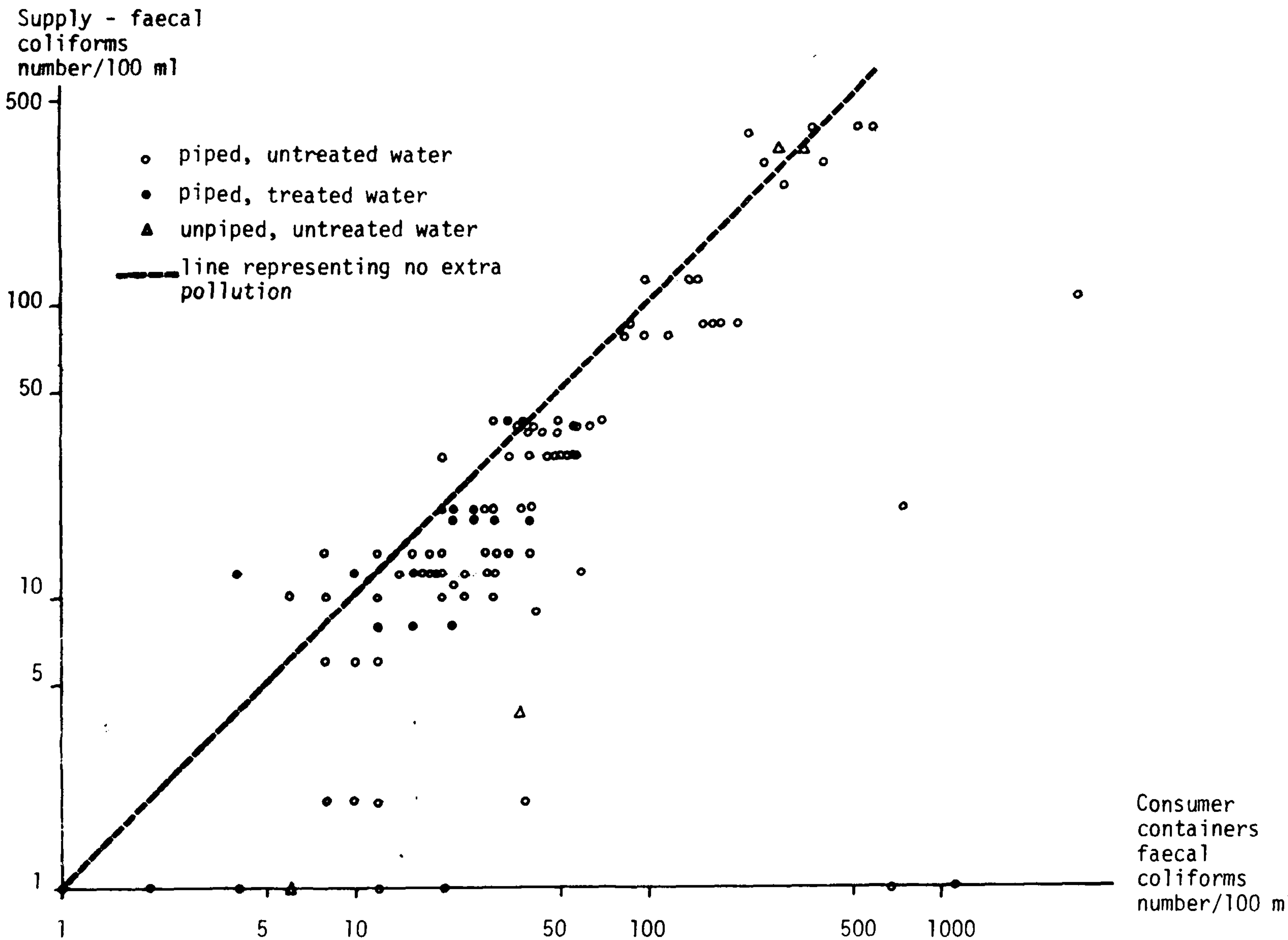
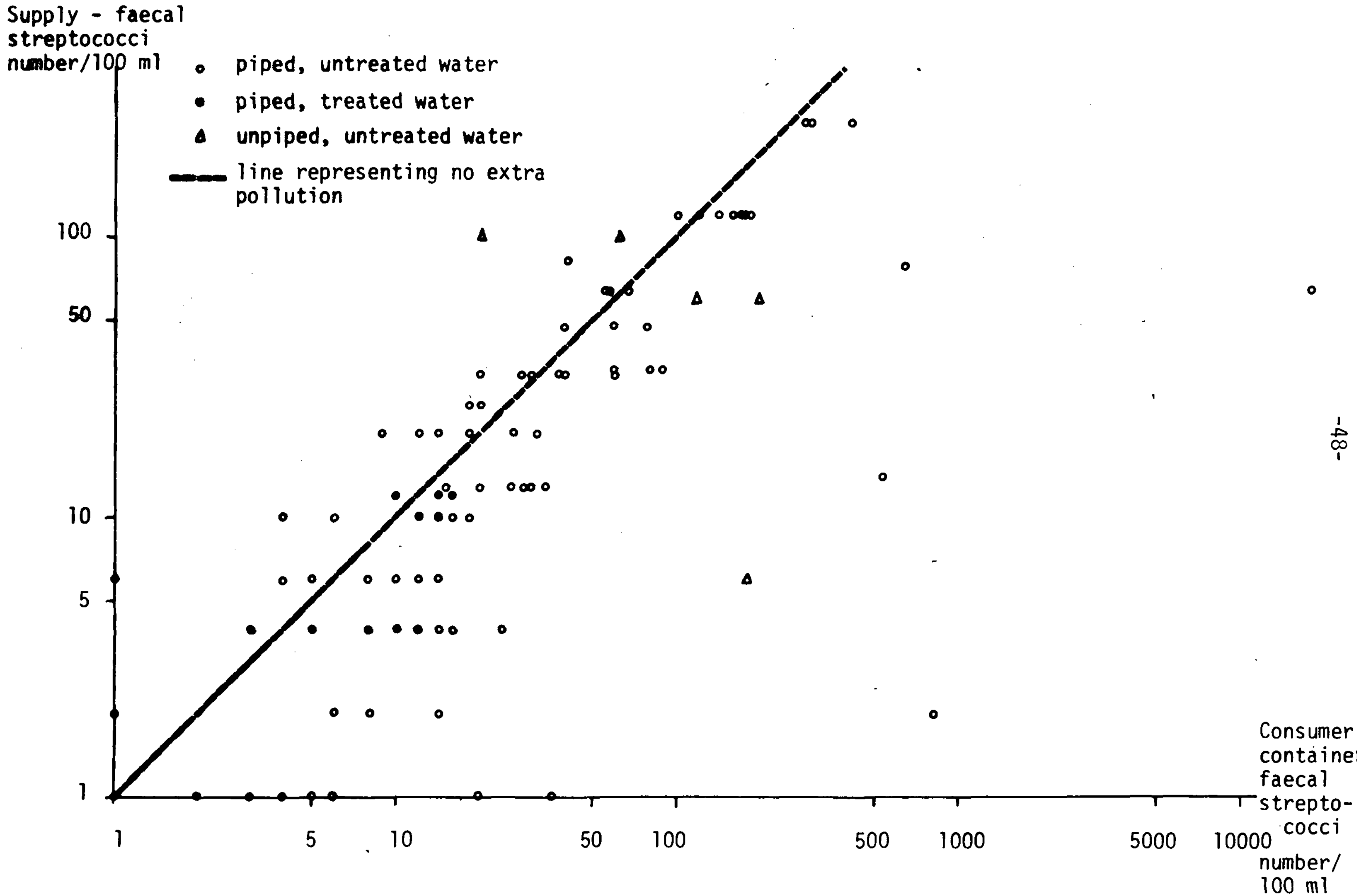


FIGURE 2.6
FAECAL STREPTOCOCCI IN WATER SUPPLY AND CONSUMERS' CONTAINERS



Basis for Information

All water chemical analyses performed at the Water Laboratory at Ubungo Dar es Salaam are assembled in report forms at present filed by region. This set of data forms a valuable basis for the evaluation of the physical-chemical situation around the country. The number of samples (reports) per region available as given in Table 2.9, and a summary of the data in Annex 2.4. Data from Water Master Plans are taken from their final reports. During the Consultant's field work most analytical efforts were devoted to bacteriological testing however some limited physical-chemical testing was possible. The data is reported in Annex 2.4.

Fluoride

Moderate concentrations of fluoride cause dental fluorosis while high ones may cause skeletal fluorosis wich is much more serious.

The presence of areas with high fluoride concentrations in Tanzania is well known. Bardecki (1974) prepared an excellent statistical evaluation of fluoride concentrations.

Fluoride in water usually originates from the minerals fluorite and fluoroapatite. These seem to be found in granites. There is no direct evidence as to location of fluoride bearing rock so it is not now possible to relate the chemical results reported here to any direct mineralogical data. The fluoride dissolves in water from the weathered bedrock. When the weathering processes have produced fluoride in water secondary processes can influence the concentration. Evapotranspiration will increase it while precipitation as calcium fluoride will diminish or prevent it from increasing. Both dissolution and secondary processes will influence the concentrations of other ions in the same way. Thus there should be some relationship between fluoride concentration and conductivity. However, no significant correlation could be found in the Tri-Region WMP data. It should be noted that high concentrations have not been found in water with low conductivity. Since fluoride has its origin in rock and soil it is obvious that the high concentrations will normally be found in groundwater. The distribution of fluoride is shown in Table 2.10 and regions with high concentrations are shown in Map 2.2. A concentration of 4 mg/l was chosen to describe the distribution. The most severe situation is found in Arusha Region where the Consultant's evaluation indicates 23% of sample sources are above the Tanzanian water quality standards (8.0 mg/l). For his set of samples Bardecki found 18%. These differences are due to the different sets of data used (both from Ubungo

TABLE 2.9

NUMBER OF WATER QUALITY REPORTS FILED AT UBUNGO LABORATORY

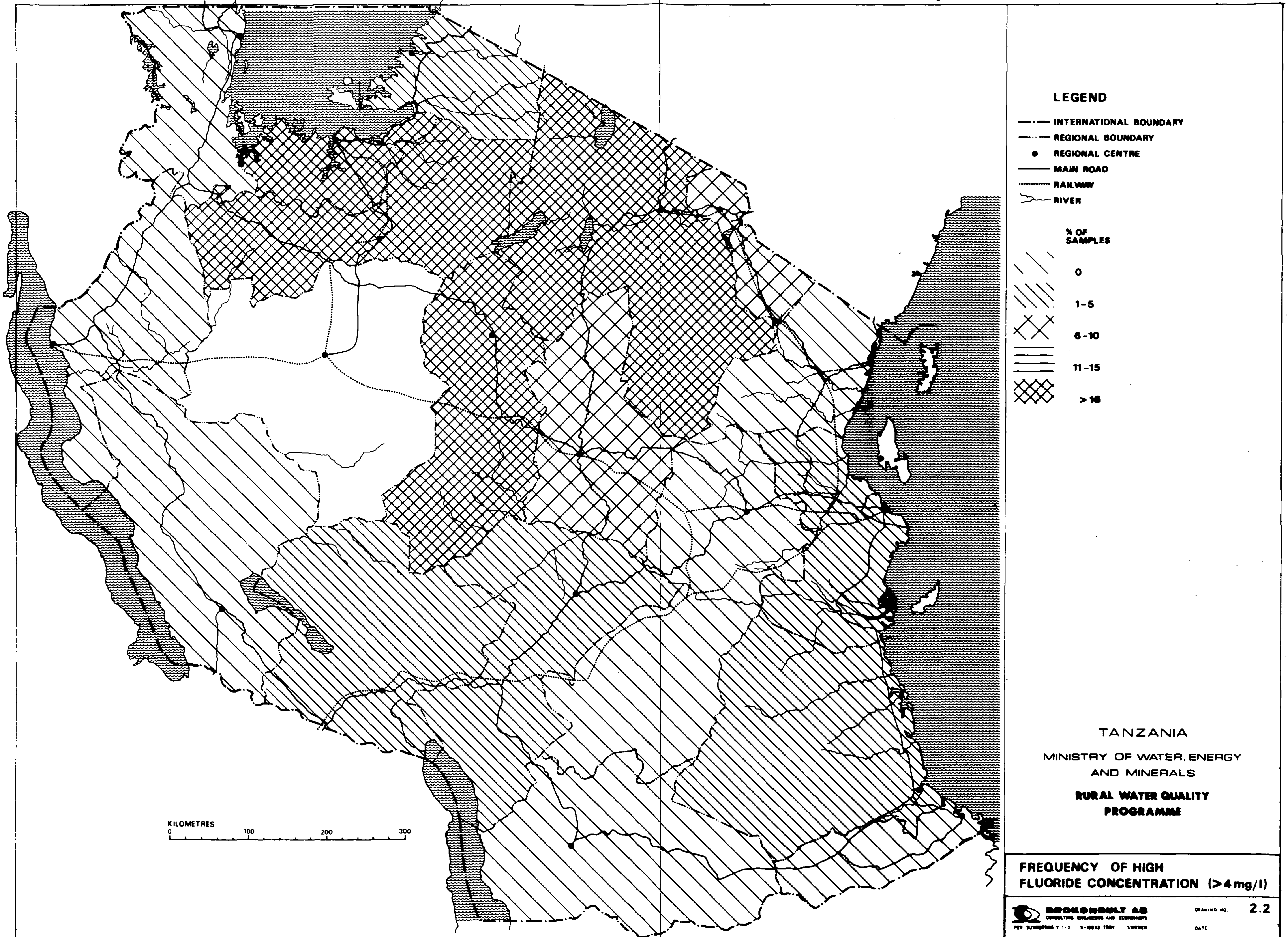
Region	Number
Arusha	212
Coast	198
Dodoma	119
Iringa	194
Kigoma	116
Kilimanjaro	113
Lindi	101
Mara	153
Mbeya	185
Morogoro	113
Mtwara	103
Mwanza	119
Rukwa	43
Ruvuma	53
Shinyanga	103
Singida	202
Tanga	134
West Lake	101
TOTAL	2362

TABLE 2.10

FREQUENCY OF SAMPLES WITH SPECIFIED CONCENTRATION OF FLUORIDE
(values from Bardecki within brackets)
Data from Ubungo Laboratory

FLUORIDE CONCENTRATION MG/L

REGION	0-1.0	1.1-2.0	2.1-4.0	4.1-8.0	8.1-16.0	16.1-	4.1-	8.1-
ARUSHA	25	24	18	10	9	14	33	23 (18)
COAST	94	4	1			1	1	1 (0)
DODOMA	70	15	8	7			7	0 (1)
IRINGA	88	8	3	1			1	0 (0)
KIGOMA								
KILIMANJARO	62	21	8	5	3	1	9	4 (5)
LINDI	86	8	5	1			1	0 -
MARA	32	35	20	9	2	2	4	2 (3)
MBEYA	83	10	3	2	1		1	0 (0)
MOROGORO	92	6	2				0	0 (0)
MTWARA	98	2					0	0 -
MWANZA	52	9	13	15	10	2	27	12 (10)
RUKWA	94	3	3				0	0 -
RUVUMA	93	7					0	0 -
SHINYANGA	57	12	11	17	1	2	20	3 (12)
SINGIDA	34	26	14	9	13	5	27	18 (24)
TABORA								
TANGA	75	19	3	3			0	0 (0)
WEST LAKE	96	3	1				0	0 (0)


LEGEND
INTERNATIONAL BOUNDARY
REGIONAL BOUNDARY
REGIONAL CENTRE
MAIN ROAD
RAILWAY
RIVER
% OF SAMPLES
0
1-5
6-10
11-15
> 16
KILOMETRES
0
100
200
300
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RURAL WATER QUALITY PROGRAMME
FREQUENCY OF HIGH FLUORIDE CONCENTRATION (>4 mg/l)
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2.2
DATE

laboratory). Also Singida and Mwanza have high percentages of non-compliance sources. In the Consultant's set of data Shinyanga has only 3% non-compliance, while Bardecki records 12%. The last figure is obviously more valid, as it confirms with the information from Shinyanga WMP. Differences are also found when comparing with Mara, Mwanza and West Lake WMP data. In Mwanza only 4% of the total number of samples had concentrations above 8 mg/l. The corresponding figure for borehole samples was 6%. The present set indicates 12% for all samples. The WMP data is extensive over the region while the data set in this analysis probably contains some double sampling and bias towards boreholes samples.

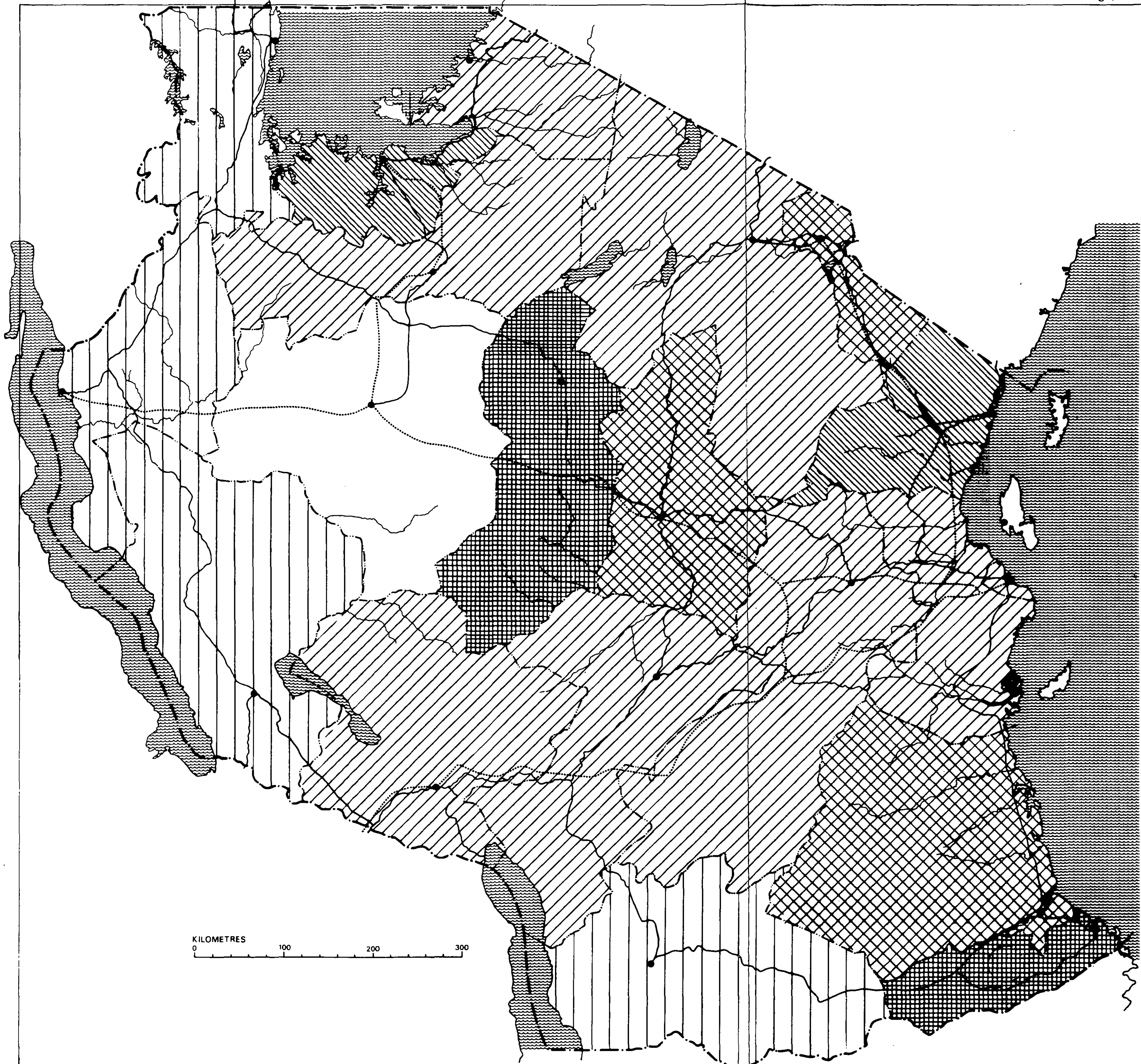
Nitrate

Nitrate is produced from excreta and vegetation when nitrifying bacteria oxidise its ammonia content. In reasonably wet areas with vegetation the ammonia or produced nitrate be taken up into the plants. In dryer areas however with scarce vegetation, the nitrates seep into the ground. Evapotranspiration increases the nitrate concentration before the water seeps down to the groundwater. High nitrate concentrations can be an indication of more remote faecal pollution. High concentrations are only found in groundwater.

All nitrate concentrations are reported as nitrate nitrogen. This must be multiplied by the factor 4.43 to obtain values as nitrate. The presence of high nitrate concentrations in regions is shown in Map 2.3. The level (6.8 mg/l of nitrate nitrogen) was chosen to avoid more erratic variations in the data. The data is also presented in Table 2.11. The most severe difficulties are found in Singida where as many as 15% of the samples had a nitrate nitrogen concentration above 22.7 mg/l (100 mg/l nitrate). Other regions with frequent relatively high concentrations in samples are Dodoma and Mwanza.

Conductivity

High concentrations of salts in water make it unpalatable. The Tanzanian domestic water standard gives the salt content as total filtrable residue. The relation between conductivity (as mS/m) and total filtrable residue (mg/l) is approximately 0.13. With the standard value of 2000 mg/l this corresponds to 260 mS/m. There are two sources of high salt concentrations



TANZANIA

MINISTRY OF WATER, ENERGY AND MINERALS

RURAL WATER QUALITY PROGRAMME

FREQUENCY OF HIGH NITRATE-NITROGEN CONCENTRATION (> 6.8 mg/l)

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DATE

TABLE 2.11

FREQUENCY OF SAMPLES WITH SPECIFIED CONCENTRATION OF NITRATE NITROGEN
Data from Ubungo Laboratory

Nitrate mg/l	30	50	100			30-	50-	100-
Nitrate Nitrogen mg/l	0-6.7	6.8-11.3	11.4-22.6	22.7-45.2	45.3-	6.8-	11.4-	22.7-
Arusha	96	3	-	-	-	3	0	0
Coast	98	1	-	1	-	2	1	1
Dodoma	94	2	3	-	1	6	4	1
Iringa	97	-	1	1	-	2	2	1
Kigoma	1	-	-	-	-	1	1	0
Kilimanjaro	95	-	5	-	-	5	5	0
Lindi	93	4	1	-	1	6	2	1
Mara	97	1	-	-	1	2	1	1
Mbeya	98	2	-	-	-	2	0	0
Morogoro	97		3	-	-	3	3	0
Mtwara	86	7	5	2	-	14	7	2
Mwanza	91	5	4	1	-	10	5	1
Rukwa	100	-	-	-	-	0	0	0
Ruvuma	100	-	-	-	-	0	0	0
Shinyanga	98	1	-	-	1	2	1	1
Singida	75	3	8	7	8	26	23	15
Tanga	88	7	5	-	-	12	5	0
West Lake	100	-	-	-	-	0	0	0

in samples. One is sea water either fossil or from intrusion, the other due to concentration caused by evapotranspiration. The regions along the coast are examples of the first while Dodoma may be chosen as an example of the latter. The frequency of high conductivities in the regions is shown in Map 2.4 The data is also compiled in Table 2.12.

Total Iron

Iron is present in natural water in either dissolved form as iron (II) or as iron (III) in a collodial or solid form. Divalent iron is stable only in water without oxygen, such as water from boreholes, shallow wells and springs. In aerated water such as streams and often lakes and dams, the iron will be in solid form suspended in the water. Also iron is found in laterite soil which erodes and is found in the suspended matter in streams and rivers.

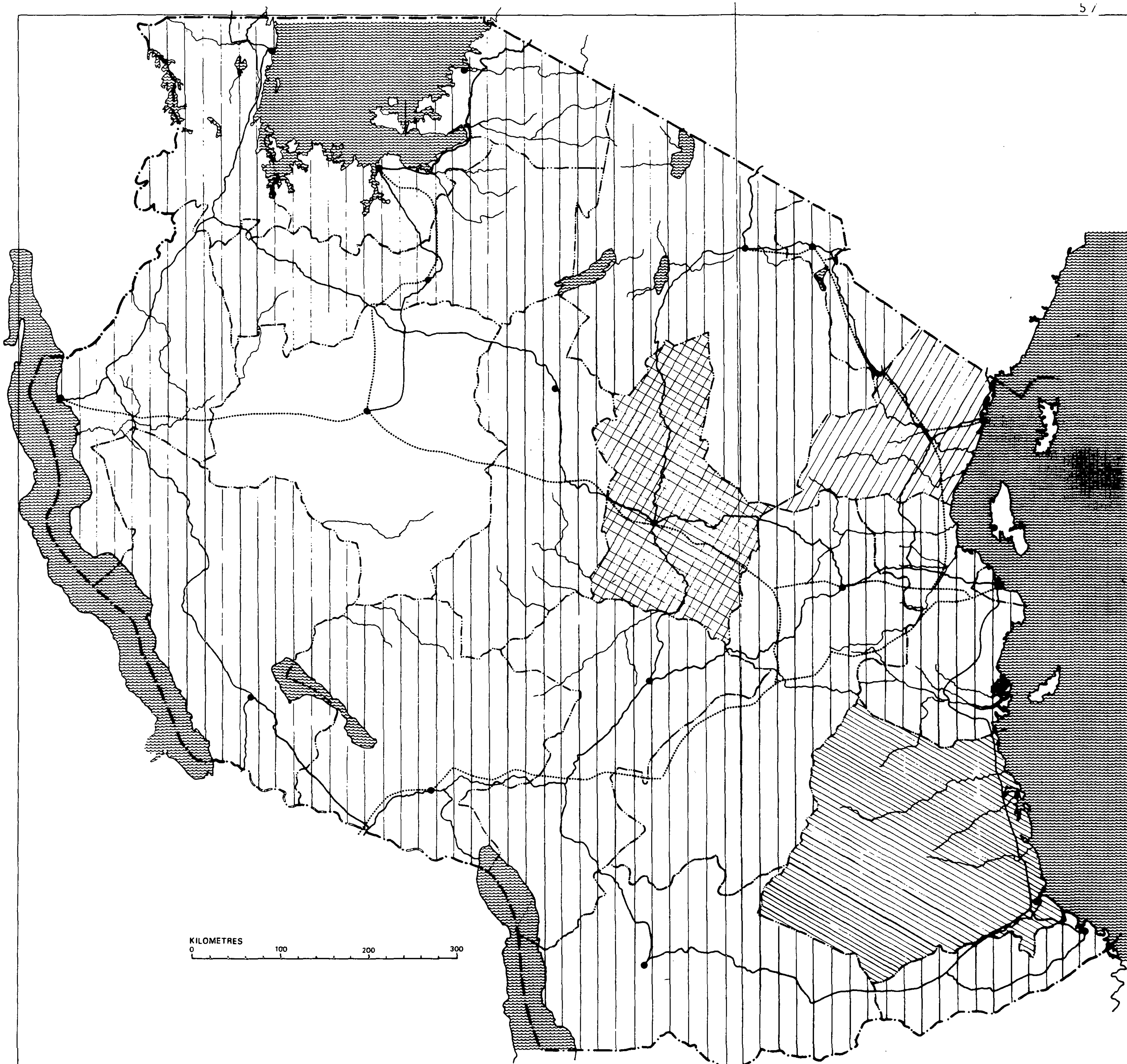
The drinking water standards given by Tanzania and WHO are based on technical effects and not on medical ones.

The frequency of high iron concentrations (above 2 mg/l) is shown in Map 2.5 and Table 2.12. On an average as much as 23% of the samples have a concentration higher than 2.1 mg/l while 13% had concentrations above 4.1 mg/l. However, the possibility of erroneous analyses should be taken into account. As mentioned above, iron is or soon will be in particulate form in the sample. Insufficient shaking when subsampling can easily produces too high an estimate of the iron concentration.

The mentioned connection between total iron concentration and suspended matter is indicated by data from Mtwara-Lindi WMP. During the wet season 36% of samples from streams and rivers had concentrations above 1.0 mg/l while the corresponding value for the dry season was zero. No such seasonal variation exists for other sources.

Colour

Colour has been chosen to demonstrate the turbidity of a sample. Turbidity measurements give results that may vary much depending on the method used. Both colour and turbidity have high seasonal variation in surface waters. The data is compiled in Table 2.12 and the regional frequency of high colour is shown in Map 2.6. On an average 14% of the samples had a colour above 100. Coast Region WMP found 66% of the sources to have a colour above 50. In Tri-Region area (Mara, Mwanza, West Lake) 11% of the water schemes failed to comply with the Tanzanian standards for drinking water (50).



LEGEND

- INTERNATIONAL BOUNDARY
- REGIONAL BOUNDARY
- REGIONAL CENTRE
- MAIN ROAD
- RAILWAY
- RIVER

% OF SAMPLES

- 0 – 10
- 11 – 20
- 21 – 30
- 31 – 40
- 41 – 50

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RURAL WATER QUALITY PROGRAMME

FREQUENCY OF HIGH CONDUCTIVITY > 200 mS/m

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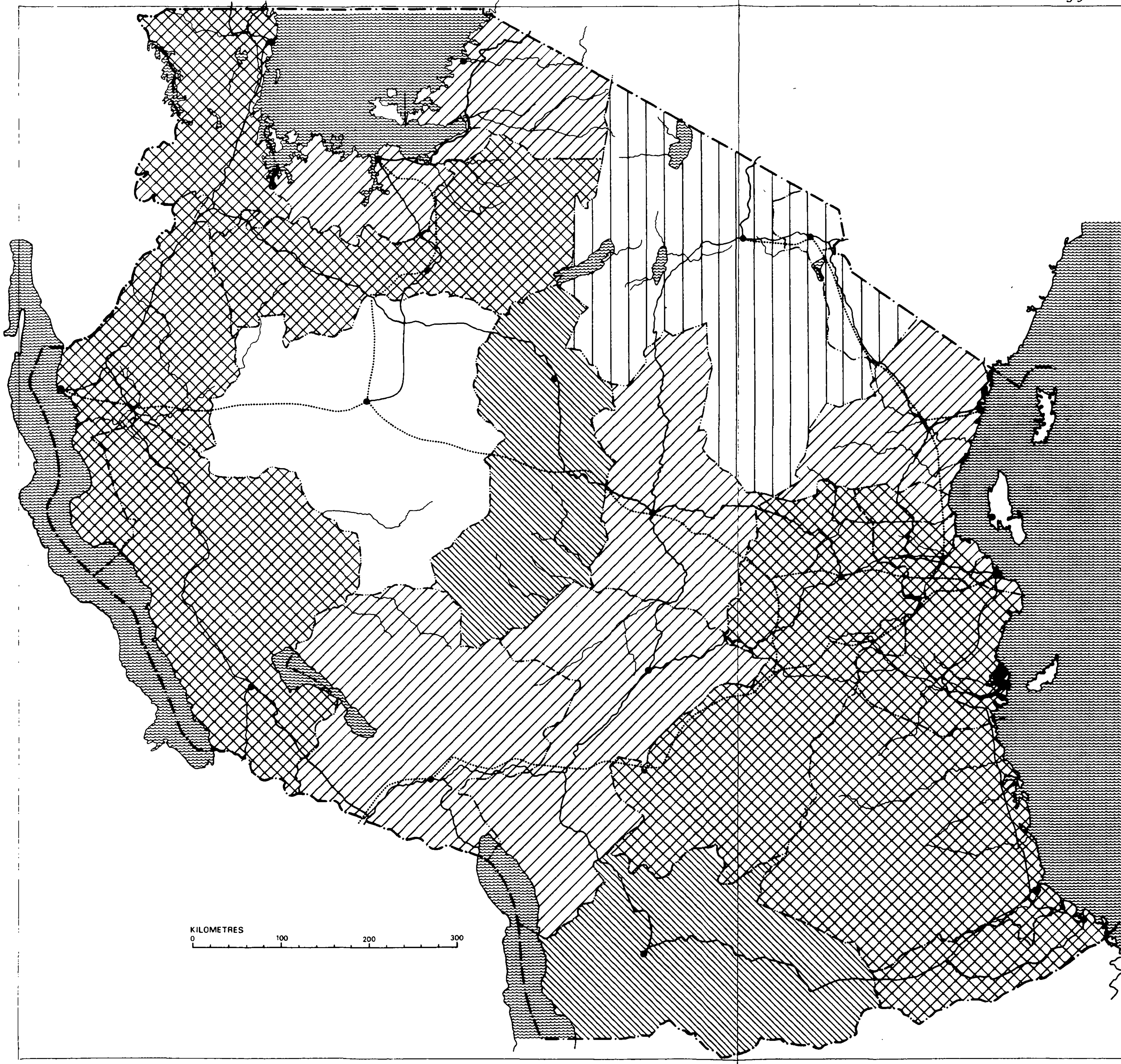
TABLE 2.12

FREQUENCY OF SAMPLES WITH SPECIFIED QUALITY OF COLOUR, CONDUCTIVITY AND IRON

Data from Ubungo Laboratory

REGION	Colour Pt mg/l			Conductivity mS/m			Iron mg/l		
	101-200	201-	101-	201-400	401-	201-	2.1-4.0	4.1-	2.1-
ARUSHA	3	3	6	6	1	7	3	6	9
COAST	14	15	29	6	4	10	13	15	28
DODOMA	5	5	10	22	8	30	4	14	18
IRINGA	10	8	18	2	1	3	10	10	20
KIGOMA	4	5	9	3	3	6	10	20	30
KILIMANJARO	2	-	2	1	0	1	6	1	7
LINDI	7	5	12	25	10	35	11	15	26
MARA	7	7	14	4	1	5	10	10	20
MBEYA	13	7	20	2	1	3	5	12	17
MOROGORO	5	4	9	6	3	9	14	12	26
MTWARA	8	5	13	7	3	10	8	22	30
MWANZA	1	9	10	1	8	9	6	12	18
RUKWA	3	-	3	-	-	0	13	8	21
RUVUMA	6	6	12	-	-	0	22	11	33
SHINYANGA	12	31	43	4	-	4	15	15	30
SINGIDA	5	12	17	2	1	3	12	19	31
TABORA									
TANGA	5	3	8	9	4	13	5	12	17
WEST LAKE	4	4	8	-	-	0	11	16	27



TANZANIA

MINISTRY OF WATER, ENERGY AND MINERALS

RURAL WATER QUALITY PROGRAMME

FREQUENCY OF HIGH TOTAL IRON CONCENTRATION (>2 mg/l)

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PER SUNDBERGS V 1-3 S-18363 TÄBY SWEDEN

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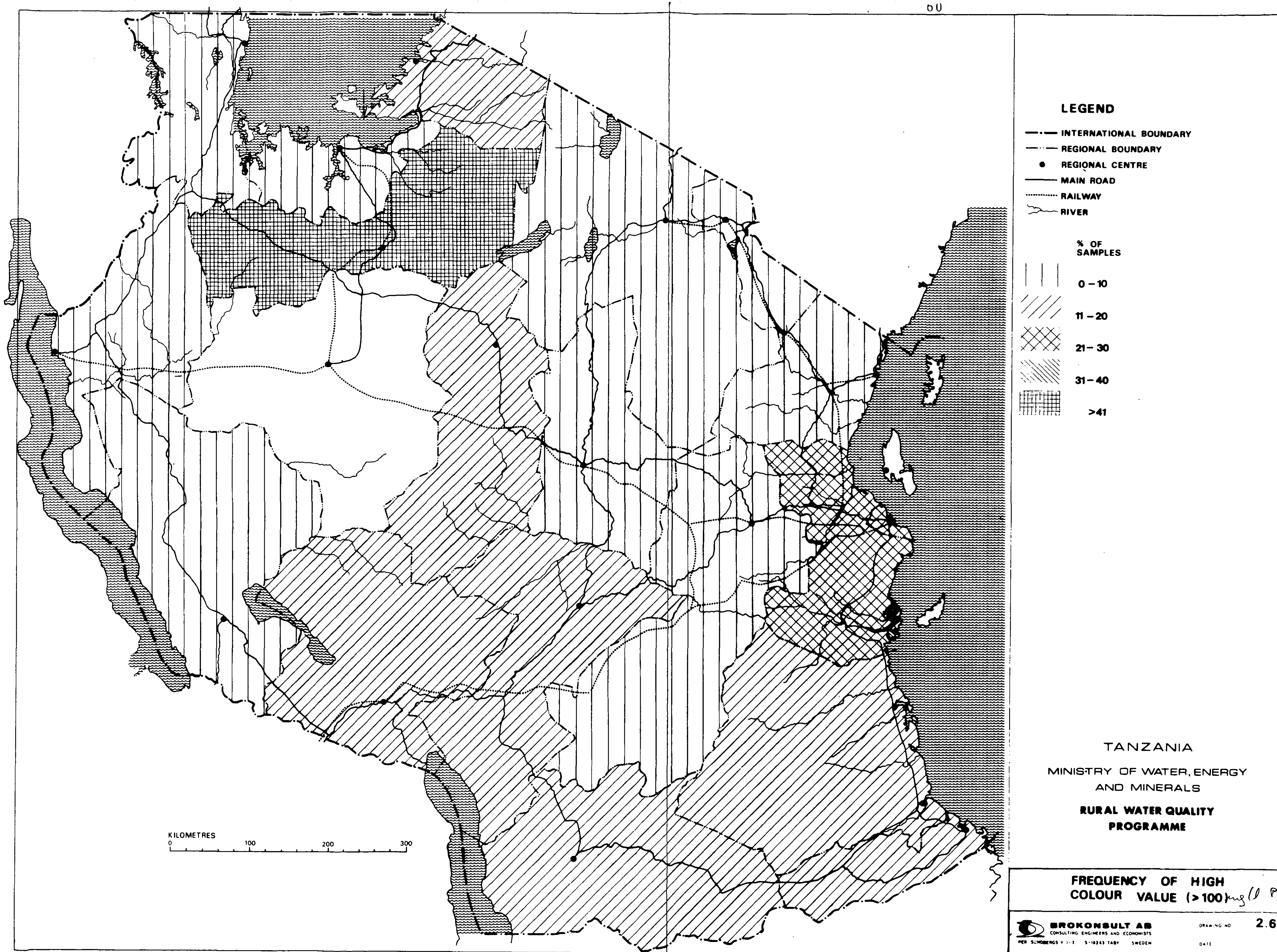
DATE



FREQUENCY OF HIGH COLOUR VALUE (>100) mg/l Pt

Chemical Pollution

The problem of chemical (industrial) pollution has been excellently discussed by the Effluent Standards Committee. Their recommendations are found in Annex 8.3.

Industries within Tanzania already pollute and decrease the quality of inland waters. The scarcity of receiving fresh water amplifies the problem. Problems may also arise from extensive use of agrochemicals. It is, however, felt that at present this causes little problem. As for industrial pollution an interview survey of industry to establish potential pollution, followed up by a study of physical-chemical and biological conditions in selected areas is recommended in order to establish the situation. Furthermore a study of biological conditions is required in order to establish appropriate receiving water standards. Pangani and Ruvu Rivers are examples of river basins where these problems already exist or will appear in the near future and are proposed as initial study areas.

Variation with Season

The variation in numbers of bacteria in water is well known. The variation in concentration of chemical constituents in water is less evident. Any variation would however interfare with the interpretation of a test result.

It is well known that boreholes and the large lakes have a relatively stable water chemistry. The variation increases for shallow wells, dams and streams. An indication of the stability of groundwater chemistry, is the seasonal variation in conductivity of Mtwara-Lindi samples for boreholes compared with that for small lakes, dams and ponds as shown in Table 2.13.

TABLE 2.13

SEASONAL VARIATION IN CONDUCTIVITY IN BOREHOLES AND SURFACE WATERS

Data from Mtwara-Lindi WMP.

Cond mS/m	0-30.0	30.1-70.0	70.1-200	200.1-500	500 -
Boreholes					
Wet season	-	3	24	14	5
Dry season	-	5	30	13	5
Surface sources					
Wet season	3	2	6	0	0
Dry season	5	2	8	7	4

High concentrations of the two most important constituents from a health point of view, fluoride and nitrate, are usally found in boreholes or springs (groundwater). Of course exceptions occur as is the case with fluoride in many rivers in Arusha region. Thus the establishing of chemical water quality can reasonably well be based on a single sample.

CHAPTER 3

PRESENT WATER SUPPLIES AND WATER TREATMENT

3.1 Source - Population Using Different Sources

From the Inventory of Rural Water Supply Projects in Tanzania carried out in 1975 a total of 1005 existing schemes have been tabulated against the type of water source used and against the number of people the water supply scheme is reported to be serving.

The types of water sources considered are:

Borehole
Well
Spring/River/Stream
Lake or Reservoir

The definitions of the source types are: 'Borehole' refers o a deep borehole; 'Well' is used for sources from which shallow groundwater is extracted. Spring/River/Steam are sources that are perennial with flowing water. The Consultant found that springs and river/steams are sometimes mixed up or not distinguished in reports. Therefore our classification, though inadequate from a quality point of view, is considered to be the best possible interpretation to the data available. The same applies for lakes and reservoirs. Taking "lake" and "reservoirs" in the samt type of source is different from the grouping used in the projection of "Water Source Use" that is described later in this report.

As can be seen from Table 3.1 half of the existing schemes supply villages with less than 2000 people and two thirds of the existing schemes supply less than 3000 people. The most modal size (26%) of water scheme supplies a population in the range 1001-2000 people. Thus the average scheme supplies a relatively small number of persons, typically a village.

The distribution of water source type indicates that about three quarters of the existing schemes use boreholes and streams etc. as the water source, the shallow well is the least used type of source. In the group lake and reservoirs the number of schemes using a lake as water source is believed to be in majority in the group. In Table 3.2 the percentage of existing water supply schemes are listed against type of source and scheme size.
The last column shows the distribution according to the projection of source use made for the cost estimates later in this report (Chapter 6).

TABLE 3.1

NUMBER OF EXISTING WATER SUPPLY SCHEMES

Data from Engström - Wann report

WATER SOURCE TYPE	SCHEME SIZE (Population)										
	< 1000	1001-2000	2001-3000	3001-4000	4001-5000	5001-7000	7001-10000	10001-20000	20001-50000	> 50001-	TOTAL NO OF SCHEMES
Borehole	121	107	67	23	14	10	7	6	2	2	359
Well	16	26	17	4	2	3	1	2	-	-	71
Spring/River/Stream	76	93	79	37	46	25	29	21	7	3	416
Lake/Reservoir	21	40	25	13	15	17	12	12	2	2	159
Total number of Schemes	234	266	188	77	77	55	49	41	11	7	1005
%	23	26	19	8	8	5	5	4	1	1	100

TABLE 3.2

DISTRIBUTION OF SCHEMES VERSUS SOURCE IN %

WATER SOURCE TYPE	EXISTING SOURCE USE (Population)				PROJECTED SOURCE USE
	1001-[1] 2000	2000[2]	3000[3]	ALL SIZES	
Borehole	40	46	43	36	40
Well	10	8	9	7	21
Stream etc.	35	34	36	41	33 [4]
Lake etc.	15	12	12	16	6 [4]

1) Represents 26% of existing schemes

2) Represents 49% of existing schemes

3) Represents 68% of existing schemes

4) In the projection of source-use lakes has been combined with streams/rivers and reservoirs are taken alone.

A comparison between existing and projected situation can be seen in Table 3.2.

The use of boreholes as water source is almost identical, the use of shallow wells is projected to increase considerably. The two remaining source types are not defined in the same way for existing and projected situations. The two sources taken together show a decrease in the projected situation. The implication is that the use of reservoirs will be more limited and shallow wells increased with the expansion of the water supply in future years.

3.2 Water Quality, Design, and Maintenance

Existing water supply schemes have been scrutinised during inventories and in connection with Water Master Plan studies. A brief summary of the findings relevant to water quality follows while recommendations on improvements are found in Section 9.3:

Intake

When the raw water is taken from a surface water source, as for example a lake, the siting of the intake can in some cases be improved. If the point of intake is too close to the shoreline or to an inhabited area there is always a risk of pollution from people, animals or vegetation. We have found several instances of badly placed intakes particularly for schemes using Lake Victoria as a water source (examples are Magu and Bukoba).

Pipelines

After construction and before use the pipelines, rising main as well as distribution pipes, should be disinfected. This should also be done when a section of the pipe-system is repaired or is for other reasons exposed.

Sedimentation will usually take place in the pipelines. In particular the sediment will build up in the low points in the pipe line system. A properly designed and constructed system has a "wash-out" at these low points in order to facilitate the cleaning of the pipes from the sediment load. A proper maintenance of a pipe-system means that these "wash-out" shall be used at regular intervals.

Included in sound maintenance programs is the recommendation that a continuous routine search for leakages should be carried out. A leaking pipe does not only mean a waste of water, it also includes a risk of pollution caused by water surge in the pipeline, i.e. a transport into the pipe of possibly polluted groundwater. The branching of the rising main should be prohibited since this makes treatment of consumed water impossible.

We observe widespread pipe leakage, lack of use of wash-outs to clean pipes, and insufficient efforts made to identify and fix leakages.

Storage Tanks

According to the existing design criteria, the storage volume shall not be larger than what is required for balancing purposes between delivery from the source and consumption. This means a detention time of only a fraction of a day, which is not long enough to improve the quality of the water.

As we noted for pipelines the storage tanks ought to be disinfected before taken into use after construction as well as after repair. A regular cleaning of the tank volume as part of the maintenance is also recommended. If only one tank is included in a scheme a partition wall in the tank will facilitate the use of the tank when cleaning. We found insufficient protection of storage tanks, serious structural damage in some cases, and little cleaning; generally storage volumes were low and average detention time of water in the source was very short.

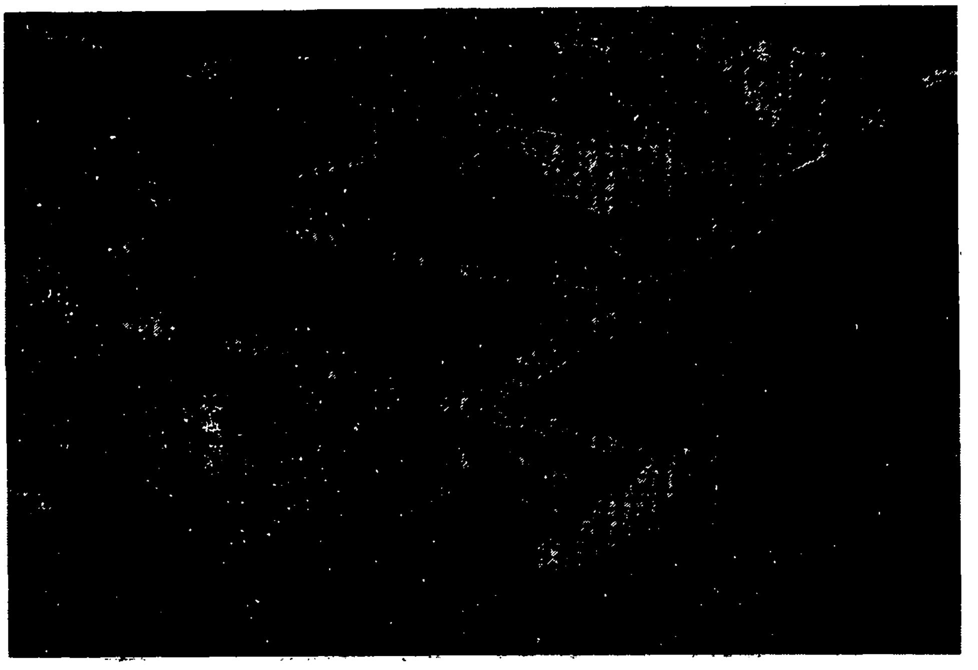
Consumption Points - DPs

It has been frequently observed that the drainage from the domestic water points (DPs) is non-existing or under-designed. A flooded area around a domestic point implies a health hazard to the consumer as well as a risk of pollution of the delivered water.

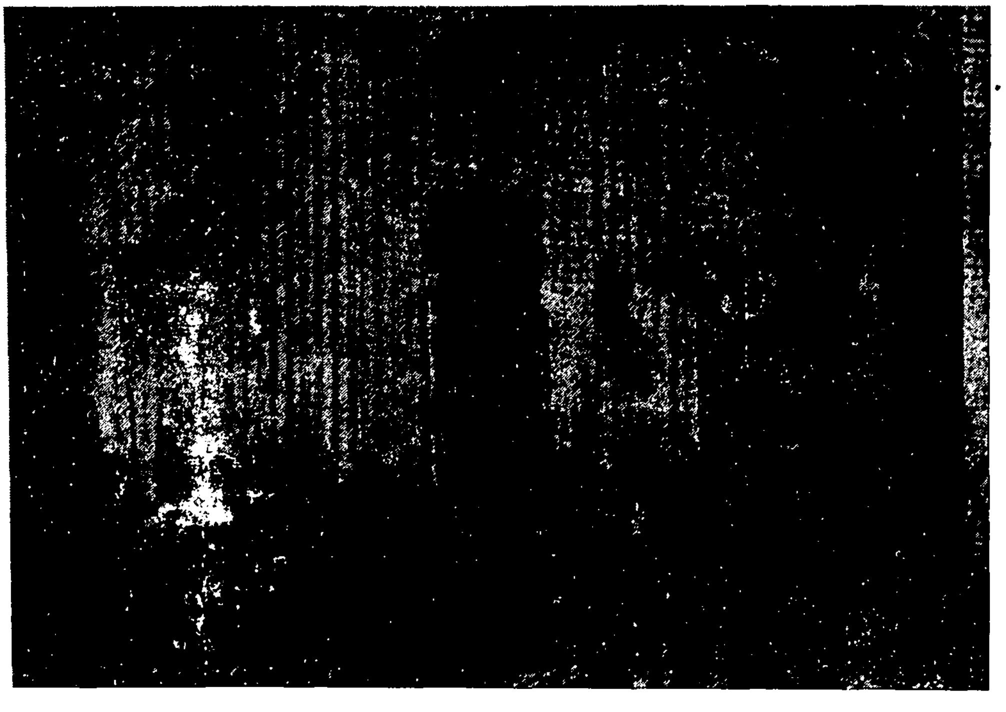
3.3 Existing Treatment Plants

The definition of a treatment plant has been chosen to be a water scheme where a change in water quality is produced by active mechanical or chemical intervention. This can be done with equipment ranging from a simple drip feeder to advanced treatment plants.

We have inventoried the existing treatment plants in most cases by a visit to the water scheme. In this report some treatment plants out of order have been included. The number of treatment plants reported by different inventories can differ due to the way to count plants out of order and also as the number of drip feeders can vary quite quickly.



SIMPLE RUNWAY FOR COAGULATION WITH ALUMINIUM SULPHATE AND FOLLOWING SEDIMENTATION. NINGWA DAM, SHINYANGA REGION.



ADVANCED TREATMENT PLANT FOR IRON REMOVAL. OUT OF ORDER. MLINGANO, TANGA REGION.

The Consultant's inventory results in a total of 43 schemes identified with treatment. The results are given in Annex 3.1. The distribution throughout the country is found in Map 3.1. The basis for information are own visits, interviews with RWEs, available Water Master Plans and the compilation of questionnaire data made by F.J. Gumbo. Also the excellent SIDA inventory of rural water supplies made in 1975 by Engström & Wann has been used. The information from this inventory has been utilised unless other more recent information has been available. Thus minor deviations between the Engström-Wann inventory and ours are found; the total number of rural treatment plants reported in the SIDA inventory, 37, compared with 43 in the Consultant's survey.

Type of Treatment

Sandfilters are recorded at 15 schemes (35%) (Annex 3.2). Four of these are slow and eight rapid sandfilters. (The other three we could not determine.) Water treated by the two different filter types will have substantially different qualities, which will be discussed further in Chapter 6 on Engineering. It has not been possible to determine the surface load on the filters. Eight of the filters were not in working order. The situation is even worse for slow sandfilters, none of the reported was in working condition. Neither were the two pressure rapid sandfilters working.

Aluminium Sulphate Flocculation

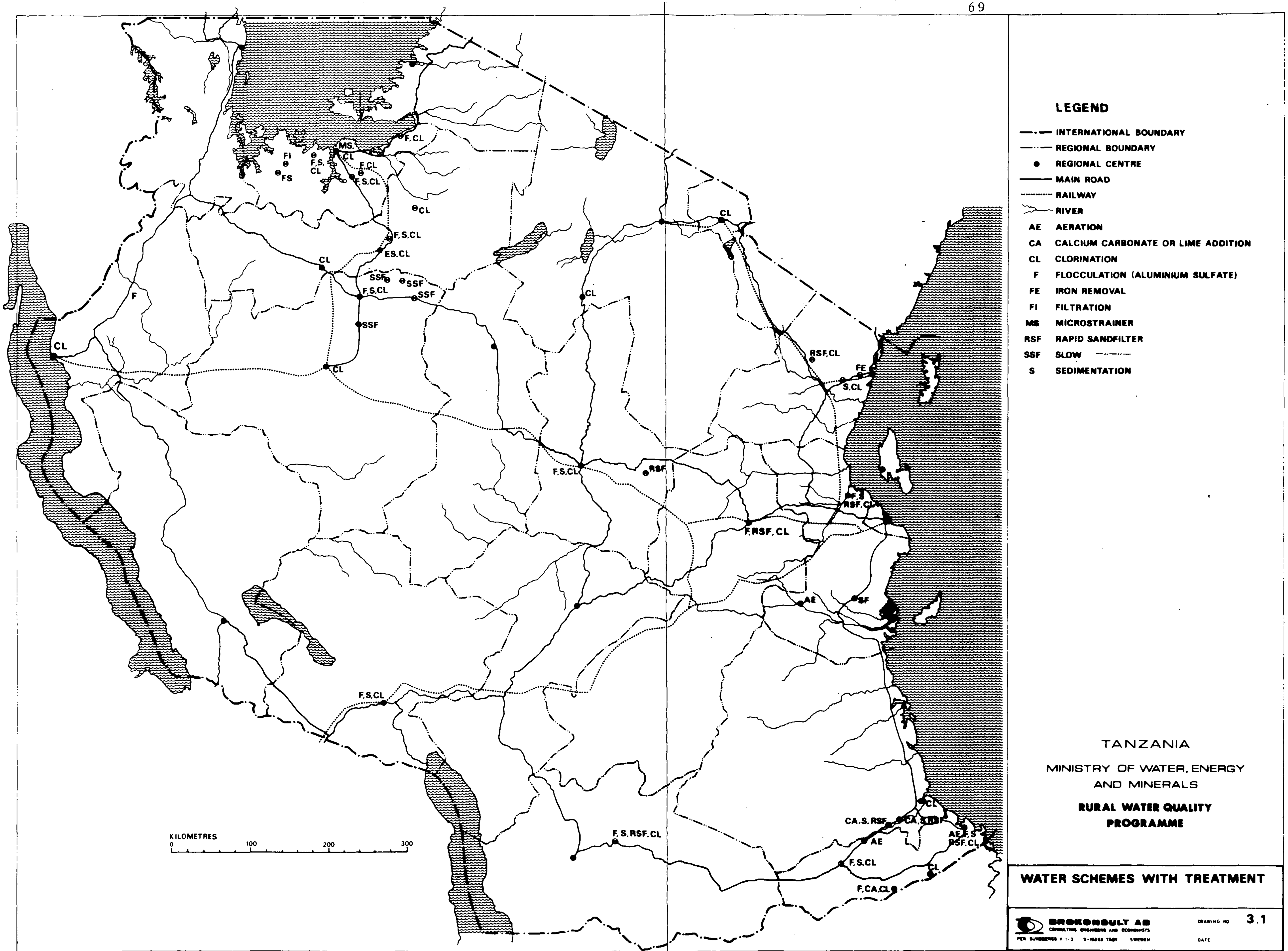
Flocculation with aluminium sulphate was found to be the treatment method for 19 schemes (43%), Annex 3.3.

For the dosage of alum usually drip feeders are utilised, lumps of alum placed in the runway are also used (for example in Shinyanga) for dosage.

The mixing is performed in runways with vertical (as in Shinyanga) or horizontal (as in Nzega) baffles. The floc is built up in other runways with a lower water velocity. Properly designed, such systems seem to work well.

The dosage of aluminium sulphate reported by operators or calculated from own tests varied between 2.5 and 72 g/m^3 (average 36 g/m^3). A high dose often lowers the pH below the Tanzanian standard. At the same time the effect of the alum diminishes. No equipment for the estimation of proper dosage was found at the schemes.

Addition of alkali, as soda ash or lime, will cure this tendency to low pH. Such additions were being made in Morogoro, Mtwara, Mkunya and Nzega. The reported use of calcium carbonate in Mtua and Myengedi is to eliminate the corrosiveness of the raw water. The extent of this treatment could not be determined during our visit.


LEGEND
INTERNATIONAL BOUNDARY
REGIONAL BOUNDARY
REGIONAL CENTRE
MAIN ROAD
RAILWAY
RIVER
AE AERATION
CA CALCIUM CARBONATE OR LIME ADDITION
CL CLORINATION
F FLOCCULATION (ALUMINIUM SULFATE)
FE IRON REMOVAL
FI FILTRATION
MS MICROSTRAINER
RSF RAPID SANDFILTER
SSF SLOW
S SEDIMENTATION
KILOMETRES
0
100
200
300
TANZANIA
MINISTRY OF WATER, ENERGY AND MINERALS
RURAL WATER QUALITY PROGRAMME
WATER SCHEMES WITH TREATMENT
BROKONSULT AB
DRAWING NO
3.1
DATE

Chlorination

Disinfection with chlorine agents was used at 28 treatment plants (see Annex 3.4), (61%) and is thus the most common type of treatment.

Chlorinated lime was usually used in 12 plants, sodium hypochlorite in 6 and chlorine gas in one. Liquid chlorine agents are normally dosed with simple drip feeders with poor means of regulation. In some cases an improved Indian type of drip feeder (Candy) was seen (as in Magu and Mkunya).

Aeration

Aeration is used to diminish the aggressiveness (removal of carbon dioxide) and/or iron (oxidation of soluble iron (II) to iron (III) compounds that flocculate and can be removed).

The reduction of aggressiveness is the object in two plants (Mtwara and Ndandani) and iron removal in two (Mwaseni and Magoti). The aeration is considered to reduce only part of the aggressiveness. Aeration as a means of iron removal is effective only when iron in the raw water is in reduced form (iron (II). This is the case for boreholes and shallow wells but usually not in dams and never in streams. The aerator at Magoti is thus unnecessary.

Other Methods

In Annex 3.5 we give the treatment plants which use other chemicals.

Comments on Operation and Maintenance

The operation of water schemes varied. As mentioned above all slow sandfilters were out of order, probably due to clogging caused by raw water which was too turbid.

Treatment plants using chemicals were sometimes not operating due to lack of these chemicals. A shortage of aluminium sulphate and chlorine agents (chlorinated lime and sodium hypochlorite) was mentioned by both treatment plant operators and RWEs. Drip feeders used were often severely corroded and thus not possible to adjust. Only the Indian type of drip feeder seemed to work properly (Candy).

Both these chemical treatments require testing in order to optimise their action. Simple comparators for testing of free chlorine and pH were usually not found, with the exception for Morogoro; when found they were without reagents and incomplete.

Record keeping was found only at Mkunya (Makonde w/s) and even in this case not to a satisfactory level.

The dosage of chlorine agents was very often low. This is verified by tests of residual chlorine in tap water.

In Mwanza testing was performed nearly daily at least during May-July 1978 by the MAJI laboratory. Residual chlorine and bacteria were determined. On eight occasions out of 46 more than one faecal coliform per 100 ml was recorded and on three above 10 per 100 ml indicating a too low chlorine concentration.

Manpower

The treatment plant operators that the Consultant's staff ~~on~~ met had no formal training. At present on-the-job training is the only ofrm of learning, resulting in a very varying knowledge. However during our visits and interviews, we remarkably often found a good understanding of the treatment processes. But occasional lack of understanding of details sometimes reduce the effectiveness of the operation.

CHAPTER 4
PRESENT WATER LABORATORIES

4.1 Introduction

In this chapter we present the results of evaluation of existing water laboratories in the Ministry of Water, Energy and Minerals. The main characteristics of laboratory are reported and occasional recommendations for minor improvements made; comments are made on laboratories at AFYA and Kilimo but not detailed assessment.

Water laboratories are defined as laboratories able to perform both bacterial and physical-chemical analysis of water. However, several laboratories are found in Tanzania that are able to test water only partially. Some of these are included in this report. For details, see Annex 4.1.

The MAJI laboratory at Ubungo forms one center for water laboratories. In Dar es Salaam, physical-chemical analysis of water also is made at Government Chemist laboratory (AFYA) although at present to a lesser extent than earlier. The Government Chemist has equipment and staff to perform many more complicated test of water quality such as gas chromatography for pesticides. Bacteriological analysis is performed at the Central Pathology Laboratory (AFYA). In addition to the indicator bacteria (total coliforms (37^{o})) and faecal coliforms (44^{o}), this laboratory is able to test for the presence of cholera vibrios in water. These two laboratories have not been evaluated by the Consultant. The capabilities of these two laboratories should be utilized for the development of methods and testing for more special constituents in water.

Outside Dar es Salaam, water laboratories were set up by Water Master Plan Consultants in Mtwara, Mwanza, Shinyanga and Tanga. Only Mwanza still has a complete functioning laboratory, Mtwara and Shinyanga are incomplete and no equipment was found in Tanga.

Three laboratories attached to MADINI were visited; the Mineral Laboratory at Dodoma and two laboratories in Bukoba. These were the Mineral Laboratory of Mineral Exploration in North West Tanzania and Soil Laboratory of Kagera River Basin Project. The last two have been evaluated.

4.2 Ubungo Laboratory

From our review of its activities the Ubungo water quality laboratory at present carries out the following tasks:

1. Analysis of water samples delivered by RWEs and others; preparation of reports and making recommendations based on the results.

2. Analysis of water samples drawn from the Dar es Salaam water supply.

3. Analysis of soil samples.

4. Perform water quality surveys for specific purposes.

5. Supervise the work at the Mwanza laboratory.

6. Perform research within the field of water quality.

7. Train laboratory technicians.

8. Train water treatment plant operators.

Building

The laboratory has been built in two steps and a third part is under construction (see drawing in Annex 4.1). The old part (I) has an area of about 215 m^2, solidly constructed and in a working but somewhat deteriorated condition. A detailed description of the building is made in Annex 4.2.

The new part (II) of the present building has a floor area of about 200 m^2 and is less well planned and constructed. It is doubtful that full use can be made of this space without some reconstruction.

The existing laboratory store (III) with an area of 50 m^2 has not been evaluated.

Block (IV) is under construction. It has an area of about 50 m^2 and is planned to accommodate stores and a water still room.

Block (V) with an area of 125 m^2 is under construction. It is planned to accommodate one store room, three water research rooms, one effluent analysis room and one working room.

Equipment .

The existing stock of equipment has not been evaluated in detail as a substantial addition to the laboratory is under delivery from UNICEF so that the equipment position will radically alter in the near future. However, some remarks on the present equipment will be made.

1. Distilled water is essential for a laboratory. The Manesty still used at Ubungo produces a reasonably good quality water for most purposes but provision for production of high quality distilled water is not available. If analysis of heavy metals in water is to be made it is necessary to have a better quality of distilled water than now available.

2. Balances seem to be available for all purposes.

3. The Bausch & Lomb spectrophotometer should be supplemented with an additional photometer.

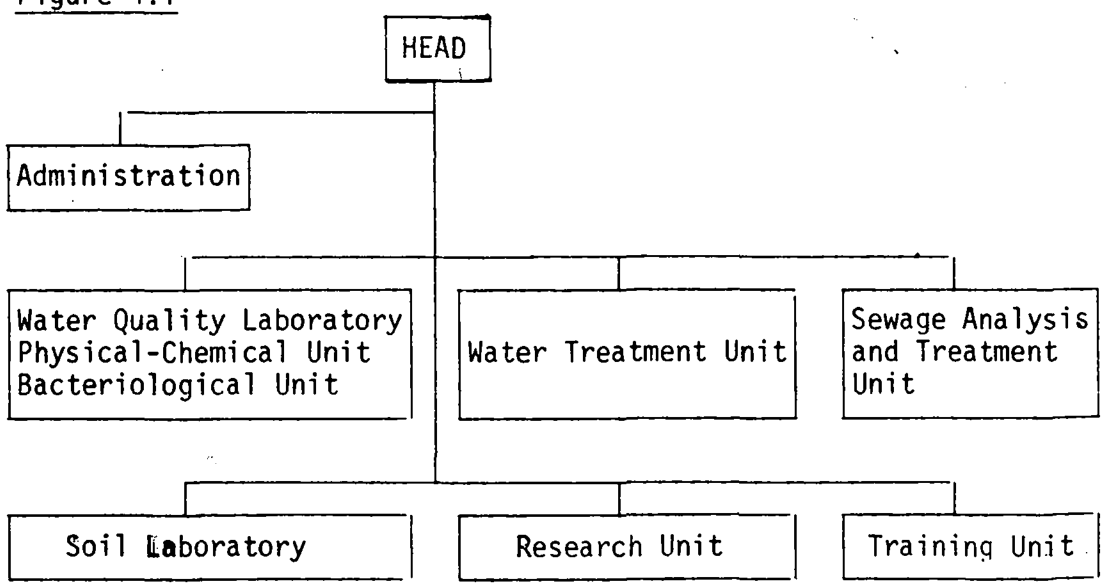
4. The autoclave is unreliable and should be replaced with a similar one as the present.

Organisation and Staff

The laboratory is organised as a subsection of Project & Planning Division. The water quality laboratory has at present a total staff of 12 persons of whom two are expatriates and two are assigned to Mwanza laboratory. The staff is organised as shown in Figure 4.1.

UBUNGO LABORATORY. ORGANISATION

Figure 4.1



This is a somewhat idealised picture as staff is not available for all units and some units are not in full action. The organisation lacks a position for a laboratory supervisor to deal with the day-to-day work at the laboratory.

The reported authorised establishment is as follows:

Subsection head	1
Research officer	3 *
Senior water technician III	10 **
Water Technician I	2
Water Technician II	1
Water technician III	2
Trainee	2 **
Typist	1
TOTAL	22 *

* Two are expatriates
** One assigned to Mwanza Water Laboratory

There are discrepancies between the organisation chart (Figure 4.1) and the composition of the present staff. Some of these will be mentioned and discussed.

Water quality analysis implies bacteriological as well as physical-chemical investigations. At present only one (expatriate) of the senior staff has formal bacteriological training and only two of the water technicians. Water and sewerage treatment is studied by the organisation but only one engineer is atteched to the staff (expatriate).

To carry out the functions indicated in the organisation chart such as research and training, additional senior staff are required as well as properly trained water technicians. The present situation, with only four university educated staff members and most laboratory technicians without formal training, does not give a solid basis for a good performance of all tasks. As a first step several of the "on the job" trained laboratory technicians could themselves participate in the course for laboratory technicians at Ubungo to improve their theoretical background.

Budget

No records of budget appropriations or expenditures for the water laboratory were available to the Consultant. The salary, wages etc. for existing staff have been estimated at TSh 231 000/- per year. This does not include the expatriate costs which in this instance are carried by the Finnish aid program. Nor does it include the nights-out allowance or other personnel overheads that are paid for by the Ministry. The cost for consumables (glassware and chemicals) has been estimated by the laboratory head at TSh 40 000/- per year. The original value of equipment is 612 000/- and the estimated annual depreciation is 118 000/- or approximately 20%.

We estimate then the total cost of the laboratory at 410 000/- per annum. This is not a complete cost estimate since it does not include electricity, water, building costs, any transportation used, nights-out and travel cost, personnel overhead costs. These we take at 40 000/- per year less 15 000 for staff assigned to Mwanza, giving a total annualised cost of 435 000/- for laboratory operations.

In 1977 about 1 630 samples were tested (physical-chemical and/or bacteriological); this was the most samples that the laboratory had handled as noted below. The cost for testing of one sample thus is approximately 270/-. An estimated comparable cost in Sweden is 260/- per sample. We note that the above Ubungo cost was achieved with maximum demand ever placed on the laboratory. Furthermore, if the equipment costs are reduced to include only essentials for the proposed tests the cost per sample would decline about 30/-.

The estimated cost will decrease upon a more intense use of the laboratory. We anticipate a substantial increase in number of sewage and effluent samples, bacteriological testing and testing for additional analyses (group III of Annex 9.8).

The present charge for a test is 65/-. We propose this price to be kept in order to stimulate to increase testing thus aiding in the struggle to improve water quality. Additional costs should be covered, as present is the case by the Ministry.

Present Working Conditions

Space

Available space now totals about 25 m^2/person or, after deduction of store rooms, about 20 m^2/person. After completion of the new building (IV and V) the values with present staff would be about 34 and 26 m^2/person respectively. The space available per person can be judged as more than adequate. Based on Swedish experience the staff could be doubled within the existing buildings.

Another way to estimate the utilisation of a laboratory building is calculation of laboratory bench length per person. The total bench length has been estimated only for building I to be 63 m giving 3.5 m/person. Even excluding building II, this is considered a high value.

Work Performed

The work load can be estimated from the number of samples handled for physical-chemical and bacteriological testing. These are given in Tables 4.1 and 4.2. From Table 4.1 average values of 500 samples respectively were estimated. Provided testing was the sole occupation of the staff, this would imply 34 and 26 samples/person - year, respectively. For comparison, we mention that the Mwanza laboratory, when operated by the Consultant managed to handle up to 70 samples/month for physical-chemical analysis with a total staff of 5 (excluding the bacteriologist) giving 14 samples/ person - month. Assuming ten working months per year, this corresponds to 140 samples/person - year.

A trained bacteriologist (laboratory technician) can, without any problem, test more than 10 samples/day, provided he is not engaged in collecting the samples. Assuming 250 working days this corresponds to 2 500 samples/year.

Even provided testing only occupied on the average half of the working time for the staff the result of this calculation would be 68 and 52 samples/person-year for physical-chemical and bacteriological testing, respectively. This indicates a substantial under-utilisation of the laboratory. This is also indicated by the fact that 1 214 samples (including Coast Region WMP) were tested physical-chemical at the laboratory in 1977 with the existing staff.

Sampling

Most samples for physical-chemical testing are delivered to the laboratory. For 1977 the breakdown of samples for physical-chemical testing is as follows:

Collector	Number of Samples
Coast Region WMP	585
AFYA	8
Kilimo	25
Other (largely RWEs)	596
Total	1 214

TABLE 4.1

NUMBER OF SAMPLES TESTED AT THE UBUNGO LABORATORY

Year	Number of Samples Tested	
	Physical-Chemical	Bacteriological
1969(9/30-12/31)	93	-
1970	417	-
1971	835	-
1972	648	-
1973	690	-
1974	510	-
1975	406	-
1976	685	416(305)2/
1977	1214(585)1/	574(409)2/
1978(1/01-6/26)		184

1/ Coast Region WMP.

2/ Dar es Salaam Water Supply.

TABLE 4.2

MONTHLY DISTRIBUTION OF SAMPLES TESTED
AT THE UBUNGO LABORATORY 1976

Month	Physical-Chemical	Bacteriological	
		Total	Dar es Salaam W/S
Jan	25	1	1
Feb	76	43	-
Mar	44	13	6
Apr	37	31	25
May	50	38	31
Jun	87	24	9
Jul	29	35	32
Aug	63	28	21
Sep	72	51	43
Oct	107	71	62
Nov	50	53	48
Dec	45	28	27
TOTAL	685	416	305

This is a non-typical year with respect to the presence of samples from Coast Region WMP but should be considered relevant in other respects. A breakdown made for regions reveals the expected geographical variation: Most samples were delivered from (in diminishing order) Coast, Mbeya, Dar es Salaam. Then followed Dodoma, Shinyanga and Morogoro, the first two of which are known for their chemical water quality problems. During the period of observation (beginning of 1978) the number of samples from nearby regions varied from 50 (Coast) to 7(Morogoro), down to zero. As many as six regions delivered no samples during the period (total samples for the period was 134).

Bacteriological Testing

For 1976 the breakdown of samples was:

Source	Number of Samples
Dar es Salaam w/s	305
Regions and other	111
Total	416

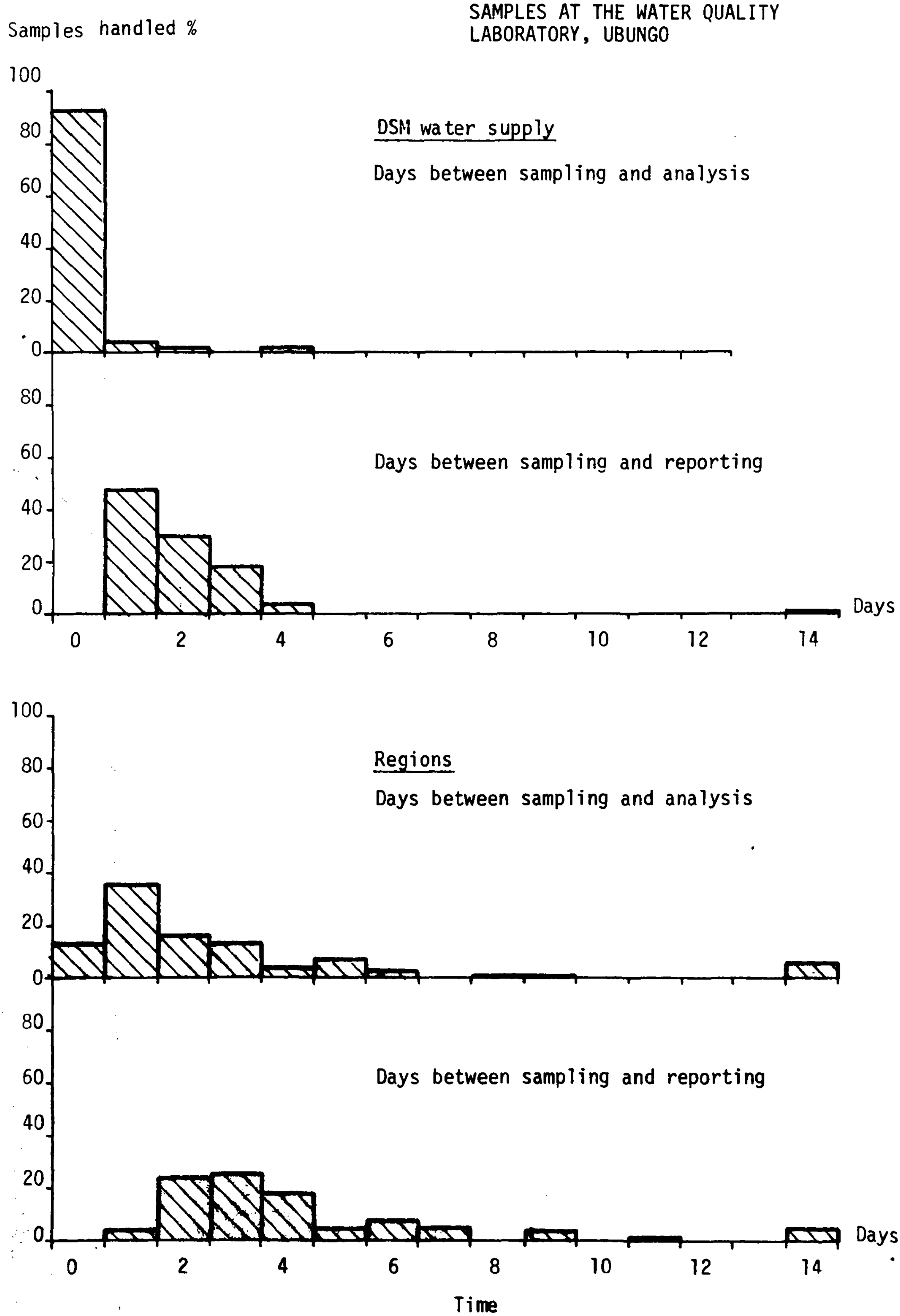
The Dar es Salaam water supply was thus roughly sampled once a day. Very few samples arrive from regions, which is due to problems associated with the sampling procedure, the need for using sterile bottles, and the requirement of fast delivery of the sample to the laboratory (maximum allowed 24 hours). The time between sampling and analysis is shown in Figure 4.2. 87% of the samples from Dar es Salaam w/s were handled the same day and 92% within 48 hours. The problem of transport, which affects sampling in the regions is clearly shown, only 49% of the samples were handled within 48 hours and 94% within two weeks.

Analytical Procedures

Analytical procedures follow a stencilled compendium prepared at the laboratory. The methods referred to are compiled from different standard handbooks on the subject. The procedures are, with few exceptions, satisfactory. Some comments are given in Annex 9.8. The bacteriological testing is performed with membrane filtering technique (Millipore) and is also used in the field.

The analytical methods used are applicable or can easily be adjusted for the analysis of effluents and receiving water.

FIGURE 4.2: TIME BETWEEN SAMPLING, ANALYSIS AND REPORTING. BACTERIOLOGICAL SAMPLES AT THE WATER QUALITY LABORATORY, UBUNGO



Records and Dissemination of Data

Incoming samples are recorded in a ledger. After analysis data are recorded on a printed form shown in Figure 4.3, which is checked and signed by a chemist.

The report form is subsequently sent to the sampling authority. In the case of RWE:s they are usually filed in separate Water Quality Files maintained by the RWE:s.

At the laboratory a copy is filed, at present on a regional basis. For bacteriological analysis a prompt answer is usually of great importance. The time between sampling, analysis and reporting is shown in Figure 4.2. For regions reports for about half the samples were sent within three days and 90% within one week from sampling. However, the value of these results is limited in any case, as the analysis is done within 24 hours of sampling only in about 20% of cases.

A direct telephone line enabling more prompt reporting is recommended.

Other Activities

The laboratory staff is engaged in other activities than analysis. Most important are field trips made for specific purposes. Such trips have been made for surveillance of a region (as Tanga) or an area such as frequent trips to cholera infected parts (as Moshi and Kigoma). These trips are made after requests from regional water engineers and are well appreciated by RWEs. They are carried out in a similar way as proposed for the mobile units (see section 9.4).

Laboratory staff is also engaged in teaching at the laboratory technician course as well as training staff for water treatment plants (Dar es Salaam; requests have come from Sigi River in Tanga).

Conclusion

The Ubungo laboratory is technically satisfactory but has underutilised capacity due to a lack of samples presented for analysis. The staff is sufficient except that a day-to-day supervisor for the laboratory is necessary to improve efficiency.

FIGURE 4.3

THE UNITED REPUBLIC OF TANZANIA

WD. & ID. H26A
(Revised 73)

MINISTRY OF WATER, ENERGY AND MINERALS

Telegrams:................................ ....LABORATORY,

Telephone:................................ ....

In reply please quote: ....

LABORATORY No.................. Date...

WATER ANALYSIS REPORT

(1) ORIGIN OF THE SAMPLE

Analysis requested by..Ref. No..Dated......................

Date received at the Laboratory...........................Date collected for analysis..............Time...........Temp.........°C

Source .... Site...Sampling position.............................

Depth.. Treatment...

(2) PHYSICAL EXAMINATION

Appearance: Colour ....mg pt/l

Turbidity ..............................J.T.U. Odour ....

Sediments .... ml/l pH ....

Taste.. Conductivity at 25°C...................micromhos/cm.

(3) CHEMICAL EXAMINATION (In milligrams per litre)

Alkanity (as $CaCO_3$)	Total Nitrogen	Sodium ....
Phenophthalein..............................	Ammonical Nitrogen	Potassium..............................
Total..	Albuminoid Nitrogen..........................	Sulphate ....
Hardness (as $CaCO_3$)	Nitrite Nitrogen	Chloride ....
Carbonate	Nitrite Nitrogen	Fluoride ....
Non Carbonate..............................	Mangenese	Total filtrable solids ....
Total..	Zinc	Total suspeded solids................
Calcium		
Magnesium	Lead	Others:
Permanganate Value (10 minutes	Iron	....
boiling using N/80 $KMnO_4$)	Copper	....
B.O.D. (5 days)		....

(4) BACTERIOLOGICAL EXAMINATION

Number of colonies per ml growing on Nutrient agar (a) In 1 day at 37°C ....

(b) In 3 days at 25°C..Coliform M.P.N. per 100 ml...

Escherichia Coli, (faecal coli.) M.P.N. per 100 ml..................................Other Tests..................................

....Class of Water...

REMARKS: ....

....

....

....

RECOMMENDATIONS: ....

....

....

....

Date................................ ....

Senior Research Officer

G P Dsm 9667/3-78/30m'2up

4.3 Other MAJI Laboratories

Laboratories have been established by Water Master Plan Consultants at Mtwara, Mwanza, Shinyanga and Tanga. After completion of the Plans the equipment was handed over to MAJI. The details are reported in Annex 4.1.

No equipment could be located in Tanga, but a room is available for a laboratory.

At present only Mwanza is in working condition, e.g. has trained personnel, equipment and consumables (glassware and reagents).

Building

The total area available gives an indication of the potential capacity of the laboratory. These are as follows:

Mtwara	27 m^2	
Mwanza	29 m^2	
Shinyanga	40 m^2	
Tanga	54 + 13 = 67	(two rooms)

The four buildings are of different quality. The Mwanza laboratory has the highest quality, while Shinyanga has the lowest. Mwanza is equipped with three washing basins (3x2 taps) and seven electrical points, while Shinyanga has one washing basin (3 taps) and six electrical points. Shinyanga lacks glass windows. It also has an evacuating hood which, however, is without fan. Mtwara has a well planned room but has only one washing basin and one tap. In Tanga a room in a newly constructed building is reserved for a laboratory, but only minor special arrangements were made for this application. All rooms except for Shinyanga are well illuminated by day light. All have acceptable artificial illumination.

Equipment

A list of major equipment found in each laboratory is given in Annex 4.1. Tanga had no equipment.

All three have balances: Mtwara and Shinyanga with a reasonable sensitivity (0.01 g) in Mwanza only 0.1 g. Distilled water is produced in an allglass still with 2-3 l/h capacity in Mwanza and with a Manesty still in Shinyanga. The physical-chemical testing in all three laboratories is based on HACH units. This system requires use of manufactured reagent pads for the photometric tests. In Mwanza two HACH DR/EL 2 units were used.

With the exception of the conductivity meter in one, these were in working condition. In Mtwara three HACH DR units were found, one of which could be made to work. In Shinyanga two HACH DC/DR and two DR/B units were found. Due to lack of proper batteries it was not possible to test them. However, it seemed to be possible to put two into working condition. In Mtwara no laboratory meter was found and in Shinyanga two small portable meters in working condition were found. All three laboratories had pH-meters. The Shinyanga meter has a scale expansion and was also used for ion selective electrode determinations of fluoride.

Bacteriological Equipment

Mtwara does not have a complete equipment for membrane filter techniques. Moreover, the incubator is stationary and thus no field tests can be performed. The laboratory has a sterilising oven but no autoclave. Mwanza has a full Millipore field equipment (two incubators) and one autoclave. No sterilising oven is available so sterilising has to be done at EAIMR. Shinyanga has field Millipore testing equipment, but no autoclave or sterilising oven.

Personnel

Mtwara had no personnel at present. For the implementation phase of Mtwara WMP one trained laboratory technician has been asked for by the Consultant concerned. In Mwanza one trained laboratory technician is in charge of the laboratory. He is assisted by two trainees. In Shinyanga one on-the-job trained technician was working at the laboratory, attached to Shinyanga shallow well program.

Conclusion

The Mwanza water laboratory is the only regional laboratory now properly functioning. However, it is under-utilised and is able to perform many more tests than it is in fact asked to. 1/ Very little bacteriology is done at Mwanza due to a shortage of transport for sampling. The Mtwara laboratory will presumably be functioning soon to support implementation in the region. The Shinyanga laboratory only supports the shallow well program with a limited series of physical-chemical tests.

1/ During 1979 the Mwanza laboratory was servicing the Tabora WMP physical-chemical testing program and was working at full capacity.

4.4 MADINI Laboratories

Three Madini laboratories have been visited, and two of them evaluated (see Annex 4.1).

The Dodoma Mineral Laboratory can perform physical-chemical water analyses. Since the establishment of the Ubungo laboratory, however, the staff prefers samples to be tested at Ubungo. No special facilities (such as atomic absorption spectrophotometer) are available.

The Mineral Laboratory of Mineral Exploration in North West Tanzania at Bukoba (see Annex 4.1) is specialised for mineral testing of eight metals (Cu, Zn, Ni, Pb, Li, Ag, Cr, Co) with an atomic absorption spectrophotometer. The project staff proposed that the AAS should be transferred to Dodoma after completion of the project. The laboratory is accommodated in a building with about 65 m^2. This has to be supplied with water in order to be useful for any other laboratory use. The laboratory was staffed with two university trained chemists.

The Soil Laboratory of Kagera River Basin Project at Bukoba was closed. The laboratory is well constructed and planned with 47 m^2 in two rooms. It was found in good order even though it had been closed for some time. It is also relatively well equipped. Balance, pH-meter and conductivity meters are available. No good apparatus for distilled water or photometer is available.

4.5 Other Laboratories

Veterinary investigation centers are found at five places in the country: Arusha, Iringa, Mpwapwa, Mbeya and Tabora. They have some facilities that could be utilised for bacteriological water testing. It is however felt that this capacity should not be used for water testing.

All regional hospitals have pathology laboratories. At some of these (as KCMC and Dodoma) some bacteriological analysis is occasionally performed. They are however using multiple tube methods usually with only one dilution which permits estimation of bacterial numbers less than 16. As higher numbers are very common several dilutions must be used. Most RMOs and staff at these laboratories consider the possibilities for expansion of their work to include bacterial water testing as remote. This judgement is usually justified by the heavy burden of their main responsibilities.

PART TWO
TOWARDS A RATIONAL WATER QUALITY POLICY

The basis for sound policy must be an examination of the goals of improving water quality and the costs of achieving the improvements. The primary goal is improved human health. Although some may try to substitute arbitrary water quality standards for this goal, we are clear that when funds are limited, such an approach can and usually does lead to an unfair distribution of resources to benefit only a limited part of the population. Specification of water quality standards without reference to the benefits and costs associated with achieving such standards, when resources are not sufficient to reach these standards, results in an arbitrary selection of those population groups which will benefit, while the costs are collected from the general revenue. It is, therefore, the objective of this part of the analysis to determine a water quality policy which is justified in terms of the benefits that it generates and which can be implemented taking account of the resources available to the Government of Tanzania. We first consider health and water directly (Chapter 5), proceed to an analysis of methods and costs of achieving the water quality improvements (Chapter 6), and then consider the costs and benefits of three possible levels of improvements (Chapter 7).

The objectives of rural policies aimed at health improvement are:

To reduce morbidity
To reduce mortality

In achieving these goals resources can be directed in a variety of ways, increased medical facilities and treatment as well as public health measures. Ideally one would like to identify the appropriate mixture of health related activities which would provide the greatest improvement in the public's health net of the resources expended, all valued in comparison with alternative uses of the resources utilised. This ideal program must be simplified into something which can be managed analytically and for which data is available.

There are seven ways to improve health in rural areas that we consider briefly:

(1) Treatment of Water

This is the central theme of our analysis. There are a variety of treatment methods that can be considered with different costs and different beneficial aspects.

(2) Selection of Source and Scheme Design

As was seen in Chapter 2 there is a wide variation in water quality drawn from different sources; hence, by using certain sources and by proper design one can obtain better water without explicit water treatment processes. Analysis of the alternatives here is extremely complex; we have designed the analysis in this study based on the assumption that provision of rural water will be done using good quality sources whenever these are available. As for design, the costs of a good design to improve water quality are low compared to other elements of the scheme and we recommend these be used whenever feasible. In Chapter 9 there is a specific discussion of scheme design elements which will generate improved quality of raw water.

(3) Source Protection

Much can be done to improve water quality by protecting the water source. This type of action is usually rather cheap but requires social discipline and leadership more than financial resources. In Chapter 9 there is a discussion of source protection.

(4) Sanitation

Improved methods of excreta disposal will most certainly have a beneficial impact on health. In this analysis we have not considered this as an alternative investment to improving water quality. In fact we suspect there are strong complementary effects between rural sanitation and water quality improvements but any analytical description of sufficient detail to permit estimation of the correct balance is far beyond what available data tells us. We note that sanitation is expensive, but that the costs can to a very large extent be met from resources available to the village; on the other hand large treatment programs certainly call for resources which must be obtained outside the village. This study recognises the importance of rural sanitation improvements but makes only a few recommendations as to what should be done.

(5) Expansion of Medical Facilities

There is room for much larger inputs of medical facilities. Tanzania has one physician per 20 000 persons, approximately the average for the 34 poorest income countries and in contrast with 2 500 persons per physician in middle income countries and 650 persons among the industrial countries. Of course this method of improving health is extremely expensive, but it is a feasible way to proceed. We have not considered this as an alternative use of funds.

(6) Malaria Eradication

Programmes to control and reduce malaria are another potential public health expenditure that can have a major beneficial impact but also are rather expensive. We have not attempted to compare this or similar public health programmes with improvements in water quality as a means to improve health.

(7) Public Education Campaigns

The education of the rural population in proper methods of water handling, source protection, and excreta disposal are of great importance in any water quality program. The cost of these activities is relatively small and the benefits are really not measurable; it is a type of activity that in our view should be carried out. The problem is to define appropriate themes and prepare proper materials. It is not so much whether public education is a good thing but whether there is in hand good material relevant to the issues.

In brief, we have put aside expansion of medical facilities and malaria eradication, both because they are outside the scope of this analysis, but also because, on the face of it, these are very expensive ways to proceed. For sanitation we simply note that much can be done with the resources available within the village and recognise the importance of excreta disposal as part of the health improvements sought for the village. For scheme design and source protection the costs are low and we make appropriate recommendations. As for selection of the water source we believe this should be guided by cost considerations but that where the decision is close then the better water quality is to be preferred. We present some cost estimates on this point in Chapter 6. Education campaigns are recommended; these are relatively cheap but benefit-cost analysis cannot usefully be performed. This leaves the central benefit-cost analysis to examine the different water treatment methods. In this analysis we have examined alternative strategies of water treatment and the benefits and costs arising from them. These are the questions discussed in detail in the following three chapters.

CHAPTER 5

WATER QUALITY AND HEALTH

5.1 Water and Disease

Water may injure health in two ways: An excess of certain minerals and chemical substances may give rise to disease and water may also be concerned in the spread of microbial and other communicable diseases from one person to another. The latter is by far the greater hazard from water in Tanzania, but water of poor chemical quality also causes significant problems. Water which injures or potentially injures health we define as of poor quality.

We set out here the general relations between water quality and disease and then examine the detailed data collected in Tanzania. This leads to estimates of the morbidity and mortality from FO diseases.

Communicable Diseases

Water affects the spread of infections in four ways: By acting as the vehicle for carrying microbes from one infected person to others (as when cholera vibrios get into a well), by providing a habitat for snails in which schistosome worms must develop before they can become infective for other people, by enabling people to keep clean and avoid spreading microbes or allowing them to grow on their skin, and providing a home and breeding ground for mosquitoes and other disease-carrying insects that develop in water or live near it. The first two of these depend directly on water quality: if there are no microbes or snails in the water used, it cannot help to spread those diseases. The relationship of schistosomiasis with water is complex and considered in Section 5.4.

The most important diseases with which we are concerned when discussing water quality are the bacterial, viral and parasitic infections of the intestine. These comprise the list of diseases designated "faecal-oral" in Table 5.1. The main components of this group are diarrhoeal diseases caused by salmonellae, shigellae, intestinal protozoa, rotaviruses, enterotoxigenic coliform bacilli and a host of other viral and bacterial pathogens. Acute infections of this type will usually be fairly short-lived, and serious disability due to stomach ache and diarrhoea may last only 3-5 days in a typical case. Also in the faecal-oral group are included the much feared massive diarrhoea, cholera and the serious systemic fevers typhoid and infectious hepatitis.

Their mode of transmission is straightforward: Faeces from an infected person contain the pathogens, often in large numbers, and these may be ingested by somebody else. Water may be involved in two ways. First, it may become contaminated

TABLE 5.1

CLASSIFICATION OF DISEASES

WHO NO.*	DISEASE
	Faecal-Oral
0	Cholera
1-3	Typhoid, paratyphoid and other salmonelloses
4	Bacillary dysentery
6	Amebiasis
7-9	Other diarrhoeal diseases
70	Infectious hepatitis
100	Leptospirosis
127.0	Ascariasis
561	Gastroenteritis
	Water-Washed
76	Trachoma
80	Louseborne typhus
88.0	Yaws
102	Tinea (any type)
133	Scabies
360-369	Inflammatory eye disease
680-709	Ulcers and diseases of the skin and subcutaneous tissues
	Water-Based
120.0	Schistosomiasis haematobium
120.0	Schistosomiasis mansoni
120.9	Schistosomiasis unspecified

* These are the numbers assigned to the diseases in the WHO International Disease Classification.

by infected faeces, either directly (as might happen in surface waters) or indirectly from the hands of the infected person which may have become contaminated during anal cleansing. This type of transmission is called "water-borne". Second, minute quantities of faecal material may be dispersed into places where they can subsequently be ingested. Thus hands, cooking utensils, water pots and so on may all carry the pathogens. This type of transmission is termed "water-washed" as it is susceptible to reduction by good hygienic practices which may involve using more water for washing.

Successful provision of clean water supplies should affect both these transmission routes, since the full effect of improved water quality will only be realised when that water becomes easily available and supersedes older, traditional sources. Thus provision of clean water should be combined with easier access to water, and, indeed, should only be considered in conjunction with ultimately improved access.

The behaviour of the rural population in gathering water is complex reflecting a number of values - proximity to source, perceived quality, and tradition. There are many examples of improved water sources not being used whenever unimproved sources are closer. This type of irregularity of quality may be quite dangerous. Further the more handling of water between source and use, the greater the chance of contamination. Finally, improved access may lead to greater water use and reduce water washed disease transmission.

Disease due to the Chemical Quality of Water

Illness may result from the sporadic pollution of water by toxic chemicals or from a naturally high level of chemical contaminants, of which the two most common are fluorides and nitrates.

Of these two fluorides are of more concern in Tanzania, as groundwater in several regions contains high levels and symptoms of skeletal fluorosis are found in Arusha (Grech Letham 1964). The crucial question of the maximum safe concentration of fluoride in drinking water is unfortunately not answerable in a simple way. Water that is completely deficient in fluoride is associated with frequent tooth decay, and at low concentrations (0.8-1.5 mg/l) fluoride is beneficial, improving the strength of the enamel covering the teeth. At slightly higher levels there may be some discolouration or mottling of the teeth, but this is merely a cosmetic inconvenience.

At persistently high levels of fluoride intake the condition known as skeletal fluorosis may occur. This initially involves excessive deposition of bony tissue so that the bones become brittle and thick, the spine develops bony projections from the vertebrae, and cartilages and ligaments become ossified (that is, bone is deposited in them so that they become rigid). Mild degrees of these changes may cause no symptoms, but moderate fluorosis will lead to stiffness of the back and other joints with resulting disability and pain. Such symptoms have been found in one village in Sweden having 10 mg/l of fluoride in the drinking water. At very high levels of fluoride intake, the spine becomes rigid and the vertebral arches that should protect the spinal cord may thicken, as is seen in the high fluoride areas of the Punjab in India. The nerve roots may then become compressed and paralysis results.

One patient from West Mount Meru was admitted to KCMC (Moshi) in April, 1978 with a total paralysis of all limbs. A study performed at Maji ya Chai in 1973 by staff from KCMC on about 300 persons showed symptoms such as reduced range of movements and aching in knees. It also revealed high frequencies of reduced walking abilities. Furthermore 16% had spine problems, 20% had knockknees and 16% bow legs. Most people moved into the area 3-4 years before the study. The fluoride concentration of the tap water was not established during that study. Since then the source has been changed. The Consultant, however, found the spring and a test revealed a concentration of 21 mg/l.

The difficulty lies in defining the level at which these changes begin to occur. In particular there are excellent data from the USA which demonstrate no ill effects in communities whose water supply has 8 mg/l fluoride, while careful studies from India show widespread fluorosis with nervous system lesions at comparable fluoride levels and Japanese observations of bone lesions at this level are recorded. Some Indian investigations report cramps in the body and stiffness in the spinal cord at 3-5 mg/l. In Proceedings of the Symposium on Fluorosis (Hyderabad 1974) separate authors report skeletal effects at concentrations from 3 mg/l and higher. This is because it is the total intake of fluoride rather than the water's content that matters so that where water consumption is high, especially with hard labouring at extremely high temperatures, toxicity will be relatively more common.

The food intake of fluoride and probably of calcium and other minerals, as well as the general level of nutrition play some part. Consequently, to set a completely safe limit of say 2 mg/l is easy, but to be certain that any higher level will not be dangerous is not possible. There is, however, reason to believe 8 mg/l to be too high for human consumption. However, a recommendation on a drinking water quality standard should be based on studies within Tanzania.

There are no such adequate studies on communities that have been using high fluoride waters for prolonged periods. A straightforward research study should provide guidance. Community samples of, say, one hundred adults from high-fluoride supplied villages should be examined by radiography of the spine and long bones. In the absence of osteosclerosis more serious lesions are unlikely. If sclerosis is present, detailed orthopaedic and neurological studies are indicated, and some form of regular long-term surveillance of high-fluoride areas should be instituted.

As is the case with fluoride, high concentrations of nitrate are also found in groundwater (sometimes associated with high salinity which may make the water unacceptable for drinking), and may increase in waters with long-distant excretal contamination (cattle). The most serious danger to humans is to babies (below 6 months of age), who may suffer methaemaglobinaemia when bottle fed with feeds reconstituted with nitrate-rich water. The precise levels at which hazards are appreciable is again unclear. Several factors affect the toxicity of nitrate such as pH in the baby's stomach and intake of vitamin C. Presence of certain bacteria in the water (if not properly boiled) seems to amplify the effect of nitrate. The literature disagrees on toxic levels of nitrate but high frequencies of methaemoglobinaemia are found at concentrations above 23 mg/l of nitrate-nitrogen (NO_3 100 mg/l). The problem of nitrate is not too serious in rural Tanzania since most babies are breast fed and the frequency of sources with high nitrate concentrations is low.

The medical effect of moderate concentrations of iron and manganese is low. Concentrations chosen as Tanzanian standard (1.0 and 0.5 mg/l respectively) are based on other criteria. No harmful medical effect would arise from a doubling of these values.

Chemical contamination of drinking water by industrial effluents and agricultural pesticides is at present a local problem as compared with bacterial contamination, but must be surveyed and regulated within a near future. The Recommendations (Chapter 9) propose legislation and administrative and surveillance organisations that may serve this purpose.

Diseases Otherwise Related to Water

Some other diseases not potentially related to water quality have also been included in the analysis, to cast some light on the quality issue itself.

The first group of these is those diseases designated "water-washed" in Table 5.1. They include diseases of the skin and eye and are broadly controlled by two factors. The first is personal hygiene, with the skin diseases particularly, being decreased by regular washing. They may thus give some insight into hygiene on its own, instead of in conjunction with water quality, as in the case of faecal-oral diseases. The second factor is climatic, with some skin diseases being favoured by warm, humid conditions, while eye diseases may be promoted by dry, dusty environments.

Another group of diseases considered is the intestinal parasites (excluding Schistosoma, dealt with in Section 5.4). These are spread by infected faeces, but almost never in water as the microscopic parasite eggs tend to sink. Hookworm and Strongyloides infect through the skin, the larvae hatching out and waiting in the ground until they can penetrate the skin of bare feet. Ascaris, Trichuris and several protozoa are spread by ingestion of infected faecal material. The tapeworms (Taenia) are spread through cattle and pigs eating infected human faeces, and then themselves being eaten. The common factor running through all these infections is the way in which they are favoured by increased dispersion of faeces around the environment. As they are essentially unrelated to water quality, they can give some insight into the other ways in which faeces are spread from person to person, and around the environment.

Identification of Risks

Having shown how water pollution may lead to disease, we now address the issue of identifying the location and magnitude of disease risks from such pollution.

The important case of microbial pollution is hard to quantify. Much of this has already been discussed in Chapter 2, on existing water quality conditions, but some points are worth underlining here. The day-to-day variation of the microbiological quality of a water source, coupled with the inherent variability of the methods of measurement immediately creates some uncertainty about the measured level of pollution. The second difficulty occurs when considering the source of any pollution when it is found.

The usual indicators of microbial pollution are to be found in the faeces of nearly all warm-blooded animals, although microbial pathogens are more or less specific to a single species. Thus, heavy pollution from a non-human source may be less dangerous than moderate pollution from human excreta. Pollution by humans themselves may also vary in importance. For instance, pollution within the home merely exposes the immediate family to the disease risk, and they may be exposed through vehicles other than water in any case. On the other hand, limited pollution of a centralised water supply serving many people immediately exposes all of them to a risk to which they might not otherwise have been exposed. Thus, in addition to looking at the water quality per se, it is necessary to see from where the pollution is emanating and to examine other routes of transmission of faecal material.

5.2 The Amount of Disease Related to Water Quality

The Data

To assess the importance of water quality problems in Tanzania requires data on the prevalence and incidence of faecal-oral and other water-related diseases. We have collected available information on the present health status of the population from many sources. All such data are to some extent defective, as they were recorded for other purposes, and in particular there is an inverse relationship between diagnostic accuracy and the extent to which the information is representative of the population. The best diagnoses come from larger hospitals whose catchment is ill-defined and selection necessarily non-random, while the smallest health units come nearest to handling problems from a defined population, but lack diagnostic sophistication. Such problems as these are best looked at critically from the outset so that we are aware of the uncertainties of any conclusions drawn from the data.

The backbone of the data collected is the regional summary of hospital returns for each year considered. The hospitals include both voluntary agency and government units. The government hospitals, overstretched and understaffed, give priority to other matters than recording accurate diagnoses and are even less regular in reporting them. This will produce data of lower quality rather than systematic bias. The voluntary agency hospitals, though generally better at keeping and reporting their records, are available only to those patients able to pay (albeit a small sum) for their treatment, and are thus systematically biased towards higher income groups. In addition, all hospitals tend to attract a higher proportion of those ill from nearby than from further away, so there is another bias towards the towns, where the hospitals are mostly situated.

The hospital data were used to gain an idea of disease patterns, but were not suitable for estimating the actual incidence or prevalence of various diseases. This was more closely approximated by using dispensary records, collected from eight different districts across the country. Results from a group of dispensaries in a district were pooled to try and reduce the effect of erratic recording on the figures obtained. These data do, however, have the advantage that the dispensary service is already well developed and easily accessible to most people in the country, and thus, less subject to structural biases.

The utility of all this information was greatly increased by holding discussions with medical and preventive health officers at all levels, and also with doctors at some voluntary agency missions. Indeed, it was repeatedly pointed out that diagnosis and recording were rather poor, especially at dispensaries. Taking into account the varying interests and capabilities of these personnel, it would not be possible to draw comparisons between different parts of the country from their experiences alone. These interviews were valuable by virtue of the many interesting and useful contributions made to our approach to the problem, and the selection of the most reliable records available.

Disease Patterns

The health data available in this study were necessarily very broad-based, and not local studies that permit the sort of analysis which is possible for individual villages when every detail of disease incidence and water quality has been collected by a large team of specialists at considerable expense. However, analysis of the data yields some revealing results on the different patterns of disease across the country, which can in turn be related to broad climatic, environmental and hydrological differences.

Due to the varying availability of hospital services around the country, it is not possible to obtain comparable estimates of disease incidence or prevalence from the hospital data, even if the catchment population were known (which it is not).

Therefore, the first step in the analysis is to convert all the data to the proportions of the various diseases making up the total outpatient or inpatient attendance. The outpatient figures were used as they cover a larger sample and a broader disease spectrum than the inpatient records, while the latter are also subject to heavy limitation from the number of beds available, giving prominence to clinically serious diseases.

This treatment reduces all the figures to a form which permits comparison among different regions. Several groups of diseases were analysed in this way and the results are presented in Table 5.2. These groups will be discussed in turn to outline their significance. The full data are presented in Annex 5.1.

(i) Faecal-oral, excluding Ascariasis. This group contains all the potential waterborne diseases of any importance, and consists of all forms of diarrhoeal disease plus typhoid and infectious hepatitis. This is the only group which can be affected by water quality, but, as outlined in the previous section, other factors such as hygiene and nutritional status may be equally important.

(ii) Ascariasis. This disease, although belonging to the faecal-oral group, is rarely transmitted through water. It is thus an indicator of the extent to which faeces may cause direct contamination of ingested material. However, it is also dependent on climatic and soil factors, survival of the parasite ova being highest under cool, moist conditions and lowest in hot, dry areas, where faeces are generally exposed to direct sunlight.

(iii) Skin and louseborne disease. This group includes bacterial, fungal and parasitic skin infections and the (much less common) fevers transmitted by lice. They are thus at least partially a function of personal hygiene. There are, however, other factors affecting the individual diseases differently. The bacterial diseases are favoured by hot, humid conditions and often start where an insect bite has caused scratching. The fungal diseases are also favoured by high humidity and such factors as wearing shoes or tending cattle. The parasitic infection of scabies is perhaps most sensitive to hygiene alone. It is therefore considered separately as well as within this larger group of diseases.

TABLE 5.2
REGIONAL AND ZONAL DISEASE PATTERNS

Region	Zone	Regional Values								Zonal Values							
		i	ii	iii	iv	v	vi	R	D	i	ii	iii	iv	v	vi	R	D
Iringa	A1	15.7	1.4	7.9	2.6	2.9	0.4	844	19	12.2	1.5	4.1	1:7	3.5	0.4	1265	34
Mbeya		11.5	1.6	3.3	1.5	3.6	0.4	1669	49	(52)	(6.7)	(17.5)	(7.3)	(15.0)	(1.7)		
Tanga	A2	12.4	1.2	8.2	0.5	0.8	1.3	1109	58	11.5	1.8	7.3	0.7	1.4	1.0	1115	73
Kilimanjaro		9.2	4.0	5.2	1.1	1.9	0.3	1387	111	(48.5)	(7.6)	(30.8)	(3.0)	(5.9)	(4.2)		
Arusha		11.0	1.0	5.8	0.9	4.4	0.1	834	50								
Kigoma	B	11.3	2.3	7.1	1.1	2.5	0.1	1207	18	9.0	1.6	5.5	1.4	3.3	0.3	1349	28
Ziwa Magharibi		4.8	4.9	7.0	3.3	3.3	0.3	1700	44	(42.7)	(7.6)	(26.1)	(6.6)	(15.6)	(1.4)		
Rukwa		9.1	0.2	4.2	1.0	3.7	0.4	824	12								
Ruvuma	C	8.9	0.2	7.5	1.0	2.4	1.6	1138	14	7.8	1.2	6.2	1.6	2.2	2.5	1176	15
Morogoro		7.1	1.9	5.4	2.0	2.1	3.0	1200	16	(36.2)	(5.6)	(28.8)	(7.4)	(10.2)	(11.6)		
Pwani	D	12.0	0.2	17.4	6.2	6.1	2.1	959	32	5.9	1.3	13.2	1.4	4.9	3.9	950	42
Mtwara		5.2	2.5	11.6	1.7	4.0	4.1	968	63	(19.3)	(4.3)	(43.2)	(4.6)	(16.0)	(12.7)		
Lindi		5.8	0.9	13.6	1.0	5.2	3.9	911	20								
Mwanza	E1	9.4	0.6	5.0	1.1	2.9	2.9	987	69	9.2	0.6	4.8	1.1	2.8	3.1	921	58
Mara		6.6	0.4	2.4	1.3	2.4	5.6	815	41	(42.6)	(2.8)	(22.2)	(5.1)	(13.0)	(14.4)		
Tabora	E2	10.9	0.4	2.8	0.9	3.8	1.6	957	20	9.7	0.7	4.6	0.8	2.8	2.1	855	25
Shinyanga		8.9	1.0	5.2	0.7	1.3	2.4	865	31	(46.9)	(3.4)	(22.2)	(3.9)	(13.5)	(10.1)		
Singida		8.7	0.6	7.6	0.8	5.2	2.2	714	19								
Dodoma	F	15.1	0.5	1.5	1.0	3.6	0.3	624	22	15.1	0.5	1.5	1.0	3.6	0.3	624	22
										(68.6)	(2.3)	(6.8)	(4.6)	(16.4)	(1.4)		
Tanzania Mainland		10.6	1.5	6.4	1.0	2.2	1.3										

Figures are % of all outpatient attendances at all hospitals

i Faecal-oral Diseases Excluding Ascariasis
ii Ascariasis
iii Skin and Louseborne Diseases
iv Scabies
v Eye Diseases
vi Schistosomiasis
R Population-weighted Average Rainfall (mm)
D Population-weighted Average Population Density (people/km^2)

(iv) Scabies. Although this disease is certainly reduced by hygienic practices and the availability of soap, it may also be epidemic in its occurrence. This leads to the possibility of missing it using the short run of data (3 years) on which this analysis is based. It is also encouraged by close personal contact, which may be more common in the cooler areas.

(v) Eye diseases. Although these are, in principle, favoured by lack of water for washing the face and eyes, it is much more likely that the prime factor in promoting these diseases is the irritant and abrasive action of dust, worst at harvest time, or at the end of the dry season.

(vi) Schistosomiasis. This is a disease dependent on contact with slow-moving or stationary water-bodies. It particularly affects children of school and pre-school age who like bathing in such rivers and pools.

Once the data on these six groups of diseases had been assembled, it became clear that certain patterns could be identified in different parts of the country. By considering the different, eco-climatic zones of the country in conjunction with the disease patterns for each region, eight zones were defined and are shown in Map 5.1. It can be seen that some of the disease groups vary in their importance within each zone. However, the greater clarity of interpretation from this approach outweighs the importance of these variations. Indeed, by taking a larger subsample (by lumping data from several regions together) the effects of random variations, both in reporting and actual disease incidence, are reduced.

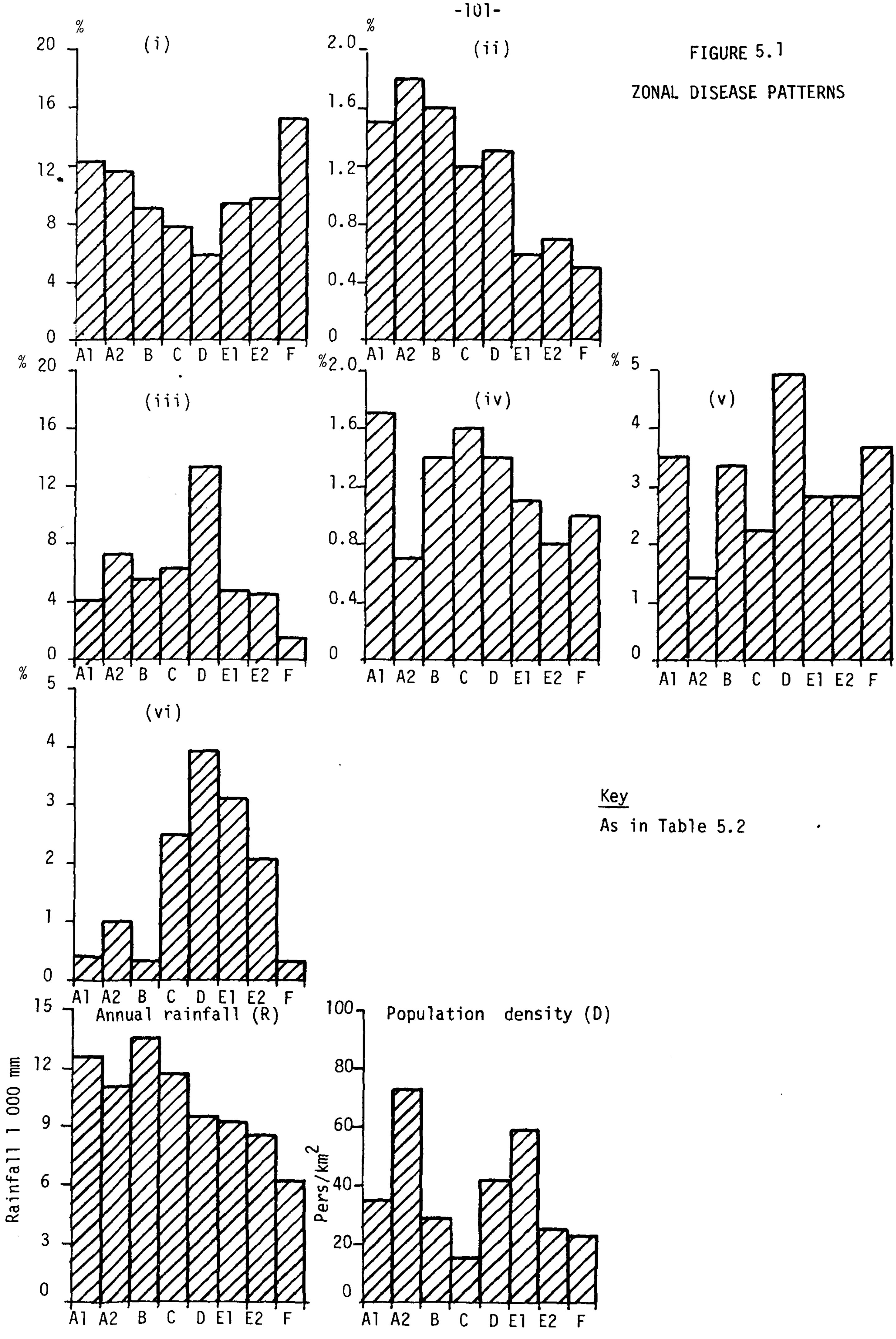
The proportions of all outpatient reportings in each zone, as well as the individual regions are presented in Table 5.2 and Figure 5.1.

To give some indication of other possibly relevant factors, rainfall and population density indices have also been calculated. As we are interested in their effects on the population, they are made on a population weighted basis from district level data. The relevant formula is:

$$X_{av} = \frac{\Sigma_i P_i X_i}{\Sigma_i P_i}$$

FIGURE 5.1

ZONAL DISEASE PATTERNS



Key
As in Table 5.2

where X_i = rainfall or population density in ith district.

P_i = total population in the ith district.

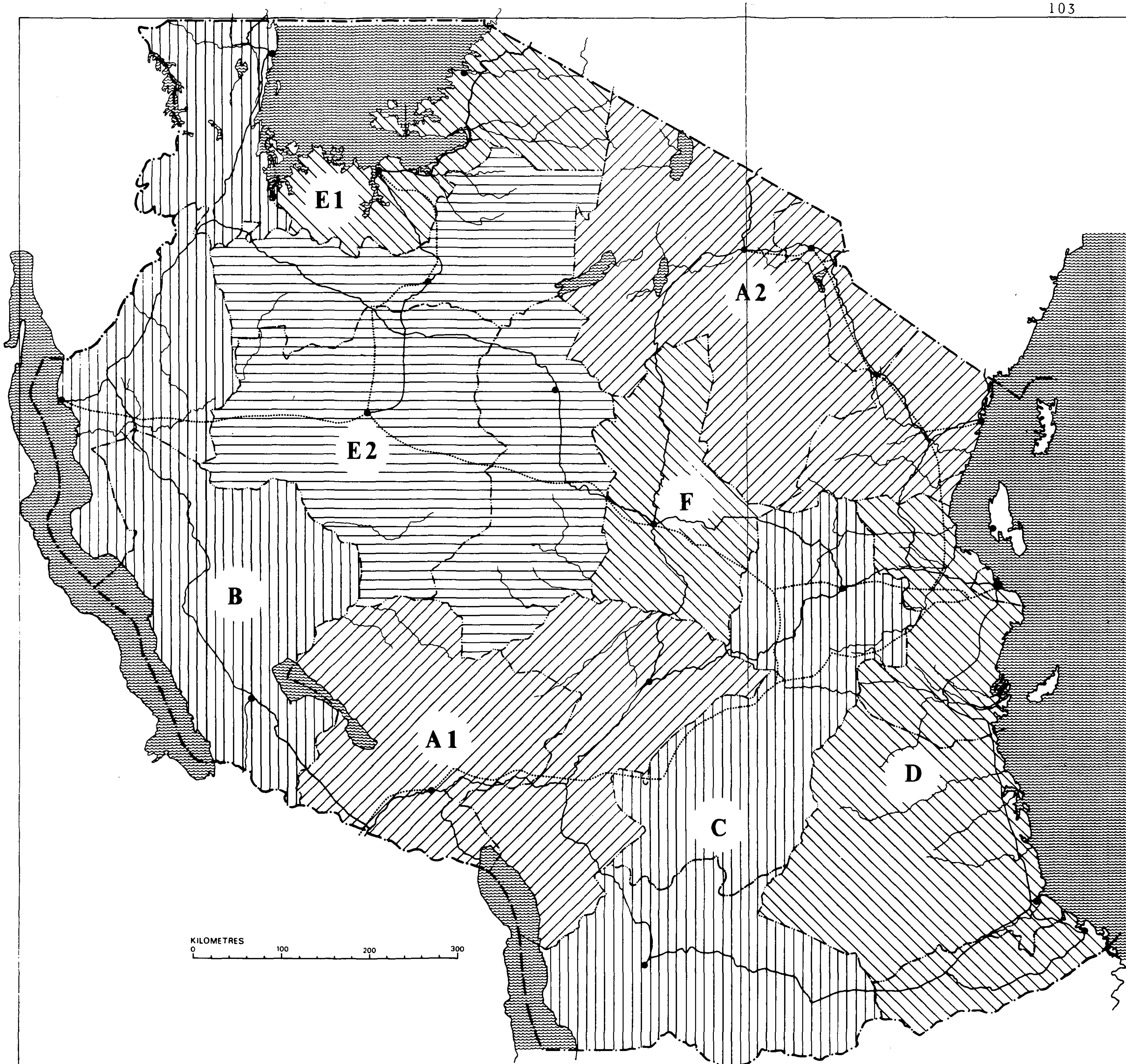
X_{av} = population weighed average rainfall or population density for region or zone.

Interpretation of the Patterns

The eight zones have been arranged in an order corresponding roughly to decreasing water availability (see Map 5.1). Zones A1 and A2 are the highland areas with abundant surface water. Zone B is the mixed upland and plateau country of the western regions where surface water and springs are commonly used. Zone C is the edge of the southern highlands and has a slightly lower rainfall. Zone D is the coastal plain area, hot and humid and relying on larger rivers or shallow groundwater for most water consumption. Zones E1, E2, and F are the parts of the central plain, arranged in order of decreasing rainfall and water availability. Broadly speaking the sequence A-F follows the decreasing overall availability of water, and the progressively more important proportion coming from groundwater as opposed to surface water.

Faecal-Oral Diseases

These comprise group (i) and (ii), the bacterial and viral enteric diseases (potentially waterborne), and ascariasis, respectively, Group (i) shows two distinct trends. Progressing from the highland regions Zone A1 through the hills to the coastal lowlands there is a fall in the proportion of these diseases, and then, reaching the progressively drier parts of the central plateau, a rise to a maximum in Dodoma region (Zone F). This may reflect a decrease in waterborne enteric disease as the water sources change from the swift streams of the highlands, where pollution may be washed from one village to another, to the wells of the coastal area. Other factors at work are the higher proportion of skin diseases and malaria as we pass into the lowlands, thus reducing the apparent importance of the group (i) diseases. The increase of these diseases towards the hot, dry areas represents an increase in direct transmission partly due to poor hygiene which reflects the chronic lack of water in these areas.



TANZANIA

MINISTRY OF WATER, ENERGY AND MINERALS

RURAL WATER QUALITY PROGRAMME

ZONES OF DIFFERING MORBIDITY PATTERN

BROKONSULT AB
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Ascariasis. This disease (ii) shows a general trend to lower levels in the hot, dry areas. This probably reflects the climatic effect on the viability of the ova more than hygienic differences.

Water-washed Diseases

These are groups (iii) to (v), the skin and louseborne diseases, scabies, and eye disease, respectively. Group (iii) shows no well-defined pattern apart from a peak in the coastal regions (Zone D) and a low in Dodoma region (Zone F). This may be accounted for by the hot, humid conditions near the coast, and the dry climate of Dodoma. Scabies (Group iv) appears to be concentrated in the southern and western parts of the country (Zones A1, B, C and D). This may reflect its epidemic qualities more than any environmental influences, which are diverse in these areas. The eye diseases (Group v) show no clearly defined pattern at all.

Schistosomiasis

This group (vi) includes both intestinal and urinary schistosomiasis and although there are subtle differences in transmission and the habitats of the host snails, these do not affect the general picture. An increasing relative frequency is noted as we pass from Zone A1 to Zone E1 and then a decrease up to Zone F. This reflects the availability of transmission sites. In the highlands and hills the main surface water is streams flowing too fast for the snails to live in. Towards the lowlands, there are more slow-flowing streams and pools, and rice paddies, all of which are good transmission sites. Progressing into the drier regions, most of the surface water is in seasonal pools, and although these are good transmission sites, they are less numerous in the drier areas, and more commonly used purely for domestic water supply.

In summary, then, it appears that the problem of water quality per se is more acute in the highland areas dependent on streams and rivers for drinking water. In the drier parts of the country, the main problem is low water availability. The provision of piped water should affect this in two ways. First, the increased availability of water should allow improvements in personal hygiene. Second, people will no longer have to congregate in large numbers to draw water from the few available water sources. The pollution inevitably arising from this intensive contact of people with the water source will thus be completely avoided, even when these traditional sources are used in preference to ground water.[x] The intermediate circumstances of the lowland areas, with adequate amounts of water and less reliance on surface water cause both transmission mechanisms of faecal-oral disease to be less important.

Other Aspects of Disease

Seasonality

Seasonal changes in climate, nutrition, work-load, vector densities and many other factors are found to have a profound effect upon disease transmission. Therefore an analysis of seasonal trends can give some insight into the transmission of disease.

However, seasonal effects are often hard to identify, and thus require a depth of personal experience by doctors, or very accurate medical records, to be revealed. In the latter case, there is an inevitable source of error, as the best records are either at the consultant hospitals, with a very wide catchment area, or at the mission hospitals, where seasonal variations in income (particularly from agriculture) may affect the ability to pay for services, and hence affect hospital attendance. These problems were partly overcome, however. At the consultant hospital in Moshi (KCMC) the pediatric department has a relatively local catchment, whilst examination of the records of mission hospitals showed no seasonal pattern in total attendances.

The doctors interviewed nearly all reported peaks of measles and pneumonia in the cold parts of the year, and in drier areas, a peak in malaria towards the end of the rains. On diarrhoeal diseases, however, opinions seemed divided. Many doctors reported an increase of cases at the start of the rains, falling away again as the season progressed. There were others who reported a fairly steady incidence over the year, especially in the drier parts of the country. Doctors in two highland areas had experienced a correlation of diarrhoea with cold weather, and considered that it was due

---

x for piped water supplies

to a specific type of virus. The picture is thus variable as might be expected from its multiple causation but at least is consistent with the view that in the hilly areas of waterborne transmission of diarrhoeal disease is of relatively greater importance than elsewhere. This would lead to a rise at the start of the rains, as they report if the increased run-off is indeed causing extra pollution. In the drier, plateau areas this would then not be expected and was indeed less often reported.

Turning to the medical records (tabulated in Annex 5.2) the picture also remains variable and without marked seasonality. Comparison of the six wettest months of the year with the six driest indicated virtually no difference in the proportion of diarrhoea amongst all reportings. The percentages of wet season diarrhoeal diseases to total diarrhoeal diseases were 50%, 56%, 55% and 41% in the four hospitals for which data was available. There was some evidence of seasonal peaking during the long rains in pediatric cases at KCMC, but even there the "wet season" frequency was only about 1.2 times that in the "dry season". The only other comparably reliable set of data we managed to collect, from Haydom Lutheran Hospital in Singida Region, showed absolutely no seasonal pattern in diarrhoea. Using these two data sets which we consider the best gives some support to the hypothesis of waterborne diarrhoea in the hills.

Cholera

In view of the position of this disease as one of the most fearful of all potentially waterborne diseases, and the recent outbreak in Tanzania, a brief discussion is appropriate.

The disease first appeared in Mbeya Region in 1974, probably coming from Malawi, but this outbreak was controlled and died away within two months. In 1975 it spread from the north down to the Kenya border, and though it has been endemic in the Kenya highlands since then, there have apparently been no incursions into Tanzania from this source. The present Tanzanian outbreak started in October 1977 and was traced to the contact of an Arab trader in the Rufiji delta. From there it spread, mainly through a succession of funeral celebrations until it reached the village of Muhoro towards the end of the month. At this point the epidemic increased when an unprotected water hole near the river, just below the bushes where people would defecate became contaminated by infected faeces. From here it spread in several ways. Coastal fishermen brought the disease to Dar-es-Salaam in November and Zanzibar in January. It spread to Lindi and Mtwara, again possibly by fishermen or step by step overland (diffusion). Also in November, the first case was recorded in Moshi. This was an example of "translocation" where somebody had obviously brought the disease back with them from the Rufiji focus. The cholera thus escaped from the affected areas, and in the subsequent months appeared in Morogoro, Dodoma and Kongwa. It also spread from Moshi into Arusha and down the Pangani River to Tanga. This was probably set off by the overflowing of the Moshi sewerage works in November 1977, when the inflow became blocked by some leather from the tannery.

Some lessons can be learnt from this and from the control strategies adopted. Perhaps the first lesson is that cholera is by no means only waterborne, and is easily spread by contact. Control should include protection of drinking water, but should not rely on it exclusively. The different control measures applied also help to define the problem. In the south, a fair degree of success was achieved with a combined strategy of quarantine, contact-tracing and treatment, and water source protection. This focussed approach compares favourably with the panic measures such as attempts to chlorinate rivers and sewerage effluent in Kilimanjaro Region, which had, predictably, no effect. The health centre at Kongwa, and the mental hospital in Dodoma both experienced outbreaks and it is clear that contact was again important in these cases.

In general, then, although it may spread over a distance in water, cholera contamination of water sources is important not in creating new foci of the disease, but rather, causing epidemics once it has reached an area. Thus, the main measure, in terms of water quality, to prevent cholera is the simple protection of water sources; even a simple parapet around the well at Muhoro might have prevented the epidemic from starting.

Intestinal Parasites and Excreta Disposal

Records of stool examination results were collected from the regional hospital pathology laboratories. This inevitably gave a sample biased towards urban inhabitants, but allows a study of comparative frequency of the various species in the different regions.

The full results are presented in Annex 5.3, but there is clear evidence to suggest that in every region, excreta disposal, or rather, the lack of sanitary methods for it, represents a major problem. In the mountain and highland areas where the soils are heavy and moist, ascariasis flourishes, and in the hotter parts where this disease is less prevalent, hookworm (predominantly due to Necator americanus) takes over as the major soil-borne parasite. In a cross-sectional study, undertaken by the East African Institute for Medical Research, at Ilemela village outside Mwanza, the prevalence rate of hookworm was 67%, and this is probably typical of many places in the central plains. Doctors at Kilimanjaro said that, almost everybody there was infected by Ascaris lumbricoides by the age of 3 years.

These depressing findings underline the importance, already well acknowledged by the health services, of the effort which must be made to improve sanitation, especially in rural areas. Studies on diarrhoeal disease in other parts of the world show that sanitation can have a considerable effect in reducing it, and, judging from the parasite rates, it is clear that bad excreta disposal practices must be responsible for much diarrhoeal disease transmission. This is especially important now, as people are being drawn together into the new, nucleated villages. Under these circumstances, without proper latrines, defecation in the bush around the village means that not only is the concentration of faeces much higher than around a typical traditional homestead, but also that contact with faeces from other people and other families is much more likely, presenting an increased epidemiological risk.

The doctor at Bukumbi Hospital in Mwanza district reported a very large increase in diarrhoeal disease and dysentery after the creation of the new village. Residents of the village found that occasionally whole families were affected at the same time, a previously rare occurrence.

It is thus clear that any attempt to address the problems of water quality and availability must also take account of excreta disposal, or else it may well be found that no benefits accrue from the program.

5.3 The National Perspective

Two questions need to be addressed when appraising the importance, to the nation as a whole, of improved water supplies. The first is to estimate the actual numbers of people affected by the diseases which better water supplies could potentially reduce. The second is to look at national trends over the years, to see if any changes are already occurring, and to try and define their causes.

Incidence of Diarrhoeal Disease

The main data base for the health studies was the hospital returns for all the regions. This allows direct comparison of disease patterns among regions. However, this data does not provide estimates of the actual level of disease in the population. It was felt that dispensary records would give a much better estimate of this, as these rural health care centers are within close enough reach of the rural population to allow those who feel they need medical attention to seek it. Records from dispensaries in a few areas were thus consulted and the recorded disease pattern compared to the hospital outpatient records for the region. It was found that in the case of diarrhoeal disease there was a surprisingly constant ratio between the proportion of dispensary attendances due to diarrhoea and the regional outpatient proportion. In addition, research conducted by BRALUP in the Pwani Region showed that, on average, each person makes 2.0 visits per year to the dispensary to report a new episode of disease, and also makes a further three reattendances. An estimate of the attack rate can be made from these data as follows:

First, we assume that the Pwani Region figure of 2.0 first attendances per person per year at dispensaries can be applied throughout the country. This means that the incidence of faecal-oral disease amongst the population is 2.0 times the proportion of first attendances for faecal-oral disease at the dispensary.

Next we determine actual incidence (first attendances for diarrhoeal diseases) for selected dispensaries by review of their records. The results are set out in Column 1 of Table 5.3. These are averaged (Column 2) and adjusted to the population base (Column 3) using the above adjustment from the BRALUP investigations. The regional percentage of diarrhoeal diseases reported from hospital outpatients is given in Table 5.3 (Column 4) and from these we compute the ratio of the real population incidence of DD as recorded at the sample of dispensaries with the hospital incidence. The resulting ratios are averaged and the result is an estimate of actual DD as 3.27 times the proportion of cases reported among hospital outpatients. In brief we use a sample of the

TABLE 5.3

DISPENSARY RECORDS OF DIARRHOEAL DISEASES FOR 1977

District	Dispensary	(1)	(2)	(3)	(4)	(5)	Remarks
Shinyanga	Samuye Busandu Negezi Bubiki	30.5 13.2 14.1 28.9	20.4	40.8	10.0	4.08	
Tabora	Ilolangulu } Ndono } Isevya	15.6 23.1	19.4	38.8	11.3	3.43 }	Country Town
Mpwapwa	Mima Iwondo Berege	22.9 21.9 28.6	24.5	49.0	15.6	3.14)))	1974
Singida	Isuna Kinyeto Mtipa Merya	15.8 25.1 26. 9.5	19.3	38.6	9.3	4.15	
Sumbawanga	Mollo Kasense Mpui	17.5 8.3 12.2	12.7	25.4	9.4	2.70	Prisons Dispensary
Lindi	Ngapa Mingoyo Sudi Mtama Milola	6.8 4.4 5.8 13.5 18.3	9.8	19.6	6.6	2.9)))))	1976 & 1977 together
Kisarawe	21 of 28 units		14.8	29.6	12.1	2.45	

Average 3.27
Standard Deviation 0.65

(1) % of first attendances due to diarrhoeal disease
(2) Average of this for group of dispensaries
(3) Estimate of real incidence (attacks/100 people·year)
(4) % of outpatients in all hospitals in the region due to diarrhoeal disease
(5) Ratio of (3)/(4)

TABLE 5.4

NATIONAL HOSPITAL RECORDS

Year	Out-patients					In-patients					Deaths					Rain Index
	F-0 %	WW %	WB %	Scabies %	Total	F_0%	WW %	WB %	Scabies %	Total	F-0 %	WW %	WB %	Scabies %	Total	
64	5.1	17.4	1.4	2.3	3 618 018	6.8	4.6	1.6	0.4	303 758	9.5	0.5	0.1	NR	7 752	1 241
65	6.4	13.3	1.4	3.2	3 934 417	6.4	4.0	4.1	0.4	371 770	8.8	0.4	2.0	NR	5 874	1 210
70	12.6	11.1	1.9	2.8	6 252 190	9.0	1.3	1.3	NR	502 840	5.5	NR	NR	NR	7 456	1 254
71	23.2	9.2	1.6	2.3	7 914 417	9.0	1.3	1.2	NR	518 408	6.1	NR	NR	NR	7 450	1 162
72	20.8	9.3	1.6	1.1	7 969 610	10.0	1.7	1.2	NR	484 593	9.6	NR	NR	NR	7 955	1 338
73	15.7	9.3	1.8	1.7	5 724 619	9.7	1.7	1.3	NR	584 224	9.0	NR	NR	NR	9 983	1 164
74	13.0	8.2	1.4	1.1	5 887 618	5.7	1.1	1.5	NR	433 406	10.2	NR	NR	NR	6 904	1 146
75	14.6	7.7	1.3	0.7	3 937 660	5.5	1.7	0.9	0.4	308 912	9.0	0.0	0.0	0.0	2 551	1 138
76	11.5	7.0	1.3	0.9	5 490 500	11.1	3.1	1.3	0.5	423 221	11.7	0.0	0.0	0.0	7 689	1 120

NR = not recorded
FO = faecal-oral diseases
WW = water-washed diseases
WB = water-based diseases (schistosomiasis)
Total = total attendance at out-patients, total admissions or total hospital deaths

dispensary records to estimate the national ratio of actual DD cases to hospital outpatient DD cases. Since we know the later for the entire country the national incidence is determined at once.

The average proportion of outpatient attendances due to diarrhoeal disease is 12.07% for the whole country (Annex 5.10). Hence the attack rate for the whole country is:

$$3.27 \times 12.07\% \quad = \quad 39.5\% \text{ per year}$$

In other words, 39.5 out of every hundred people suffer an attack of diarrhoeal disease every year, or, taking the inverse, the average person has an attack once every 100/39.5 = 2.5 years. With an average duration of illness of around 4 days, this incidence rate means a loss of 4 x 0.395 = 1.58 days per person per year due to diarrhoeal disease.

Trends Over Time

The national hospital records for the years 1970-1976 were consulted, and records previously abstracted by Bradley from 1964 and 1965 were also available. The information is presented in Table 5.4 and Figures 5.2-5.5. The clearest trend is that for the decrease of water-washed diseases as a proportion of outpatient attendances. This seems to be a steady and continuing fall (see Table 5.4 and Figure 5.4), and levels now are less than half of those in 1964-1965.

Turning to the faecal-oral diseases we see a less clear picture (Table 5.4 and Figure 5.3). The main feature is a significant peak in these diseases in 1971-1972, falling away again subsequently to around the previous level. This appears to be a peak in an otherwise fairly uniform pattern, so it is probably attributable to some natural (climatic) factor rather than the cumulative factors of education and provision of basic services. It is, however, probably not coincidental that total hospital attendances were also very high in 1971-1972. This may be a reflection of the same physical factors which caused the peak in diarrhoea - bad conditions which could easily adversely affect nutritional status and general resistance to disease, as much as diarrhoea. Hence, there is no clear conclusion to be drawn, except, perhaps, that diarrhoeal disease has not yet started to decrease in response to efforts made by the government.

FIGURE 5.2

TOTAL ANNUAL ATTENDANCE AT HOSPITALS AND HOSPITAL DEATHS

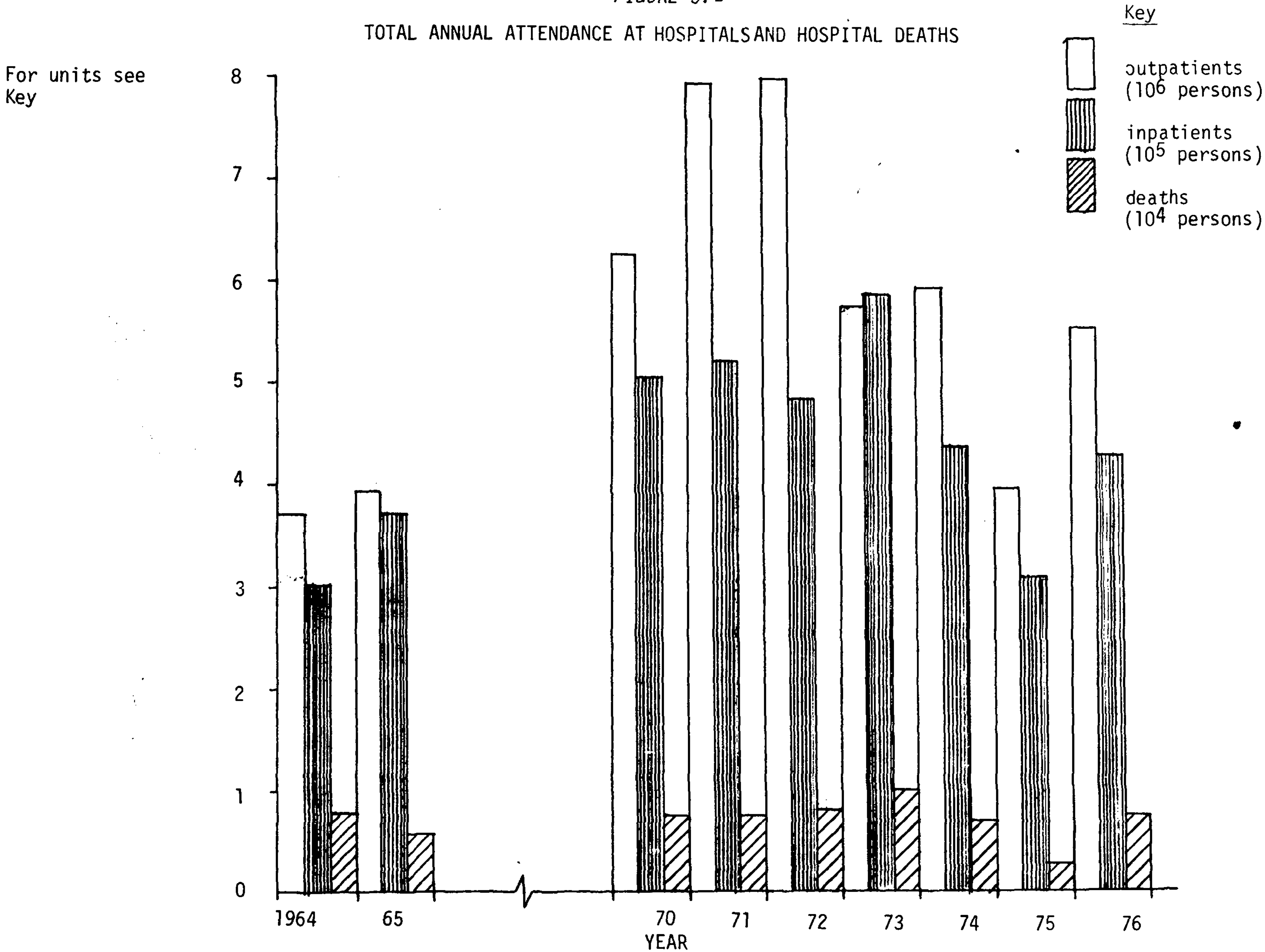


FIGURE 5.3

FAECAL-ORAL DISEASE AS % OF ALL DISEASE

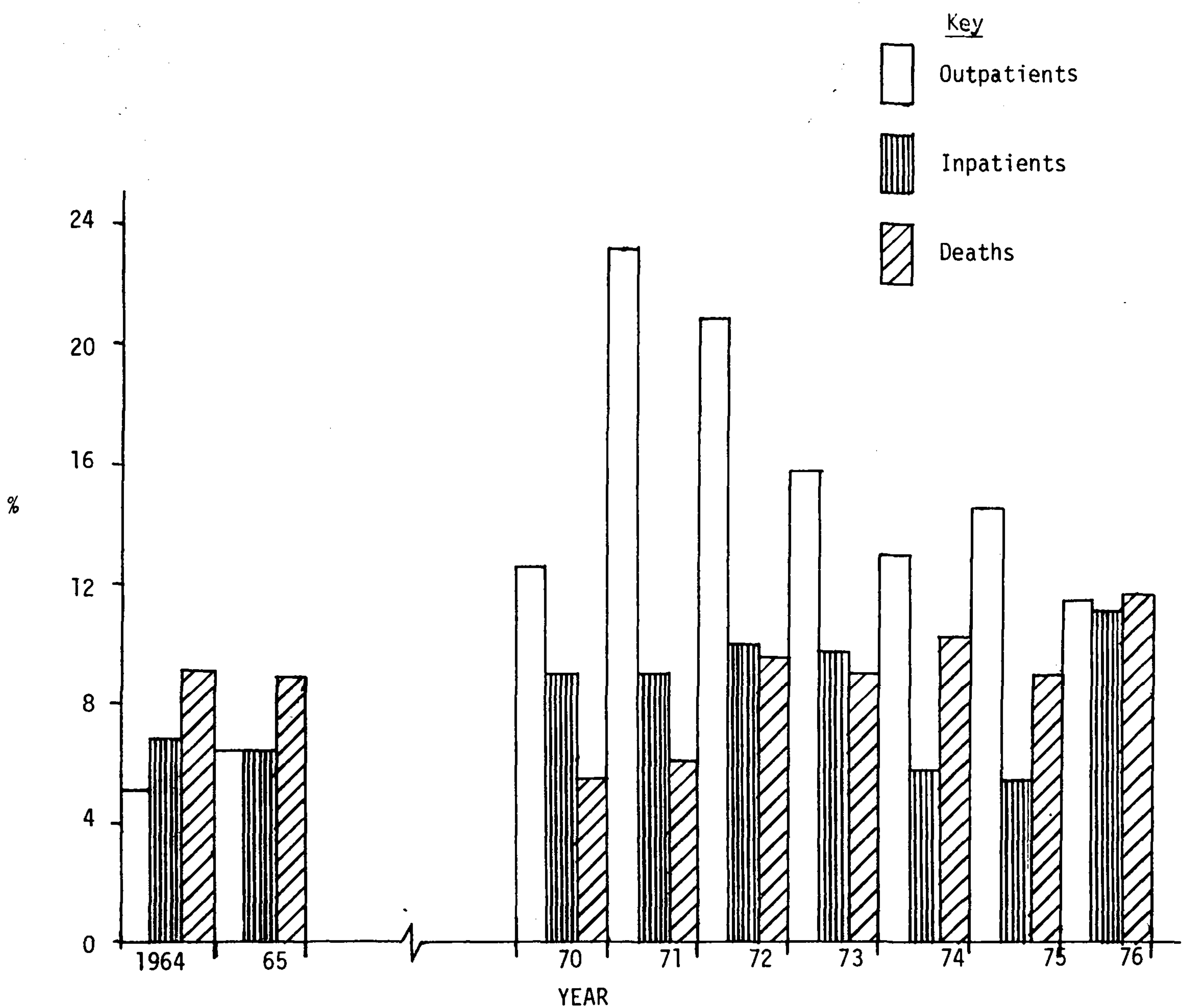


FIGURE 5.4

WATER WASHED DISEASES & SCABIES AS % OF ALL DISEASES

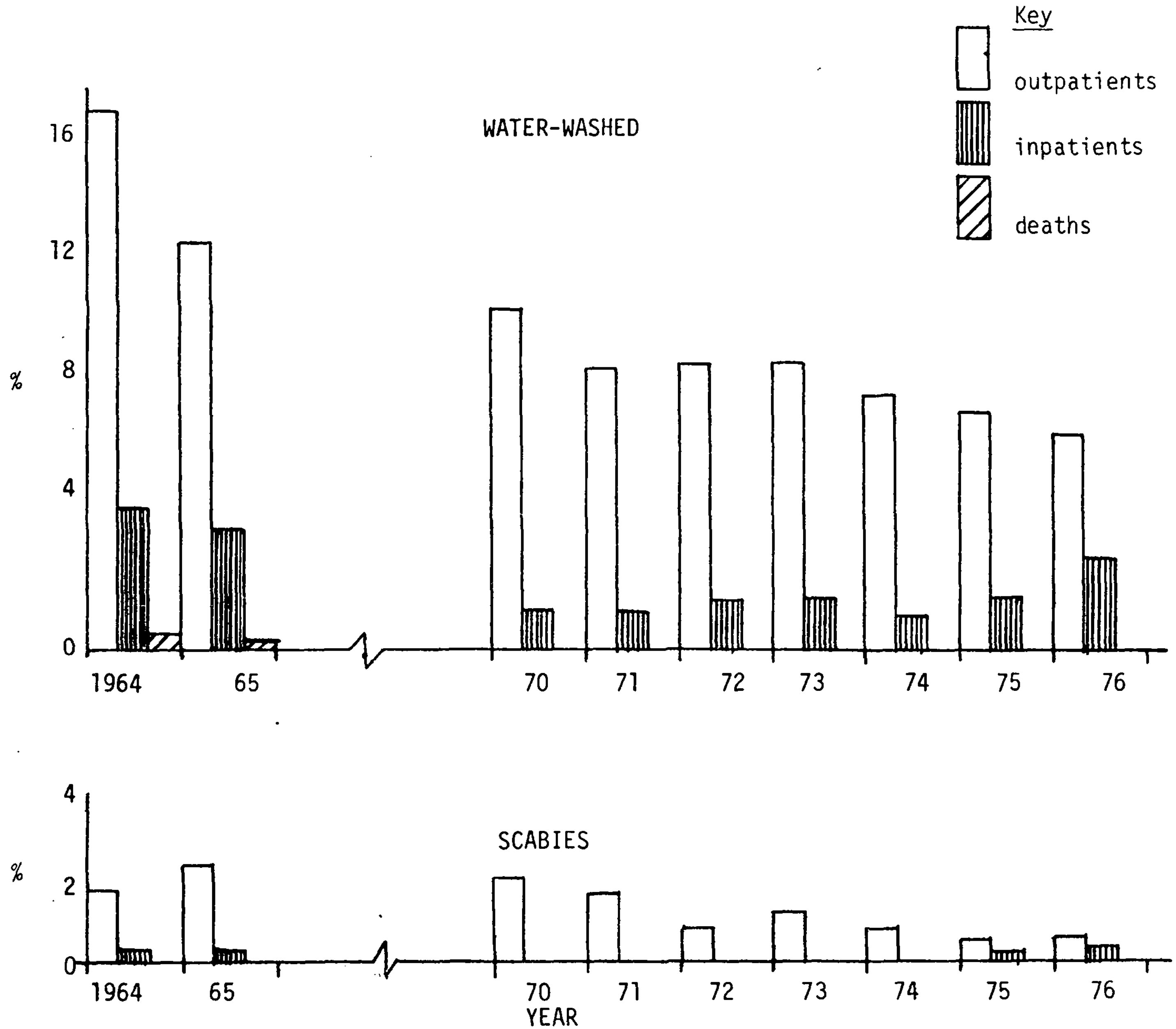
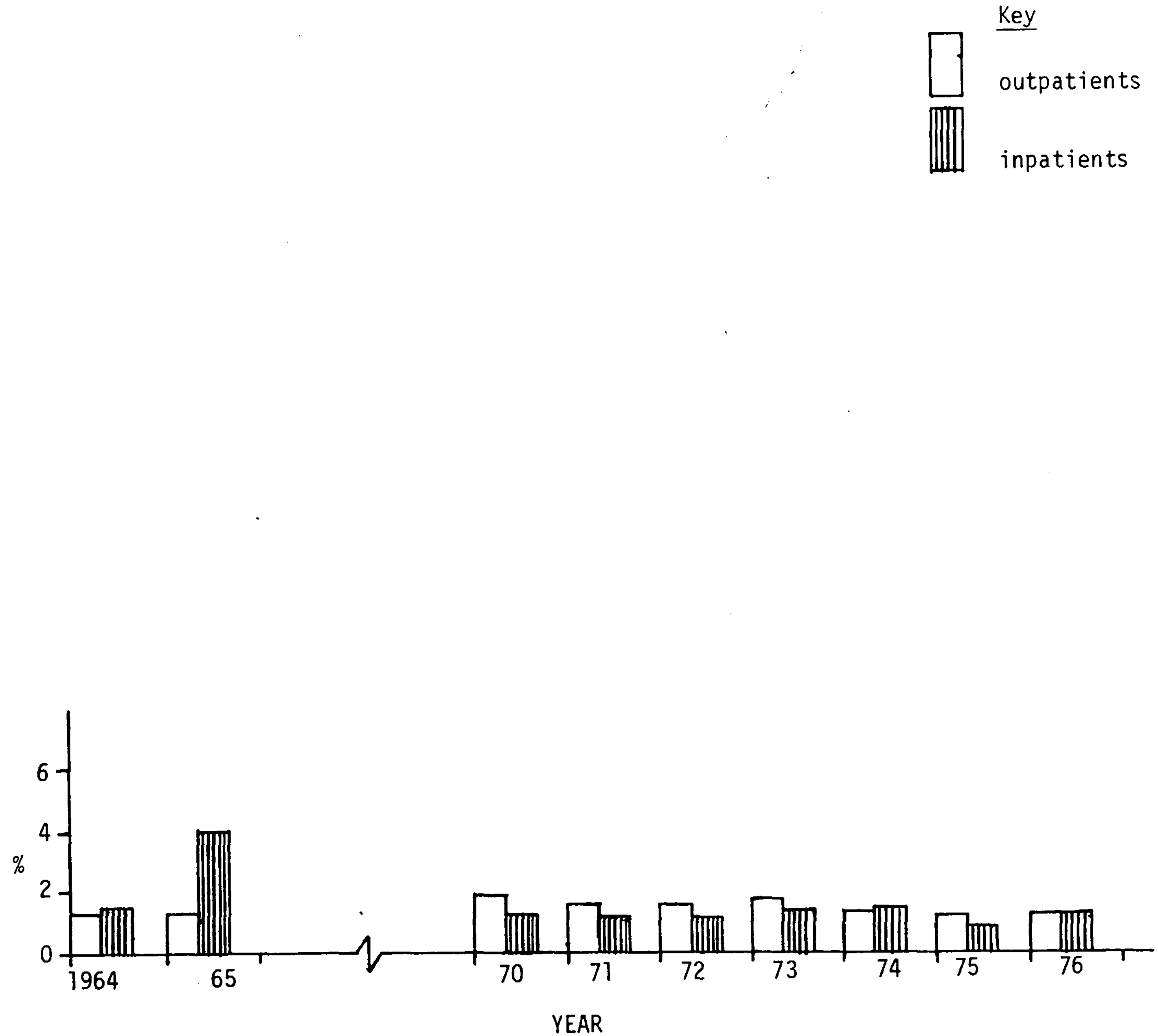


FIGURE 5.5

SCHISTOSOMIASIS AS % OF ALL DISEASES



For schistosomiasis there appears to be little change since 1964. This is not altogether surprising as no large-scale control measures have been attempted, and people's water contact patterns have probably changed little in the intervening years despite the recent villagisation. The somewhat lower proportion of inpatients and hospital deaths due to this disease are merely a function of the current medical policy of not treating schistosomiasis patients unless they are suffering acute symptoms, as they are very likely to be reinfected once cured.

Likely Benefits from Improved Water Quality

Before going on to make any estimates of the benefits to society it is important to define clearly the role of water quality improvements in preventing potentially waterborne diseases. This is only one of a number of complementary inputs affecting health which have but little effect without each other. As the target diseases are all spread through faeces, a very obvious complementary factor is the provision of excreta disposal facilities on a wide scale. This will not only decrease the extent of water pollution but also attenuate the other, more direct, transmission processes going on. A second important complementary area is the public information campaign for health education and the fuller use of the health officers and auxilliaries, who are at present accomplishing little, perhaps because the importance of their work has not been emphasised enough. This could help to improve hygienic practices. Indeed, unless they are improved, there is little point in supplying clean water, if it is only to be contaminated by the users, or used for cooking dirty food.

Thus, drawing on experience from other parts of the world, we can put a ceiling of about a 50% reduction in faecal-oral disease from the very best (and most sophisticated and expensive) water quality attainable in the absence of these complementary activities. For more practical methods of water treatment and hence lower (but substantially improved) levels of water quality, a reduction in faecal-oral disease by some 10% - 20% is considered practical.

The Potential for Benefits

The approach adopted in this analysis is to try and define the total cost of faecal-oral disease to the nation, and compare this potential saving from reducing such costs, to the cost of different levels of water treatment. This will allow the definition of a "balance point" for each level of water quality improvement, i.e. the percent reduction in faecal-oral disease which would justify the investment in water supplies. The likelihood of this improvement in health being attained from the stipulated water treatment can then be discussed. This approach allows the use of the powerful tool of cost-benefit analysis without laying it open to criticism by making inevitably loose estimates of disease reductions from improved water quality.

That point made, let us examine the costs to the social system of faecal-oral disease. These are, broadly:

(i) disability
(ii) mortality
(iii) expenditures by health services

This latter factor (iii) is included, although it is not expected that less will be spent on health services as a result of a decrease in faecal-oral diseases. It is seen more in terms of money which can be spent on other diseases such as tuberculosis and leprosy, for which AFYA is short of funds.

(i) Reduced Disability

This has already been discussed in a previous section, and the estimate of 1.6 days per person per year lost due to faecal-oral disease has been calculated.

(ii) Reduced Mortality

Unfortunately, the hospital deaths do not reflect the pattern of mortality in the population as a whole. Also when counting the loss of productive life due to early death, it is necessary to know the age-distribution of deaths due to faecal-oral disease. There are no good figures on this for Tanzania. The data which have been used for this estimation are:

a. a life table for Tanzania based on recent demographic data;

b. age-distribution of deaths from faecal-oral diseases measured in Guatemala.

A major proportion of the total estimated cost of diarrholes diseases turns out to be due to reduced life expectancy, so the use of foreign data demands some justification. Recent research has shown that if the overall age-specific mortality is known, the age-specific mortality for individual diseases can be estimated with reasonable accuracy. The Tanzanian total mortality rates were thus compared with those for several countries where the disease-specific rates were known, and found to parallel the Guatamalan data quite closely. This allowed use of these data, established by field surveys, as opposed to speculative extrapolation from the very inadequate Tanzanian mortality data. It is thus felt that the estimate made here and presented in more detail in Annex 5.4 is the best which can be made under the circumstances.

It is felt that the Guatemalan data are preferable to any available alternative, or guesswork, since they are based on field surveys, although the extrapolation is speculative.

As in the other economic calculations, children under five have been entirely ignored, those from five to fifteen are regarded as having increasing productivity of 10% at age five up to 100% at age 15, and people above 50 years old are assumed to have a productivity of about 25% - all related to middle-aged adults.

The full analysis is in Annex 5.4. The estimate made is that 19 821 deaths per year are caused by faecal-oral disease in the over-five age groups. The average productive time lost is 20.46 years per death, and the proportion of all deaths due to faecal-oral disease is 18.3%.

(iii) Reduced Expenditure on Health Services

This has been assumed to be directly related to the outpatient attendance level. This is consistent with the analysis of data which uses this as its baseline. Detailed accounts are in any case not available, but this is unimportant, for two reasons. First, the proportion of inpatients (and therefore inpatient expenditure) due to faecal-oral disease is roughly the same as that for outpatients (12.1% and 11.4% respectively). Second, although the proportion of dispensary attendances for these diseases is somewhat higher, they account for only a small fraction of the total health expenditure.

Other factors such as transport to hospital will be discussed fully in Chapter 7.

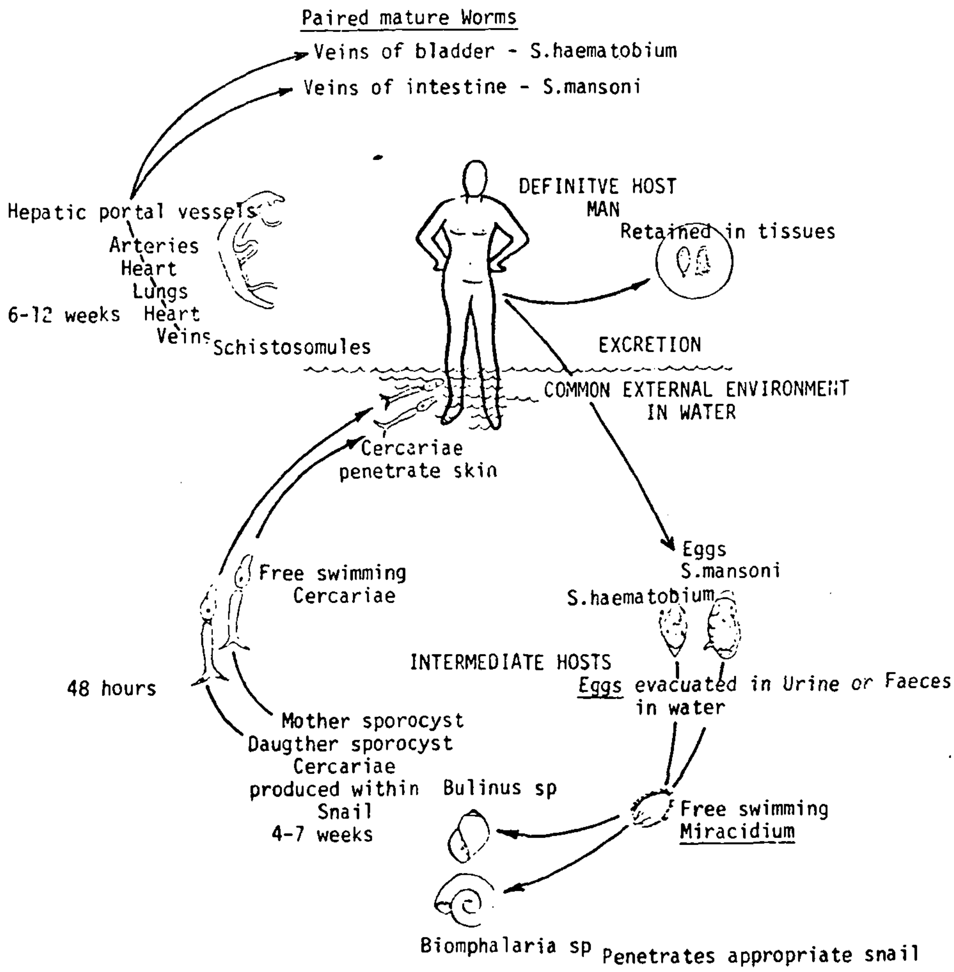
5.4 Schistosomiasis

Background

Schistosomiasis differs from the other infections considered here in that it depends on water quality in a more complex way. It may be classified as a water-based disease, one whose transmission from person to person depends on an intermediate development stage in an aquatic invertebrate animal. The other major African water-based disease, guinea-worm, is of little importance in Tanzania and will not be considered.

Schistosomiasis in Tanzania is due to either of two species of parasitic worm or helminth, Schistosoma haematobium or S. mansoni. The former gives rise to urinary schistosomiasis and the second to intestinal schistosomiasis. Both are widespread and important. The adult worms live in the blood vessels around the urinary bladder and intestine respectively. They are long-lived: up to decades, though a few years is more typical. The male and female worms are separate. Each female lays several hundred eggs daily. Some of these are retained in the tissues and cause disease. A proportion pass through the bladder wall to escape with the urine or through the intestinal wall to be passed with the stool. Further development only occurs if the eggs reach water, in which they hatch. A small larva emerges and swims about for up to 6 hours. If it encounters an appropriate water snail host it penetrates and multiplies within the snail for about one month, after which small tailed larvae, called cercariae, emerge. Cercariae are shed at a rate up to several hundred daily for a period of weeks until the snail dies or the water body dries up, with the snail either burrowing into the mud with a chance of surviving through to the next wet season or being killed by the lack of water. The cercariae survive for up to two days in water but no longer. If they come into contact with human skin they quickly penetrate it and shed their tails. The young worms then migrate along lymphatic and blood vessels, and are carried to the heart and lungs where they develop for several days before migrating to the liver and, eventually, males and females pair and migrate along the veins agains the current of the blood to the vessels around the intestine or bladder, where egg laying begins. The interval between penetrating the skin and the start of egg-laying is one to three months, usually longer for S. haematobium than S. mansoni. See Figure 5.6.

FIGURE 5.6
THE LIFE-CYCLE OF SCHISTOSOMA



Epidemiology in relation to water quality

Several key features of schistosome epidemiology are relevant to the water quality program

Schistosomiasis should not be thought of as a disease which one either does or does not have. This is because the schistosome worms cannot multiply through a complete life cycle inside man. Additional worms are only acquired by further exposure to infection. In other words, the infection needs to be thought of in quantitative terms. People may have few worms or many, a light or a heavy infection. The worms lay eggs and it is the eggs that do damage to man. So a person with a heavy infection is much more likely to be seriously ill than someone with very few worms.

The worm load depends on how much a person has been exposed to infection. Although in time people acquire resistance to infection, at any rate in the case of Schistosoma haematobium, this takes years to develop and it is by no means complete. This implies that reducing the exposure to infection will in fact tend to lower the worm burden of the people and so reduce the severity of disease. It follows that any reduction in exposure tends to bring health benefits. (This is unlike the situation in highly endemic malaria where a moderate reduction in transmission may bring few health benefits).

Schistosomiasis is usually acquired through the skin. Infection from drinking water is unusual though the cercariae are able to pass through the mucous membranes of the mouth. They are destroyed in the stomach so there is no risk of infection through the intestines. Infection from domestic water is therefore by bathing or when washing clothes, rather than from drinking water. The actual process of collecting water from an unprotected source may expose women to infection. To assess the precise role played by domestic water in the total exposure to schistosomiasis requires detailed water contact observations. The effectiveness of improvements in water quality depends less on the quality changes than upon how successful the new supply is in keeping people out of natural water bodies. In Tanzania, the greatest risks to younger children, who particularly tend to catch S. haematobium, are unlikely to be affected by a water quality program since playing in water is unlikely to be altered by it. Benefits would be chiefly expected for women and any others who fetch water or have to do their laundry, while access to water is at least as crucial or more so than quality as such.

For transmission to occur, contact has to be with water from a source that is both polluted and contains snails. Preliminary analyses of data collected in the highly endemic areas south of Mwanza suggests that, where water contact has regularly been with 'drinking ponds' - small pools to which special rules for use apply traditionally - the infection levels of the people have been lower than among those utilising other pond sources. The traditional customs seem to reduce urinary pollution of 'drinking ponds' since bathing by children is not permitted there. Here is a local water quality improvement measure that could usefully be reinforced.

The widespread campaign to increase construction and use of pit latrines in Tanzania may be expected to reduce contamination by faeces and so diminish S. mansoni transmission somewhat, but the amplification provided by the snail host is such that even low level residual contamination will support the disease.

As for S. haematobium transmission is probably mainly due to children - who have the greatest egg output - passing urine while playing in or near water. We consider that feasible control of excreta is unlikely to affect this transmission much in the near future.

The effect of snail distribution and habitat preferences on transmission is discussed below.

In this context a general comment on what is known of schistosomiasis in Tanzania is appropriate. The East African Institute for Medical Research (EAIMR), sited at Mwanza, has carried out work on schistosomiasis since the late 1950's and this has been its main research topic from 1962 up to the present for which it has had an international reputation. Consequently as much is known about urinary schistosomiasis in the Mwanza area as for any place in the tropics and thorough epidemiological studies of S. mansoni are also available. Less is known about other parts of Tanzania but there is no reason to expect uninvestigated qualitative differences from the studied areas, though intensity of infection will differ.

Public health importance

To assess the importance of a chronic disease, particularly one with such diverse manifestations as schistosomiasis, is notoriously difficult. Tanzania has been the site of some of the most detailed community studies of this problem however, and it is possible to set out, at any rate for some sites in the Mwanza area, the consequences of the infection in medical terms, though the difficulty of converting these to economic values is very great.

First, the picture of infection: Data on the prevalence by age for S. haematobium and S. mansoni in rural areas endemic for each parasite are available. These indicate that in the Misungwi area almost all children are infected with S. haematobium by the age of 12 years and many much earlier. The numbers of eggs passed in the urine are large, and reach a peak about the same age. Thereafter there is a gradual decline and only about half the middle-aged and elderly are passing eggs at any one time. Nevertheless, they have almost all been infected in the past and may have disease consequences of that infection in spite of no longer excreting eggs. The picture with S. mansoni shows a slower increase in prevalence with age, and that prevalence then tends to be maintained into later life.

The consequences of infection differ in the two infections, except for the general effects such as lassitude and failure to do well at school. Some evidence for both these effects exists though they are hard to quantify. It is mentioned because, as is well known to the readers in the case of influenza, common colds, and malaria, some of the general malaise and misery of infections is very real and disruptive of a satisfactory life in spite of difficulties in demonstrating it objectively. 80% of those infected with S. haematobium have more specific symptoms, including pain on passing urine and the need to rise at night to pass urine.

Several community studies have shown that up to 20-25% or more of the total older child and adult population (not just those passing eggs) may have damage to one or both kidneys or ureters to an extent that, were it encountered due to another cause in a developed country, surgery would be considered. The natural history of this severe urinary tract damage is uncertain. A proportion will revert to normal after treatment to kill the worms, and possibly even without this. Some of these are thereby predisposed to bacterial infections so that death may result indirectly rather than directly from schistosomiasis. Numerical results for mortality are subject to great uncertainty, but to suggest that of those ever infected 50% will have some symptoms, 10% will have major upper urinary tract lesions and 1-2% will die from the infection is not unreasonable.

In the case of S. mansoni the differences in intensity of infection between communities are more dramatic. In many endemic areas worm burdens are light and though general symptoms of lassitude and abdominal pain may occour, more serious consequences are rarely seen. But in the very heavily infected fishing communities, on Ukerewe island for example, highly specific damage to the intestines and liver occur. Most characteristic is pipe-stem fibrosis of the liver which occurs in early adult life among perhaps 10% of very heavily infected communities and which leads to death in a proportion of these by vomiting of blood or liver failure, while most have som degree of anaemia and greatly enlarged spleens. The course of typhoid fever in S. mansoni patients is greatly prolonged, even with treatment, and the parasite itself may produce recurrent dysentery-like attacks. Among heavily infected communities the death rate is higher than for communities infected with S. haematobium.

Schistosomiasis is therefore important as a common cause of low-grade morbidity, with occasional serious disease and death. Unlike many parasitic diseases it is increasing in frequency in the world as a whole including Tanzania. This results from water development for agricultural and hydroelectric purposes so that surface water is both more abundant and more persistent and human occupational water contact is increased. Much of this increase is independent of changes in domestic water supply, but has implications that are considered below. Studies in Northern Tanzania have demonstrated that the productivity increases and medical costs averted exceeded the cost of schistosome control on irrigated sugar estates.

Distribution of Schistosomiasis in Tanzania

The greater part of Tanzania is endemic for one or both main species of schistosome. The most widespread surveys were undertaken 20 years ago and comprised the upper forms of some 60 primary schools throughout the country. They were therefore not subject to the large sources of bias inherent in clinic and hospital laboratory reports, and were all carried out by the same experienced workers. The results are set out in Annex 5.5 together with other unpublished surveys carried out at that time by the consultants. More recent surveys have tended to be geographically limited though much more detailed.

The general picture which emerges is as follows. S. mansoni is found in localised areas but particularly along the shores of the great lakes. Around Victoria Nyanza it is most intensely transmitted to the south-east, both in the lake itself (by a deep-water snail, Biomphalaria choanomphala) and in streams draining into the lake. Ukerewe island is heavily infected, and remarkable clinical cases almost resembling cancer of the abdomen are found due to S. mansoni there. The parasite has invaded most irrigation schemes in central and in north-east Tanzania as well as scattered highland un-irrigated sites. It is absent from the coastal plain, probably because it is too hot for successful reproduction of the intermediate host snails.

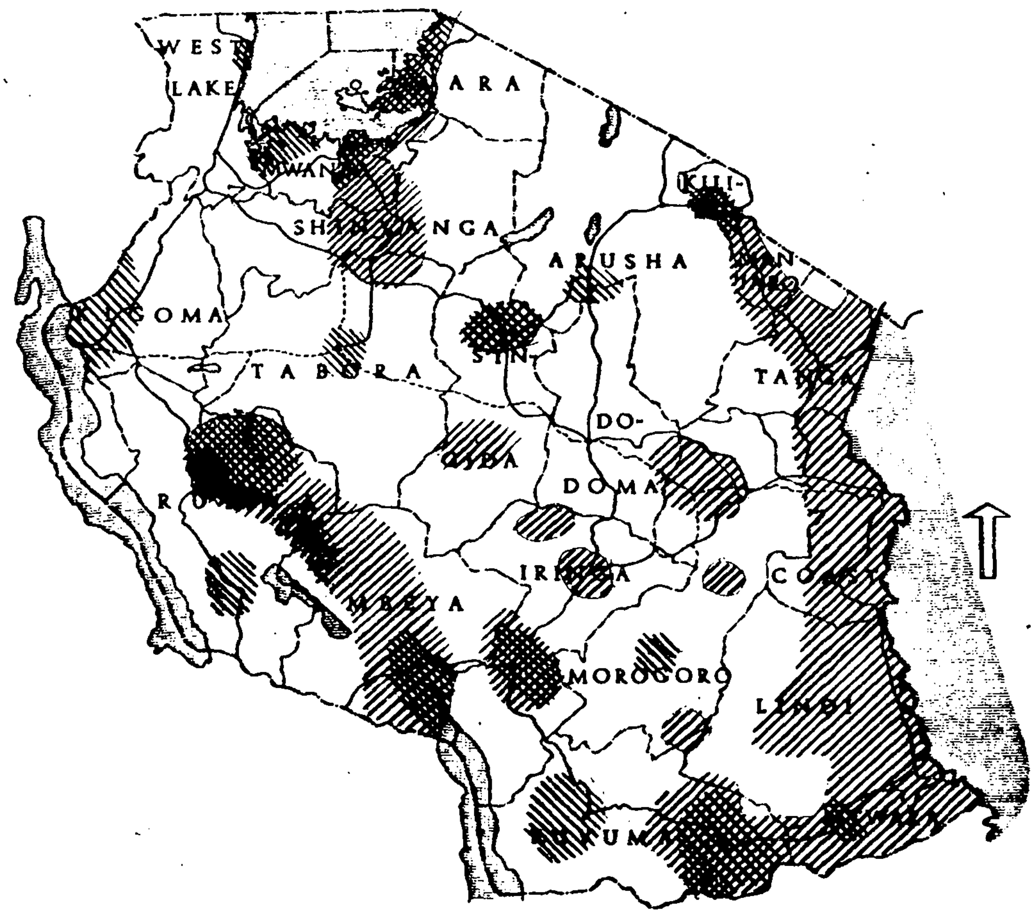
S. haematobium is more widely distributed, tending more to the areas away from the lakes and being transmitted by several snails, one of which lives in small seasonal ponds and another in rather larger cattle dams and more perennial water bodies. In the arid parts of Sukumaland, though water bodies are scarce, man-water contact may be very close and extremely high infection rates are found in dry areas where water sources, other than boreholes, are few. It is here that domestic water problems are more closely related to schistosomiasis risks. S. haematobium is transmitted along the whole length of the coastal plain.

The distribution of schistosomiasis is shown conservatively in the map, Figure 5.7, which was prepared on data collected some years ago. This indicates areas where the infections certainly occur. It is clear that they also occur in unsurveyed areas between, where they are inhabited. Not only is the disease increasing where water developments are taking place, but also infected population movements and new settlements are leading to infection of new areas where the suitable snail hosts already existed but which the parasite had not previously reached.

The likely consequences of the villagisation program on endemicity need consideration. At present these are conjectures, but research is in progress at the Medical Research Institute at Mwanza which should lead over the years to a factual picture. The localised villages lead to less water sources being used, but by a larger population. The risk of pollution will rise. Pressure to utilise excreta disposal facilities may later lead to a fall in water contamination by schistosome eggs. It is likely that in a period of rapid social change respect for the traditional category of 'drinking ponds' will be lost, the more so as population movements will move many people from the water bodies with which they are familiar. Perhaps something can be done to reinforce such memories. The concentration of people in villages will in many areas mean that traditional poor quality water sources are inadequate. Therefore, and also because of government policy, new sources will be exploited and a move towards boreholes and piped schemes from more distant sources is likely. On balance these are liable to reduce schistosomiasis transmission in intensity though the parasites' range may well continue to extend.

FIGURE 5.7

MAP OF APPROXIMATE KNOWN DISTRIBUTION OF SCHISTOSOMA



S.haematobium

S.mansoni

Blank areas do not necessarily mean absence of schistosomiasis, but instead lack of information.

Attempts to calculate the number of infected people in Tanzania are open to very large error. As a first estimate we have taken the infection rate averaged over the primary schools studied. For limited areas we have overall population surveys as well as the primary school data from schools in the survey area. Using the best studies available (Misungwi for S. haematobium) we have derived a ratio to correct school data for the general population and by age. The resulting rate has been multiplied by the national population. The resulting number of infected people with S. haematobium in Tanzania is 4.5 million. The hazards of such a calculation procedure are obvious to us and, we trust, to the reader, but the data are inadequate for a better estimation procedure. At least the result derives from community surveys and not from clinic data with its still more obvious systematic biases. Distribution of S. mansoni is more focal and the survey figures are open to much greater chances of systematic error. Certainly there are far fewer people infected with the intestinal than urinary schistosomiasis.

Localised water development projects are a special case. Here, as the risk of schistosomiasis is likely to rise, the development authority has a special responsibility to the population of the area, and the development project is likely to produce greatly increased prosperity. Such projects should be rigorously scrutinized at the planning stage to ensure that specific provision is made for domestic water supply, and that intakes are sited above the irrigation scheme. New settlements should not be sited on canals or drains. This is one occasion when access to domestic water, water quality, and discouraging use of infected water, can all be dealt with together. Even where the existing planning legislation is adequate to achieve this, the opportunity is not always taken. Additional regulations to ensure that the water hygiene division (see 8.3) and Afya epidemiologists are fully consulted before plans are passed, will be necessary.

Usually a large new reservoir or irrigation scheme will attract the attention of planners and health administrators and domestic water supplies can be considered. The far more numerous small schemes are more likely to be neglected: the costs are smaller, large organisations may not be involved, profit margins from the development may be smaller, and the scheme may be built almost without detailed plans.

To bring these under scrutiny requires specific regulations and a clear allocation of responsibility to a suitably trained individual at regional level - either the regional water engineer or regional medical officer, or the zonal water hygiene engineer. If one of the former, a manual or training course will be needed.

Particular attention in water developments is needed to provide settlement with effective water supplies from the beginning, in the hope of preventing schistosomiasis from becoming established, though any success that this may have will depend greatly on other measures for treatment of infected immigrants and reduction of water contact.

Conclusions and Recommendations on Schistosomiasis

(1) Schistosomiasis is a group of two diseases which are very prevalent in Tanzania and likely to increase. Although responsible for rather little mortality they give rise to a variety of disabilities and much misery. It is however not feasible to provide meaningful estimates of the economic costs of this disease to the society.

(2) Infection with schistosomes results from contact with water containing their larvae, shed by infected snails. Thus the relevant change in water quality is keeping cercariae, the larvae, out of domestic water or storing the water for 2 days prior to use, to allow the cercariae to die.

(3) In practice, the chief way in which improved domestic water supplies reduce the risk of schistosomiasis is by reducing contact with natural surface water sources, so that access is even more important than quality as such in reducing schistosomiasis.

(4) Monitoring of water supplies for schistosome cercariae should not be a routine procedure. While at least one technician and the water hygiene engineer in each zone should be familiar with relevant procedures, and steps necessary to make water safe from schistosomiases, special problems should be referred to the expert staff of the EAIMR.

(5) Planning machinery needs to be set up to ensure that, in rural development programs, and especially water development projects, adequate thought is given to providing accessible water without schistosomal risk. A suitable group to accomplish this might be a regional water hygiene comittee (see section 9.2 (c)) since it would contain officials from all the departments involved.

CHAPTER 6
ENGINEERING COST ESTIMATES

6.1 Introduction

In this chapter we discuss in detail the cost estimates for various treatment forms and then cost alternative strategies of water treatment. The costing of the alternative treatment methods is presented in detail. We cover increased storage, chlorination, flocculation-sedimentation, and slow sand filters. The detailed costings are then used to estimate strategy costs for three different water quality levels. The cost of a strategy is built up for every region and represents the total costs incurred to provide treatment for all water schemes assuming that within 20 years the entire rural population has been provided with water.

Costs included capital, maintenance and operations. The costs of the surveillance system are not included here as these are considered to be independent of the level of water quality at which we are aiming. These costs become the inputs into the benefit-cost analysis of the next chapter.

The strategy costs are estimated by determining how many water sources of different types will be developed according to available hydrological and hydrogeological evidence. Appropriate treatment processes are defined for the different water quality levels to be reached. The treatment processes are more expensive the lower the quality of the raw water so that the cost of a strategy takes account of the treatment costs of particular processes weighed by the extent to which this treatment is needed to achieve the target level of water quality.

To prepare the engineering cost estimates requires first the provision of appropriate bills of quantity; thus costing these to estimate the financial construction cost. Finally, the financial costs are adjusted to real resource or economic costs to provide an estimate of the extent to which resources are utilised in the water quality program. To do this, we have adjusted the costs so that imported materials become 250% more expensive leading to a preference for using local materials. Similarly, in determining the total program costs we have used 18% interest rate. The interest rate was chosen to estimate the alternative return on capital that would be available from other uses.

The detailed costing for water quality appropriate to Tanzanian conditions have a wider set of uses than as inputs for the strategy cost calculations. These costs are available for assessing the financial and economic costs of alternative treatment plants for alternative size of water schemes.

6.2 Design Criteria

In order to describe and cost appropriate treatment plants, particularly their size and efficiency, the design criteria controlling other components of the water supply scheme have to be defined. The current official design criteria for MAJI are contained in a publication dated February, 1975. The following aspects of these design criteria effect the size of the treatment plant:

Pumping Capacity

The time during which water is being pumped from source to storage is required. It is not necessary to present a detailed description of the design of a water supply's pumping units, but sufficient to note that with good engineering practice the following pumping periods should be followed:

(i) for deep boreholes the pumping unit is designed for 12 hours of pumping per day;

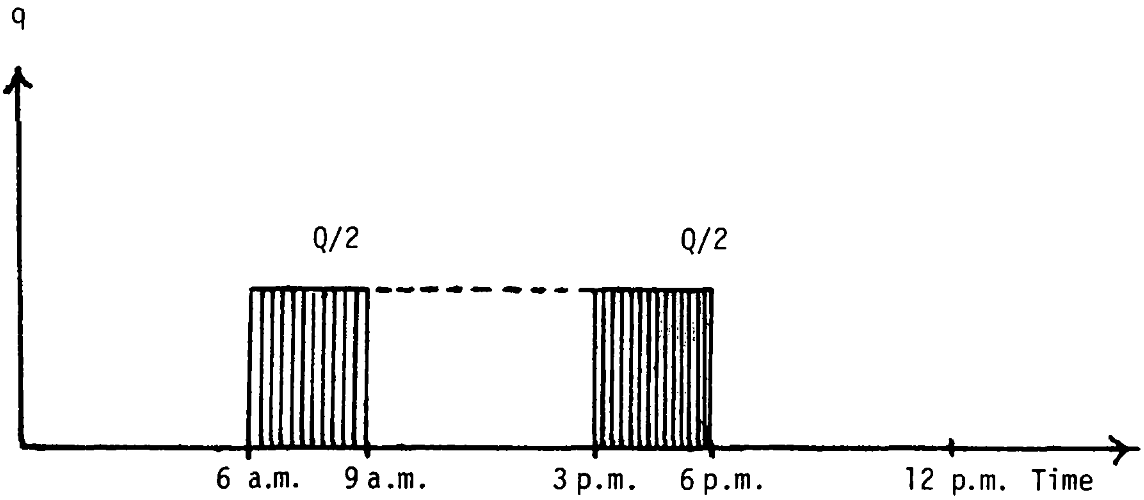
(ii) for surface water supplies, the pumping units are designed to deliver 8 hours of simultaneous pumping (there are typically more than one unit and all are considered to work simultaneously).

Consumption Pattern

The water consumption pattern (i.e. extraction from source) during the day must be given. This has been studied by several researchers, however the variations are so great among results from different sources that it is not possible to describe the daily consumption pattern in a simple manner. Furthermore, very little is known about monthly and yearly variations. Increases in income should lead to a trend of greater water use; while during the wet season we expect that there is a wider diversity of sources and so reduced off-take from improved water supplies should be observed. For design purposes the following pattern is assumed. The assumption is deliberately chosen to be "on the safe side", even at the cost of a more expensive initial investment.

Figure 6.1 represents the assumed consumption pattern which is concentrated in two three-hour periods. Hence if Q is the water demand per day; q is the water demand in cubic meters per hour; with a six hour peaking period, obviously $q = Q/6\ m^3/h$.

Figure 6.1 Assumed Consumption Pattern of Domestic Water in Rural Areas



Storage Capacity

The storage capacity, according to the design standards, shall not be larger than what is required for balancing purposes, i.e. to balance the time between pumping and consuming water over a daily period. If for the purpose of achieving higher water quality, the water shall be retained in storage for say 48 hours, then the storage volume has to be increased over and above the storage required for balancing. The difference in cost between constructing and maintaining a volume designed for 48 hours retention plus balancing compared with a volume for balancing only will be referred to as a treatment cost when longer storage is used as the treatment method. The formula for the storage volume required for balancing purpose are as follows: (C.f. Annex 6.1 for details.)

Gravity supply:	$\frac{Q}{2}$ m^3	(i.e. water from source to storage 24 hours/day; water used six hours per day.)
Deep borehole as water source:	$\frac{Q}{4}$ m^3	(i.e. water from source to storage 12 hours/day; water used six hours/day)
Surface water as water source and pumped supply:	$\frac{Q}{8}$ m^3	(i.e. water from source to storage 8 hours/day; water used six hours/day.)

A retention period of 48 hours requires an increase in volume of 2Q m^3.

The balancing storage requirements are quite conservative as the consumption pattern is probably smoother than indicated in Figure 6.1.

6.3 Basis for Cost Calculations

Economic Assumptions

The particular assumptions made in the economic cost calculations need further explanation. The choice of adjustments in wages, foreign exchange rates, and selection of an interest rate should reflect the salient characteristics of the economy. The Tanzanian economy can be characterized in this respect by three considerations:

(1) The labour force is largely fully employed. In the rural areas there are several months of fairly acute labour shortages and agricultural production is probably limited by the supply of labour. However, in the dry season when most construction takes place there is labour available.

(2) The economy faces an acute foreign exchange position. The balance of goods and services has been running a substantial deficit and the exchange rate is tightly controlled by many quantitative restrictions on imports. In this situation the official exchange rate is overvalued. By correcting for this we favour projects which utilise domestic resources and use less imported resources.

(3) Finally, the economy is acutely short of investment resources; interest rates needed to ration such resources are consequently rather high.

We have used a factor of .9 to correct for the rather high wages paid by Government to temporary workers and to reflect the fact that there is available labour during the dry season. The foreign exchange rate correction factor we use is 2.5 - i.e. we believe the equilibrium exchange rate needed to bring to supply and demand for foreign exchange into equilibrium is about 20/- to $1. This correction biases the selection among alternatives in favour of those that use little foreign exchange. In our study of the feasibility of the Msanga Road we have presented the basis for this estimate. Finally, we prefer an interest rate of 18% to calculate the present value of benefits and costs. The reason behind this choice is given in the above mentioned study. This high interest rate reflects a bias of projects towards those which are labour intensive and which carry substantial recurrent costs rather than capital costs, i.e. the more the project shifts costs into the future the more favourable will be its economic return.

All costs can be divided to the four basic categories:

(1) Labour
(2) Local material
(3) Imported material
(4) Transport

The financial and economic cost to be used for each of the four items will be defined in the following paragraphs. All prices, charges etc. will be given in Tanzanian shillings (TShs).

Labour

Labour can be subdivided into the following categories:

a. expatriate

b. local labour, further subdivided into skilled and unskilled categories.

The financial cost for labour is determined as follows: $K^f = A+B1+B2$ when A is the cost of expatriate labour; B1 is the cost of skilled local labour; B2 is the cost of unskilled local labour. K^f represents the financial cost.

The economic cost for labour is defined as: $Ke = f1 \cdot A+B1+f2 \cdot B2$ K^e represents the economic cost.

We have introduced corrections F1 for the foreign exchange rate and f2 for the opportunity cost of unskilled labour.

Local Material

Local material has an exfactory price of C. When manufacturing the local supplied items imported raw material or equipment might have been used. Assume that the foreign exchange part is x% of C, then:

$$K^f = C$$

$$K^e = (f1 \cdot \frac{X}{100} + \frac{100-X}{100})\ C$$

Imported Materials

The price for imported material comprises:

a. cif price DSM (D)

b. port charges, godown in DSM, transport etc. (E)

c. duties, sales taxes (F).

The financial cost will be:

$$K^f = D + E + F$$

$$K^e = fl \cdot D + (.75\ fl + .25)\ E$$

The factor for port charges, transport to godown etc. has been calculated as for a "local item" for which is taken as the foreign exchange element.

The taxes and duties are transfers and omited as an economic cost.

Transport

Transport is a combination of local skilled labour utilising local as well as imported material. The foreign exchange part is assumed to correspond 75% of the total price G for transport of e.g. 1000 kg for 1 km.

$$K^f = G$$

$$K^e = (.75\ fl + .25)\ G$$

Transport costs will vary from scheme to scheme depending on the distance from Dar es Salaam to the region from the regional centre. In this report costs will be calculated for a scheme in Mwanza region taken to be 75 km from Mwanza Town. The reason for this is that the figures are already available from the Tri-Region Water Master Plan (West Lake, Mwanza and Mara) and the costs associated with location assumed will probably not fall below the average for the whole country. An exact calculation requires data for each water supply (village) of distances and transport modes. As other required data on the use of different water sources and level of water demand will not be possible to obtain for all regions, and for many regions it is only possible to have an estimate of the number of water schemes using different water sources and the average water demand for these schemes, the assumption on average transport cost described above is not unreasonably given the other assumptions that it is necessary to make. In general the capital costs will be presented as a constant annual cost using an interest rate of 18% and an appropriate lifetime for the respective items. We will examine the sensitivity of the results to other discount rates. For operations and maintenance costs annual costs will be estimated.

6.4 Water Treatment Methods

General

In this section we define what is included as "treatment" and then, in subsequent parts, we describe the different treatment methods considered and present cost estimates for these. It is assumed that the design and construction of a water supply will be done in such a way that the quality of the raw water will not be lowered on its way from the source to the delivery point due to bad design or improper construction. As an example, consider Lake Victoria as the water source; this means water of good quality is available as raw water if the intake for the scheme is constructed far enough out in the lake at a sufficient and suitable depth and so located as not to be polluted from the nearby village. It is possible that a less expensive intake would be constructed too close to the shore line or too close to a village resulting in lower quality raw water than could be obtained with a better placed intake. The difference in cost between a cheaper, but badly sited intake, and a more expensive, but properly located intake structure, is not counted as a "treatment cost" even though the quality of the raw water will be increased by constructing the more expensive intake structure. Examples of this type are plentiful: proper protection of a well or a spring, carefully laid pipes so that breakages and leakages are avoided. These considerations can be extended to cover maintenance: Storage tanks shall be cleaned and sterilised at regular intervals, pipelines shall be sterilised before taken into use, etc. These are examples of actions taken during the construction or maintenance phase resulting in increased cost in order to prevent a lowering of the raw water quality but are not counted as "treatment costs" in this analysis.

Treatment processes which aim at an adjustment of raw water's hardness, to remove colour or taste, or to exclusively remove metals such as iron and manganese are not considered treatment as this type of adjustment is not required as part of health improvement. Neither are treatments like desalination or defluoridation considered as these are complex to operate and exceedingly expensive and consequently inappropriate for rural areas.

The treatment processes dealt with are those required to provide water to maintain or improve health conditions among the water consumers.

Increased Storage

If water is stored in a covered tank certain advantageous effects will occur which generally increase the longer the storage period: Sedimentation of particles; reduction of the live bacteria content; and reduction of the number of schistosomic cercariae.

The storage volume for balancing supply and demand according to existing design criteria were previously discussed and the derivations can be found in Annex 6.1. The additional volume required if the retention period is increased by 48 hours can be seen in the table in Annex 6.2. The same table gives the costs for the storage volume required with increased storage (A) and with storage for balancing purpose only (B). The costs are plotted in Figure 6.2.

In Annex 6.3 the cost estimates for storage tanks are described in detail presenting both financial and economic costs.

The cost for this kind of "treatment" is defined as the increase of total storage over the balancing storage, i.e. A-B. To determine the annual cost of treatment we use the formula:

$$(A-B)\left(\frac{1}{a_N} + M\right)$$

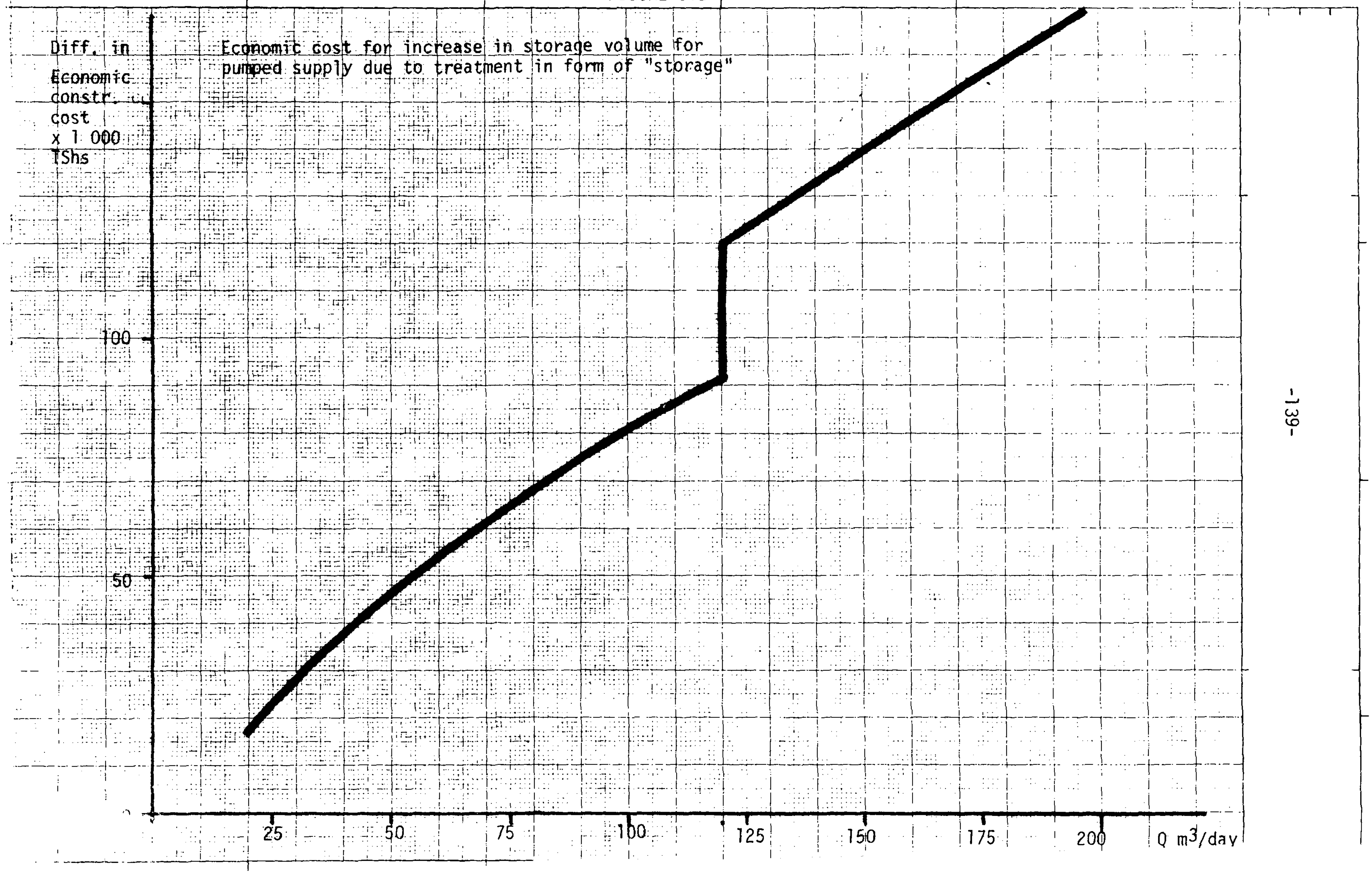
where a_N = discounting factor

N = the lifetime of the storage tank

M = the annual cost of maintenance as percent of the construction cost.

We take $M = .01$ and $N = 20$ years.

FIGURE 6.2


Diff. in
Economic
constr.
cost
x 1 000
TShs
Economic cost for increase in storage volume for pumped supply due to treatment in form of "storage"
100
50
25
50
75
100
125
150
175
200
Q m3/day

We differentiate between "pumped supply" and "gravity supply" as the required storage volume for balancing purposes is different. The case of "deep groundwater" is not dealt with as treatment by increased storage is not included it being deemed unnecessary for treatment of deep groundwater.

Chlorination

Treatment of water with chlorine is used mainly for disinfection of water or as a safeguard against possible intermittent bacterial pollution in a normally "clean" water. The chlorine will furthermore, have the effect of diminishing organic content of the raw water so it can be used as a pretreatment of water with a high organic content in order to increase the effect of a following treatment process, e.g. slow sand filtration. Disinfection by the chlorine will not take place until the organic content is low enough. Therefore, the amount of chlorine required for treatment will vary with the quality of the raw water. In general, as assumed in this calculation the amount of chlorine required will be small when deep groundwater is used as raw water. Higher doses are required for surface water of good quality and still higher doses will be needed to handle the raw water from reservoirs.

Many different chemicals are satisfactory sources for the required chlorine to be used in treatment. The alternatives considered for use in rural areas in Tanzania are: (1) chlorine gas manufactured in Tanzania; (2) calcium hypochlorite (30%) from India; and (3) sodium hypochlorite (10%) made in Tanzania. The economic capital and recurrent costs for the three alternatives have been calculated and it has been determined that sodium hypochlorite is slightly cheaper than the calciumhypochlorite alternative. The most expensive alternative is to use chlorine gas.
Within Tanzania no data has been available for the establishing of required chlorine doses.

Aiming at a "free chlorine residual" of 0.3 mg/l, it is assumed that the dose for the four different water source classes defined for these calculations will be 3, 5, 10 and 15 mg/l respectively. These doses will safely cover all relevant raw waters.

When using the Tanzanian sodium hypochlorite of a strength of 10% the corresponding initial doses will be 27, 45, 90 and 135 g/m^3 (of raw water).

The financial cost for the solution is TSh. 1/65 per kg; assume 10% represents foreign exchange. It is delivered in containers carrying 60 kg each. The container itself costs Shs.40/- each, is locally made and containers for one year's supply is included here as an investment cost with assumed lifetime of 10 years. The dosing equipment (venturimeter, etc.) is the same for all capacities considered, is imported, the cost in Tshs. 3,100/- and the estimated lifetime is ten years. Some dosing equipment, imported, has to be renewed annually. The assumed average scheme has for transport costs a rail shipment DSM-Mwanza (1,230 km) and a further 75 km from this regional center by lorry. The transport costs are Tshs.-/25 and -/80 respectively per kg and km. The cost calculation is given in detail for the alternative Q = 45 m^3/day and 90 g/m^3 in Table 6.1.

Flocculation, Coagulation, Settling and Filtration

For more polluted and turbid raw water it is not possible to use a slow sand filter as it clogged rapidly. Chemical treatment consisting of adding alum and soda ash (normally needed for pH-adjustment) is required. After flocculation and coagulation has taken place the formed flocs will settle in a sedimentation tank and filtration in an upward flow filter will take place as the last step before chlorination and pumping to the storage tanks for distribution of treated water.

A sketch lay-out of the above mentioned treatment block is shown in Figure 6.3.

The required doses of filter alum and soda ash are assumed to be 25/13.5 and 75/40 g/m^3 for raw water belonging to group (3) and (4) respectively (see Section 6.5 in this chapter). An extra pumping stage is assumed to be required. A minimum of two sedimentation tanks are needed in order to facilitate cleaning. Each unit will have its own filter below the outlet. The upward flow filters are assumed to be "back washed" simply through opening a bottom outlet for a rapid emptying of the filter unit.

The sedimentation units have been designed for a retention time for the water of four hours and a surface load capacity of 0.5 $m^3/m^2/h$. The minimum efficient water depth is 1.3 m. The upward-flow filter is assumed to be able to work with a capacity as high as 6-8 $m^3/m^2/h$.

TABLE 6.1

EXAMPLE CALCULATION OF CHLORINATION COSTS

(Arusha Region, Medium Quality Level, Source Type (3))

		Financial		Economic
	Recurrent Costs			
1.	Chemicals (Na OCl)			
	$Q = 0.03 \times 1500 = 45\ m^3/day$ Dosage: $D = 90\ g/m^3$ Cost: TSh. 1/65 per kg $Q(m^3/day) \times 365\ (days) \times D(g/m^3) \times \frac{1}{10^3}\ (g/kg) = 45 \times 365 \times 90 \times 10^3$ = 1478.25 kg/year 1478.25 x 1/65 TSh./year =	2,440	x 1.15 =	2,805
2.	Transport of Chemicals			
	TSh. 1/05 per kg 1478.25 x 1/05 TSh/year =	1,552	x 2.125 =	3,298
3.	Recurrent Equipment			
	Per year	260	x 2.5 =	650
4.	Maintenance			
	10% of equipment cost (3,100)			
	0.5 x 3,100 x 0.1 TSh./year	155	x 2.5 =	388
	0.5 x 3,100 x 0.1 Tsh./year	155	x 1.0 =	155
		4,562		7,296
	Capital Costs			
1.	Equipment, lifetime 10 years	3,100	x 2.5 =	7,750
2.	Containers, lifetime 10 years $\left(\frac{1478.25}{60}\right) \times 40/-$	1,000	x 2.5 =	2,500
		4,100		10,250

cont.

table 6.1 cont.

N = Number of schemes to be constructed during 20 years (= 223 for Arusha Region).

$\frac{N}{20}$ schemes per year.

Annual increase of population = 2.7%.

<u>Present Value of 20 Years Cost, Interest Rate 18%</u>

Financial Costs

Capital

$$\frac{N}{20} \times 4{,}100 \times \left(\sum_{n=1}^{10} 1.18^{-n} + 2 \sum_{n=11}^{20} 1.18^{-n} \right) = 283{,}954$$

Recurrent (equipment and maintenance):

$$\frac{N}{20} \times 570 \times \sum_{n=2}^{20} (n-1)\ 1.18^{-n} = 163{,}218$$

(Chemicals and transport):

$$\frac{N}{20} \times 3{,}992 \times \sum_{n=2}^{20} (n-1) \times \left(\frac{1.027}{1.18}\right)^{n} = 1{,}509{,}108$$

Economic Costs

Capital:

$$\frac{N}{20} \times 10{,}250 \times 6.2114 = 709{,}885$$

Recurrent:

$$\frac{N}{20} \times 1{,}193 \times 25.6813 = 341{,}611$$

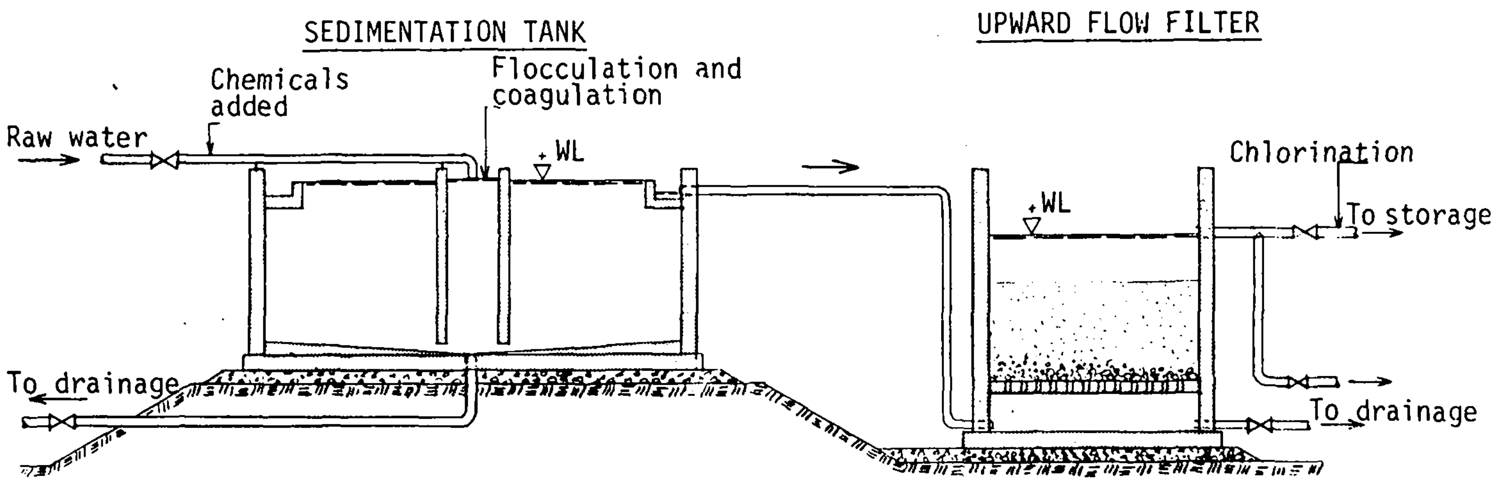
$$\frac{N}{20} \times 6{,}103 \times 33.9043 = 2{,}307{,}135$$

3,358,631

FIGURE 6.3

LAY OUT FOR CHEMICAL TREATMENT PLANT

(Flocculation, Coagulation, Sedimentation, Filtration)



The following units are required for the different daily water demands assumed to be pumped during an 8 hour period:

TABLE 6.2

NUMBER AND SIZE OF SEDIMENTATION UNITS

Q m^3/day	20	40	50	75	100	120	150	200
No. of Units	2	2	2	2	2	2	2	2
Unit Size m^3	10	10	12.5	18.75	25	30	37.5	50

For details of cost estimation of this treatment, see Annex 6.4.

Slow Sand Filtration

The biological filtration that takes place in a slow sand filter is an appropriate treatment method for surface water not having a too high turbidity. The acceptable limit for turbidity water treated by slow sand filters has been set at 30 units; at higher turbidity levels clogging will occur too frequently and make utilization of this treatment method too awkward.

The filter unit containing the sand filter and gravel bed can be made of: (1) reinforced concrete or (2) sloping earth-walls lined with puddled clay or plastic sheet and protected by masonry. The first represents a fairly advanced structure which is both expensive and too complicated to be generally recommended in rural areas. The earth-wall filter "box" requires larger suitable areas and though cheaper to construct tends to be very difficult to maintain with considerable leakages arising from inadequate maintenance. Both of these methods are rejected for rural Tanzania.

Instead we recommend a construction similar to the commonly used storage tanks of block work type. The construction material and method is well known. A section of the proposed filter box is shown in Annex 6.5 and the layout is sketched in Annex 6.6. Three unit sizes will be enough to cover the range of daily water demands for the villages. In Annex 6.7 is listed the number and size required versus the daily demand of water to be treated. The slow sand filtration may or may not require an extra pumping stage in the water scheme depending on the relative levels of the water source and treatment plant. Both alternatives are covered in the cost investigation below.

The construction cost for one filter box unit is given in Annex 6.8. The annual maintenance cost is assumed to be one percent of the construction cost of the unit. Required sand replacement is dealt with separately in Annex 6.9. The cost for an extra pumping stage is described in detail in Annex 6.10.

Apart from proper design, construction as well as maintenance, good operation of slow sand filtration is believed to be the factor on which the result of this treatment method depends. The extra input required in form of a skilled operator is described and costed in a following section. The costs for water demands between 20 and 200 m^3/day is shown in a graph in Annex 6.11.

6.5 Engineering for Three Different Levels of Water Quality

Water treatment may include one or several treatment processes such as storage, chlorination, filtration etc. Each of these treatment processes requires its own equipment and structures for which the engineering design can be done in several different ways.

The treatment required depends upon:

(a) the quality level required of the treated water;
(b) the quality of the raw water.

The cost estimates for treatment to be included in the rural water supplies have been carried out for three levels of the treated water's quality: low, medium and high.

The water sources have been divided in four classes depending on the quality of the raw water:

(1) Ground water from deep boreholes, i.e. a raw water of good quality;

(2) Water from large lakes, springs and protected shallow wells, i.e. raw water of a fairly good quality with a low level of pollution and low turbidity (<30).

(3) Surface water and shallow groundwater from less protected wells, i.e. slightly polluted water with a turbidity of about 30-100.

(4) Surface water e.g. from reservoirs which are moderately polluted and having a turbidity >100 .

For each of the twelve combinations raw water quality/ output water quality, an appropriate treatment is assumed; see the matrix in Table 6.3. Treatment includes operation of the plant and it is specified which level of staff is needed.

For source (4) and the highest quality level it is assumed that the treatment required is too complicated to be used in the rural areas. For villages close to a source of this kind it has been assumed that when the highest quality level shall be required it is necessary to draw water from a better source and transmit the water to the village in question. The cost for this transmission has been included in the cost estimate as part of the treatment cost.

TABLE 6.3

REQUIRED TREATMENT FOR DIFFERENT COMBINATIONS OF WATER SOURCE VERSUS QUALITY LEVEL TO BE REACHED

Quality Level	Water Source			
	(1)	(2)	(3)	(4)
	Groundwater	Turbidity <30 Low Pollution	Turbidity 30-100 Slight Pollution	Turbidity >100 Moderate Pollution
Low	No Treatment	No Treatment	Storage	Storage
Medium	No Treatment	Storage	Chlorination Operator Level A	Flocculation, Settling and Filtration. Chlorination. Operator Level C
High	Chlorination. Operator Level A	Slow Sand Filtration. Chlorination. Operator Level B	Flocculation, Settling and Filtration. Chlorination. Operator Level C	Source Recommended to be Rejected.

6.6 Manpower Requirements for Operation of Water Treatment Plants

When treatment is included in a water supply scheme the operations and preventive maintenance will increase the workload on the personnel at the scheme. In many cases additional personnel are needed and in all cases more skilled and trained personnel is required. The work-load will not increase significantly with increased water consumption as the quantities discussed here are rather small (20-200 m^3/day). The extent of treatment will increase the cost of operations.

Three levels of strengthening the staff are considered for rural water supplies.

(a) Upgrading of the pump attendant (or equivalent) through training to the level of water technician grade II.

(b) Additional staff, water technician grade I.

(c) Additional staff, water technician grade I plus water technician grade II.

When the treatment is only of type "increased storage" no extra skill or personnel is required, even if tank cleaning has to be more frequent. When only chlorination is included as treatment, level (a) above will suffice.

Chlorination and slow sand filtration will require a staff member skilled enough to deal only with the treatment process. The level (b) above will be required.

When even further treatment is included as e.g. flocculation and settling level manpower of (c) will be required due to the extra work load and skill required.

The cost implications at the various levels are calculated as follows:

Level (a)

The difference between a pump attendant upgraded to water technician grade II and the pump attendant is (440-380) TSh. 60/- per month.

The annual cost, taking into account annual leave and sickness will be about $(12+2)\cdot 60$ = TSh.840 per year allowing 2 months per annum for illness and leave.

Level (b)

An additional staff: (12+2).600 = TSh. 8,400/- per year.

Level (c)

Additional staff: (12+2) (600+440) = 14,560/-.

The required increase of operational staff for treatment as a funcion of the water source/quality level alternatives is represented in Table 6.4.

The table is valid for all flows dealt with (20-200 m^3/day).

TABLE 6.4

FOR ALL Q LEVEL OF OPERATIONAL INPUT - ANNUAL COST IN TSH

Quality Level	(1)	(2)	(3)	(4)
Low	-	-	-	-
Medium	-	-	Level (a) (840)	Level (c) (14560)
High	Level (a) (840)	Level (b) (8400)	Level (c) (14560)	-

Note: Water sources are as defined in Table 6.3.

The training of personnel required for the different levels will be discussed in Section 9.6.

6.7 Projections of Source Use

The cost for water treatment is based on the source type that will be used for the water supply schemes, the number of treatment plants that will be constructed, maintained and operated and the size of the population served per scheme.

The annual population increase is assumed to average 2.7%. The present situation as regards distribution of water sources, number of existing water supplies and the number of people served is discussed in Chapter 3.

In order to make a forecast for a 20 year period, some of the completed Water Master Plans have been used (West Lake, Mwanza, Mara, Mtwara, Lindi and Shinyanga). From these reports the recommended source for each village have been noted as well as the present population, i.e. the size of the scheme. The percentage of the population in the region to be supplied from each of the four different source categories has then been calculated. These distribution figures together with general knowledge of the different regions as regards hydrogeology etc. have made it possible to judge the distribution of how many people will be served from each type of water sources, in regions where no information from e.g. Master Plans are available.

The results of these projections are set out in Table 6.5 for each region. The projections are made using available knowledge of the water source conditions, and general water development characteristics of the region. Finally, the average scheme size is estimated from available dates and expert judgement.

6.8 Cost of Treatment

For each region we have estimated the total cost (operations, maintenance, and capital) for each treatment level and raw water quality. The results are presented as present values of the economic costs. The national total is also presented. The regional tables are in Annex 6.12 the national table is given as Table 6.6. The results are as follows. For the low treatment level a 47 million shilling sum is required. It must be kept in mind that this is a present value taken using an 18% discount rate. For the middle level treatment, we have a total of 192 million shillings and for the high level 937 million. These cost estimates will subsequently be used in the benefit-cost analysis to indicate whether these treatment levels will generate enough benefits to justify the expenditures.

TABLE 6.5

PROJECTED DISTRIBUTION OF POPULATION ON WATER SOURCE TYPE

(Population per Scheme valid for 1978)

Region	Total Rural Population 1978 x 1000	Water Source Type (1)			(2)			(3)			(4)		
		No. of Schemes	Pop. Scheme	% of Pop.	No. of Schemes	Pop. Scheme	% of Pop.	No. of Schemes	Pop. Scheme	% of Pop.	No. of Schemes	Pop. Scheme	% of Pop.
Arusha	742	38	3000	15	130	2000	35	223	1500	45	38	1000	5
Coast	606	31	2000	10	137	2000	45	142	1500	35	61	1000	10
Dar es Salaam	45	10	1800	40	24	750	40	6	1500	20	-	-	0
Dodoma	880	308	2000	70	59	1500	10	44	2000	10	44	2000	10
Iringa	886	133	3000	45	133	2000	30	89	2000	20	30	1500	5
Kigoma	524	79	3000	45	105	2000	40	27	2000	10	18	1500	5
Kilimanjaro	859	43	3000	15	129	2000	30	237	2000	55	-	-	0
Lindi	504	114	2071	47	78	2098	33	32	1014	6	43	1666	14
Mara	744	194	2500	65	149	1500	30	8	1000	1	20	1500	4
Mbeya	944	158	3000	50	142	2000	30	95	2000	20	-	-	0
Morogoro	813	136	3000	50	122	2000	30	82	2000	20	28	1500	5
Mtwara	492	78	2957	47	60	1634	20	67	1561	21	50	1177	12
Mwanza	1311	263	3000	60	324	1500	37	40	1000	3	-	-	0
Rukwa	354	18	2000	10	107	1500	45	83	1500	35	36	1000	10
Ruvuma	507	17	3000	10	127	2000	50	76	2000	30	34	1500	10
Shinyanga	1126	285	988	25	254	2000	45	169	1000	15	113	1500	15
Singida	517	241	1500	70	35	1500	10	35	1500	10	52	1000	10
Tabora	608	41	1500	10	183	1500	45	142	1500	35	61	1000	10
Tanga	890	45	2000	10	201	2000	45	156	2000	35	60	1500	10
West Lake	826	185	3000	67	87	2000	21	46	2000	11	6	1500	1
TOTAL	14178	2419	2330	40%	2586	1800	33%	1799	1670	21%	694	1340	6%

Rural population figures based on 1967 census and annual growth rate of 2.7%.

COST FOR WATER TREATMENT IN TShs x 1000

TABLE 6.6 PRESENT VALUES OF ECONOMIC COSTS FOR TANZANIA

Qual. level	Treatment blocks	WATER SOURCE			
		(1)	(2)	(3)	(4)
Low	Storage Chlorination Slow sand filtr. Flocc+coag+filtr. Manpower				
	Total			35,641	11,577
Med.	Storage Chlorination Slow sand filtr. Flocc+coag+filtr. Manpower				
	Total		53,080	32,705	106,077
High	Transmission Storage Chlorination Slow sand filtr. Flocc+coag+filtr. Manpower				
	Total	24,743	418,527	262,949	230,858

Grand total for low quality level 47,218
medium " " 191,862
high " " 937,077

6.9 Costs of Treatment Methods

In this section we report the results of the cost calculations for different volumes of water delivered and different methods of treatment. The capital costs are given in Table 6.7. This table reports both the economic and financial costs for daily capacities ranging from 20 m^3/d to 200 m^3/d. The economic cost reflects all foreign exchange costs revalued at 2.5 times the nominal cost and unskilled labour valued at 90% of the minimum wage. This table indicates the tremendous range of initial costs in the four treatment methods. Chlorination is the cheapest; followed by storage and then sedimentation and slow sand filters are much more expensive. Tables 6.8 and 6.9 report the maintenance and operations cost respectively. Maintenance depends essentially upon the size of the initial cost; operations costs vary from zero for storage to fairly substantial amounts for chlorination and high costs for sedimentation and lower costs for slow sand filters. Having computed the costs for the three categories we now combine them into a single cost and also a unit price. To combine the annual O&M costs with the capital costs require an interest rate; we have computed four cases:

Economic costs 18% interest rate: Table 6.10
Economic costs 12% interest rate: Table 6.11
Economic costs 9% interest rate: Table 6.12
Financial costs 9% interest rate: Table 6.13

The results for storage are graphed in Figure 6.4; for chlorination in Figure 6.5; sedimentation in Figure 6.6; and slow sand filter in Figure 6.7.

From these tables and graphs we can see that storage is the cheapest method of providing treatment. For a 100 m^3/day scheme the financial cost (9% interest) is 0.17 Tsh/m^3. Chlorination costs 0.31 Tsh/m^3 (financial); sedimentation 0.60 Tsh/m^3 and slow sand filters 1.40. The complex treatment methods add a quite considerable cost to the provision of water.

TABLE 6.7

CAPITAL COSTS OF TREATMENT METHODS
(T shillings)
Economic Financial

Quantity m³/day	Treatment method			
	Storage	Chlorination	Flocc.+Coagul. Sedimentation Filtration	Slow sand filt.
20	21 200 14 400	7 990 3 340	194 000 94 700	214 200 79 800
40	39 700 27 100	8 190 3 540	204 200 101 800	241 200 106 800
50	47 400 32 400	8 310 3 660	208 300 104 700	254 700 120 300
75	64 300 44 100	8 590 3 940	217 000 111 000	288 500 154 100
100	76 600 52 700	8 870 4 220	224 400 116 300	322 300 188 000
120	85 200 58 700	9 070 4 420	229 700 120 100	349 400 215 000
150	137 600 94 100	9 390 4 740	236 800 125 400	390 000 255 600
200	162 500 111 500	9 950 5 300	247 200 133 200	457 600 323 200

with pumping stage

TABLE 6.8

MAINTENANCE COSTS FOR TREATMENT METHODS
(T shillings)

Economic Financial

Quantity m3/day	Treatment method			
	Storage	Chlorination	Flocc.+Coagul. Sedimentation Filtration	Slow sand filt.
20	212 / 144		7 360 / 3 450	7 325 / 3 490
40	397 / 271		7 460 / 3 520	7 665 / 3 745
50	474 / 324		7 500 / 3 550	7 945 / 3 965
75	643 / 441	545 / 310	7 590 / 3 610	8 265 / 4 170
100	766 / 527		7 660 / 3 665	8 690 / 4 495
120	852 / 587		7 715 / 3 700	8 865 / 4 595
150	1 376 / 941		7 785 / 3 755	9 430 / 5 036
200	1 625 / 1 115		7 890 / 3 835	10 175 / 5 565

with pumping stage

TABLE 6.9

OPERATION COSTS FOR TREATMENT METHODS

(T shillings)

Economic Financial

Quantity m3/day	Treatment method			
	Storage	Chlorination	Flocc.+Coagul. Sedimentation Filtration	Slow sand filt.
20	0	4 205 2 875	20 645 17 730	12 420 10 845
40	0	6 920 4 650	25 630 20 380	15 220 12 665
50	0	8 275 5 535	27 730 21 515	16 695 13 810
75	0	11 665 7 755	32 875 24 315	17 875 14 415
100	0	15 055 9 970	37 440 26 840	19 780 16 015
120	0	17 770 11 745	40 510 28 590	20 085 16 405
150	0	21 835 14 405	51 545 34 240	27 260 20 285
200	0	28 620 18 840	59 845 38 900	28 935 21 825

with pumping stage

TABLE 6.10

TOTAL ANNUAL ECONOMIC COST FOR TREATMENT METHODS
(interest rate 18%)
(TSh.)
Annual Cost
Cost per m^3

Quantity m^3/day	Treatment method			
	Storage	Chlorination	Flocc.+Coagul. Sedimentation Filtration	Slow sand filt.
20	4 175 .57	7 305 1.00	55 170 7.56	76 935 10.54
40	7 815 .54	10 085 .69	57 075 3.91	85 125 5.83
50	9 330 .51	11 480 .63	57 840 3.17	89 410 4.90
75	12 655 .46	14 960 .55	59 475 2.17	97 180 3.55
100	15 080 .41	18 440 .51	60 850 1.67	105 960 2.90
120	16 745 .38	21 220 .48	61 830 1.41	111 400 2.54
150	27 085 .49	25 385 .46	63 160 1.15	126 720 2.31
200	31 985 .44	32 350 .44	65 105 .89	141 770 1.94

TABLE 6.11

TOTAL ANNUAL ECONOMIC COST FOR TREATMENT METHODS
(interest rate 12%)
(TSh.)
Annual Cost
Cost per m^3

Quantity m^3/day	Treatment method			
	Storage	Chlorination	Flocc.+Coagul. Sedimentation Filtration	Slow sand filt.
20	3 050 .42	6 970 .95	46 740 6.41	67 005 9.18
40	5 715 .39	9 740 .67	48 105 3.29	73 765 5.05
50	6 820 .37	11 125 .61	48 655 2.67	77 330 4.24
75	9 255 .34	14 595 .53	49 825 1.82	83 305 3.04
100	11 025 .30	18 065 .49	50 810 1.39	90 300 2.47
120	12 235 .28	20 835 .48	51 515 1.17	94 310 2.15
150	19 800 .36	24 985 .46	52 465 .96	107 485 1.96
200	23 380 .32	31 925 .44	53 860 .74	118 955 1.63

TABLE 6.12

TOTAL ANNUAL ECONOMIC COST FOR TREATMENT METHODS

(interest rate 9%)
(TSh.)

Annual Cost
Cost per m^3

Quantity m^3/day	Treatment method			
	Storage	Chlorination	Flocc.+Coagul. Sedimentation Filtration	Slow sand filt.
20	2 535 .35	6 805 .93	42 745 5.85	62 330 8.54
40	4 745 .33	9 570 .66	43 860 3.00	68 435 4.62
50	5 670 .31	10 960 .60	44 310 2.43	71 875 3.93
75	7 690 .28	14 420 .53	45 265 1.65	76 821 2.81
100	9 160 .25	17 880 .49	46 075 1.26	83 000 2.27
120	10 160 .23	20 650 .47	46 650 1.0	86 350 1.97
150	16 450 .30	24 795 .45	47 430 .87	98 530 1.80
200	19 430 .27	31 725 .43	48 570 .67	103 360 1.48

TABLE 6.13

TOTAL ANNUAL FOR TREATMENT METHODS

(interest rate 9%)

(TSh.)

Annual Cost
Cost per m^3

Quantity m^3/day	Treatment method			
	Storage	Chlorination	Flocc.+Coagul. Sedimentation Filtration	Slow sand filt.
20	1 725 .24	4 045 .55	20 380 2.79	35 810 4.91
40	3 240 .22	5 870 .40	21 155 1.45	40 155 2.75
50	3 875 .21	6 785 .37	21 475 1.18	42 655 2.34
75	5 275 .19	9 080 .33	22 160 .81	46 300 1.69
100	6 300 .17	11 365 .31	22 745 .60	51 065 1.40
120	7 020 .16	13 195 .30	23 165 .53	53 820 1.23
150	11 250 .21	15 935 .29	23 740 .43	61 550 1.12
200	13 330 .18	20 515 .28	24 595 .34	69 300 .95

FIGURE 6.4
TOTAL ECONOMIC AND FINANCIAL COST FOR STORAGE

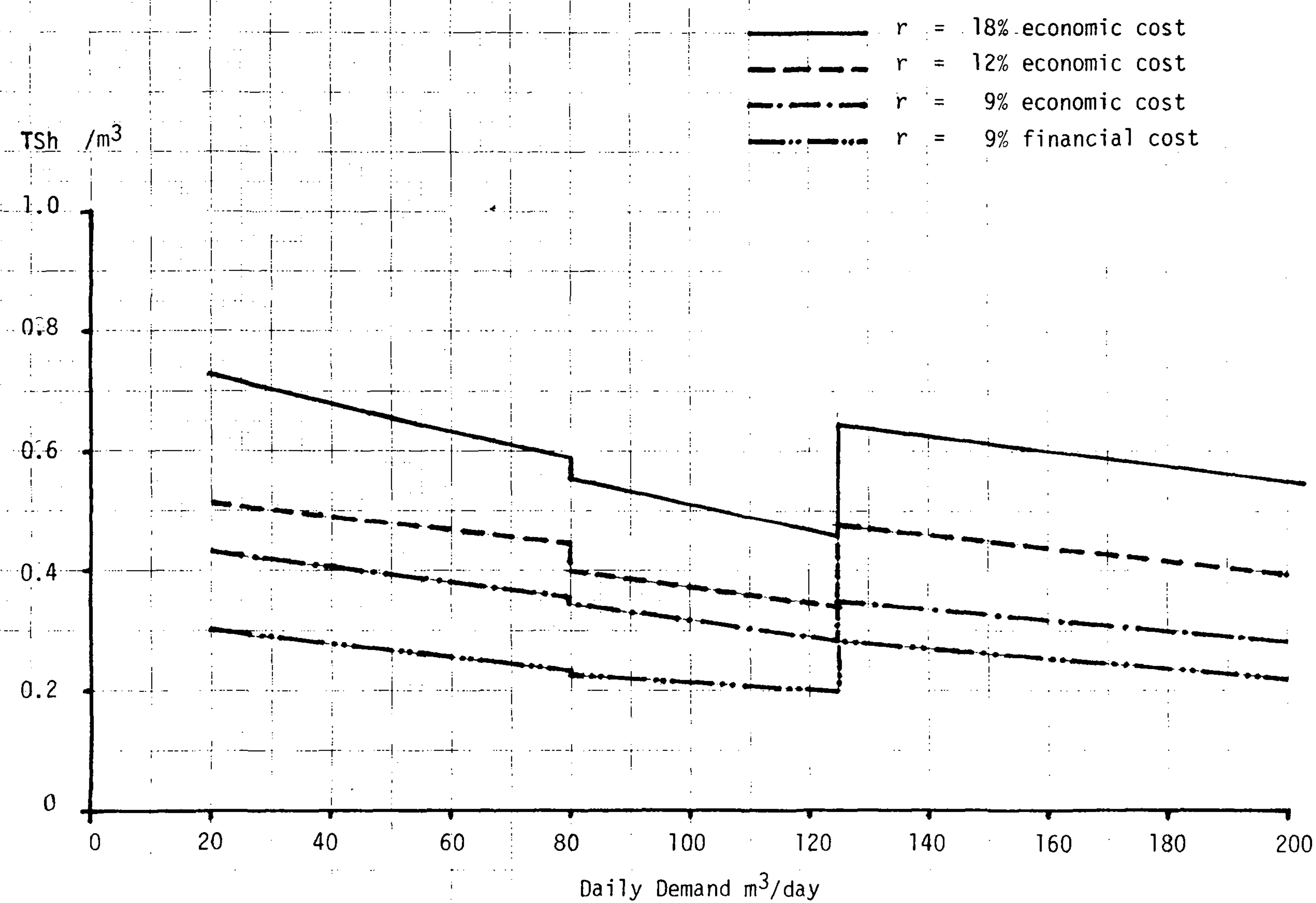
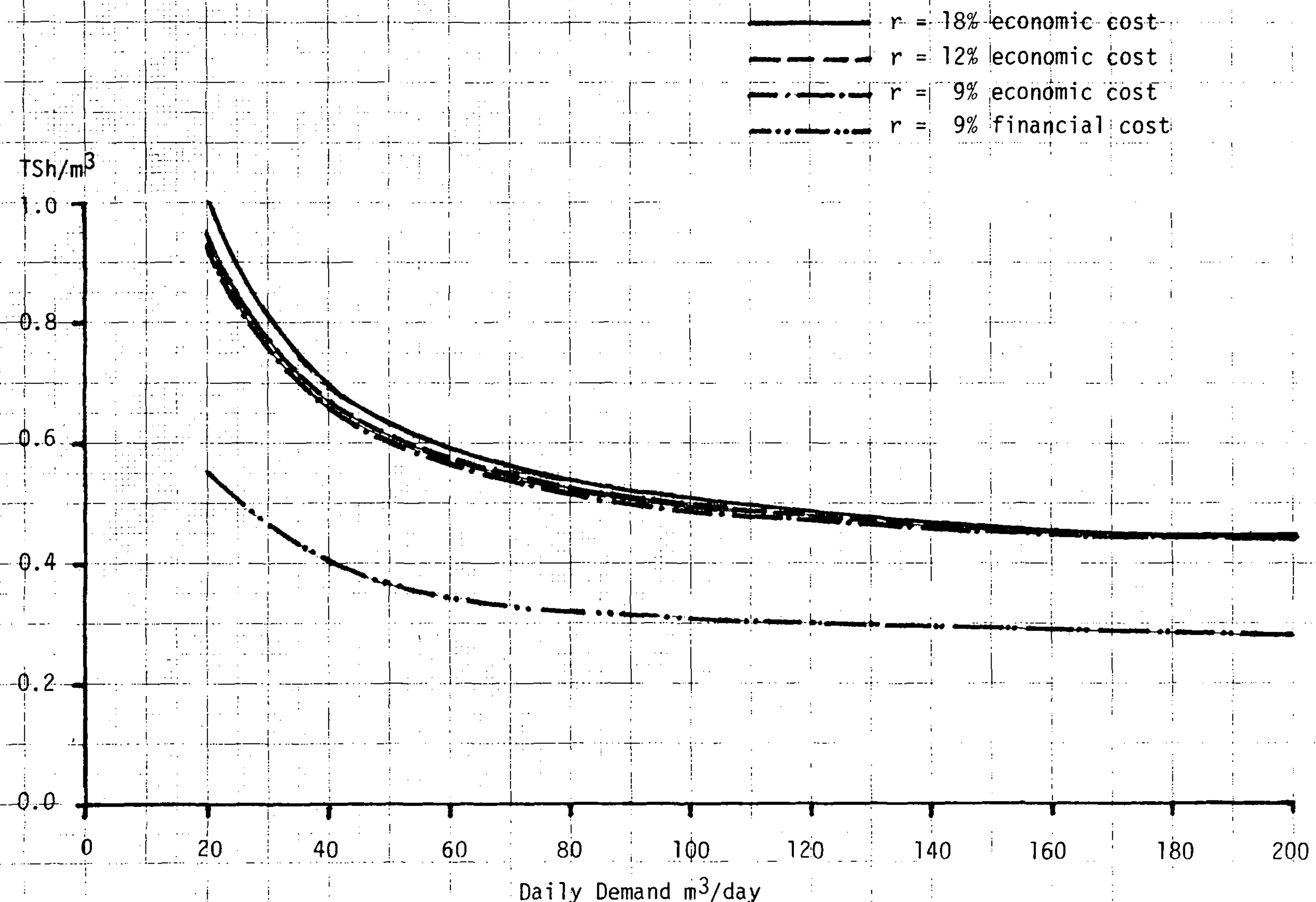
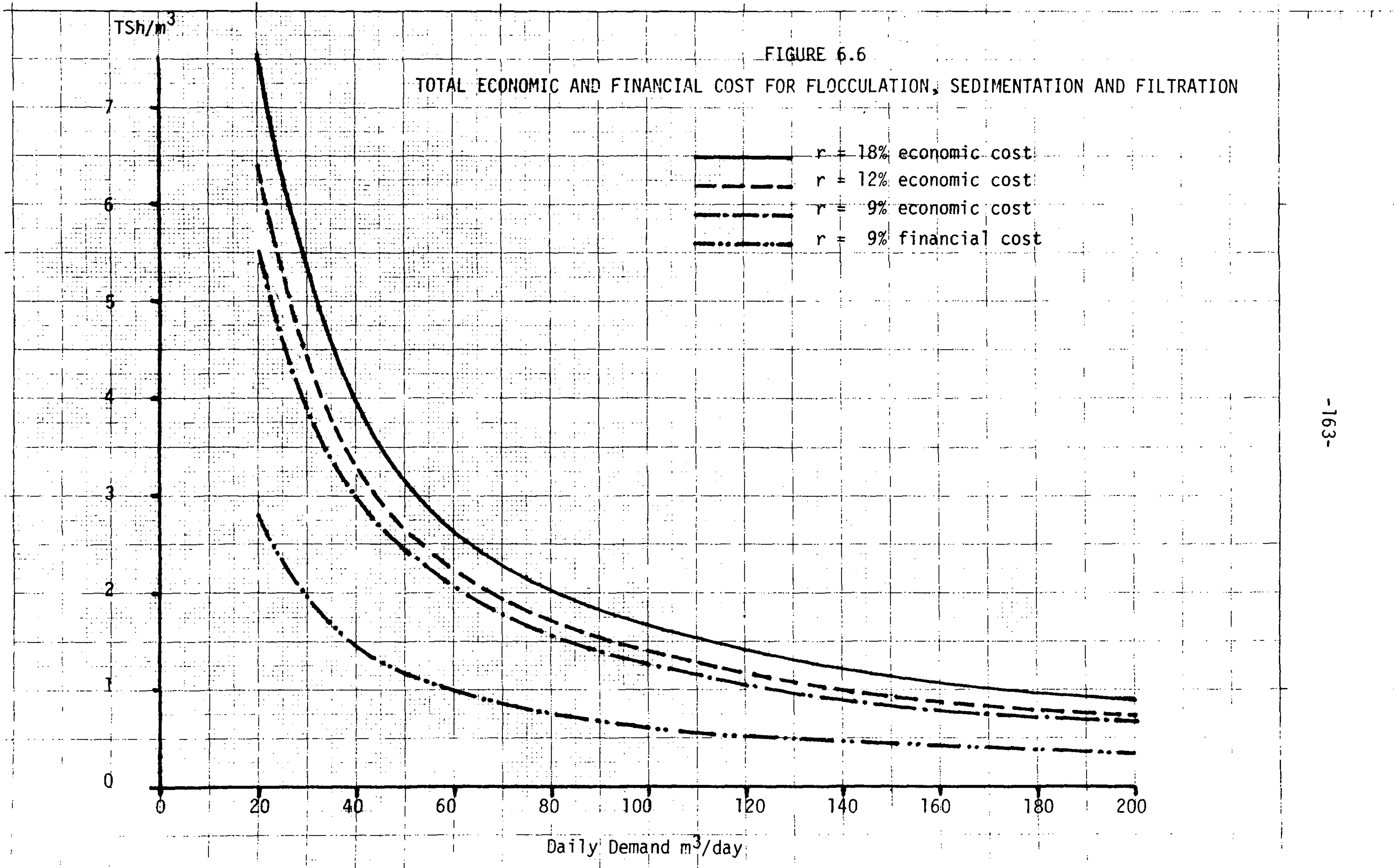


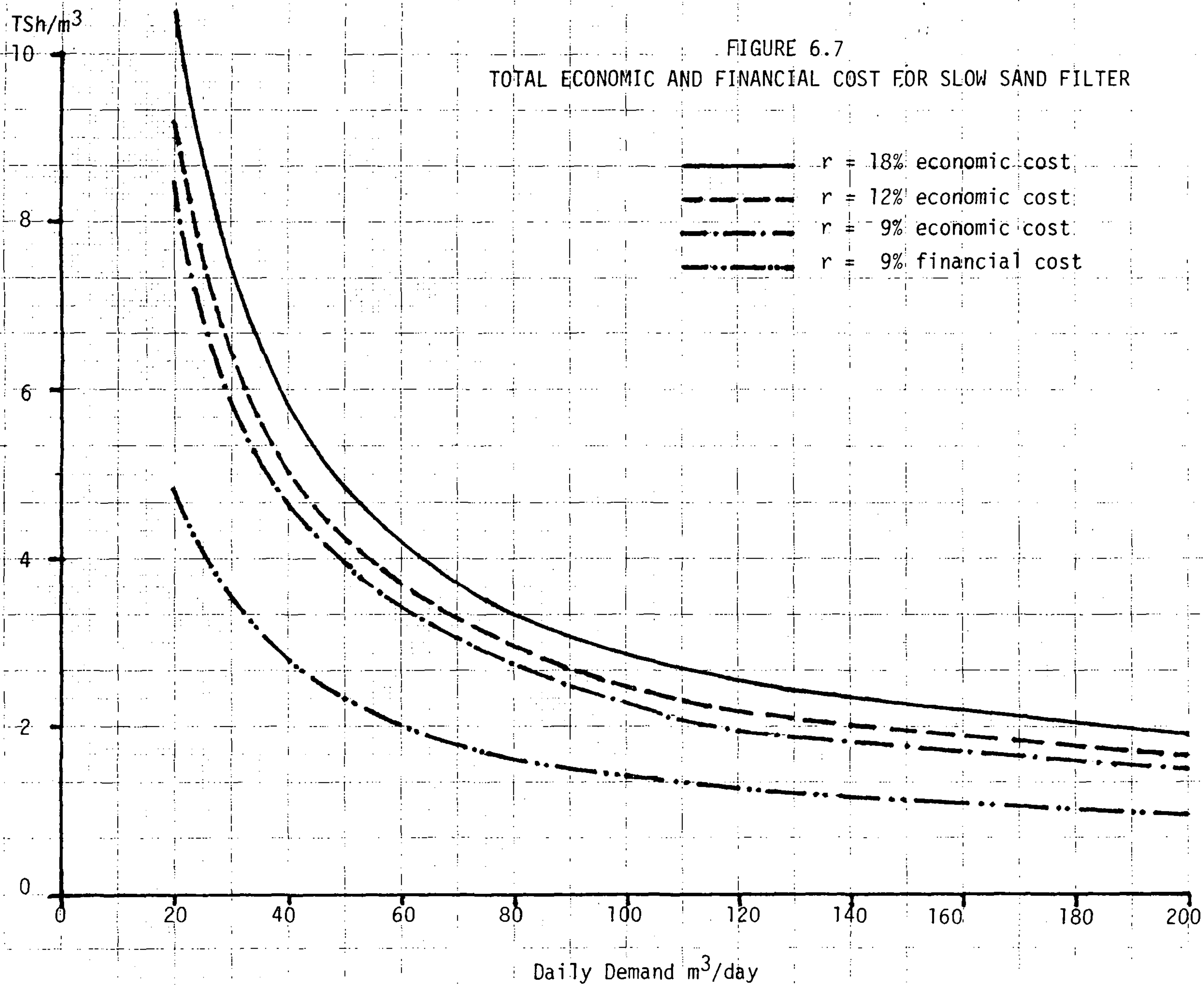
FIGURE 6.5
TOTAL ECONOMIC AND FINANCIAL COST FOR CHLORINATION





TSh/m3
FIGURE 6.6
TOTAL ECONOMIC AND FINANCIAL COST FOR FLOCCULATION, SEDIMENTATION AND FILTRATION
r = 18% economic cost
r = 12% economic cost
r = 9% economic cost
r = 9% financial cost
0
1
2
3
4
5
6
7
0
20
40
60
80
100
120
140
160
180
200
Daily Demand m3/day

FIGURE 6.7
TOTAL ECONOMIC AND FINANCIAL COST FOR SLOW SAND FILTER



CHAPTER 7
A COST/BENEFIT APPROACH TO IMPROVING WATER QUALITY IN RURAL AREAS OF TANZANIA

7.1 The Aim of Cost/Benefit Analysis (CBA)

Central to the choice of a water quality policy is the comparison of alternatives in such a manner as to permit the decision maker to choose the best policy. The "best policy" depends upon what the policy maker is attempting to accomplish, i.e. there must be a well defined objective. The approach used here is benefit-cost analysis (CBA). In Chapter 5 we have reviewed the water quality-health linkage; Chapter 6 formulated alternative engineering solutions and presented the results of cost computations. In this chapter we present estimates of the beneficial aspects of improving water quality and compare these to the cost estimates. Out of this comparison we identify the recommended approach to water quality treatment. The method we use is known as benefit-cost analysis. In this first section we discuss the background and meaning of the approach and its application to the water quality programme.

The basic idea of CBA is simple. To decide the worth of a project involving public expenditure (or any public policy choice in general) it is necessary to weigh the advantages and disadvantages so as to produce a measure of worth which can be compared to alternative investments or projects. The application of CBA is usually confined to public projects because the advantages and disadvantages are defined in terms of social gains and losses. Actually private investors carry out similar analysis but restrict the benefits and costs to those which effect them directly. The idea of weighing the social pros and cons, appears well founded in rationality, since it would seem perverse to choose a policy or a project which is known to have harmful net effects or which is less beneficial than an alternative.

Essentially, CBA purports to be a method of determining social choices. Where only one option is to be chosen from a series of alternative options, CBA should inform the decision-maker as to which option is socially most preferred. It is well known that there are grave difficulties with consistent, rational social preference systems which are sensitive to individual preferences. We follow the practitioners practice of turning our back on these difficulties and simply asserting that there is conceptionally a social preference system and that we can approximate it using the CBA methodology. In principle any consistent preference system would, do but in all applications the implicit judgement is that individual preferences should count. In a sense this way could be called very democratic: it is equivalent to obeying the maxim of consumers' sovereignty. CBA is a method of recording and adding these preferences, either as they are revealed directly in the market, or, where no market exists, or when the market is distorted, as the cost-benefit analyst sees them revealed indirectly through other means subsequently reducing all these preferences to a unique overall figure, which gives the net benefits to the society.

CBA is sometimes treated as a decision-makers dream, a golden rule which actually substitutes a simple figure for the judgement he might otherwise have to express, and consequently mechanizes decision-making. The use of CBA therefore meets a desire for certitude and simplicity. But to treat it in such a simplistic way is to venture onto dangerous ground. One should never forget that CBA is only a guide, an aid to decision-making, providing it gives an approximation of the social preference system. It does not follow that what society wants as indicated by CBA is good for society - nor that CBA has valued correctly or at all those factors the decision-maker wishes to take into account.

The decision-maker is assumed to have an objective function which he aims to maximize. This objective function measures the net social benefits, defined in a way as to incorporate all things which contribute to or detract from welfare. CBA, as we apply it here, really asks whether the proposed action generates more resources than it uses up. If there is a net contribution of resources available, then it is possible that the society will choose a distribution of the additional resources that everyone would find acceptable. Of course, the society may not do this; the generated resources may be wasted or may be confiscated by some group reducing the welfare of another group. We do not ask whether the project or policy is good in itself but whether it generates a surplus of resources. In the project under analysis it is assumed that society's welfare increases if the social benefits (additional resources to society) of the treatment of water exceed the social costs (resources used up). All those who have costs or other disadvantages can be compensated by those who have the benefits and still "something" is left. This possibility of satisfying the economists "Pareto-criteria", is the welfare basis of all cost-benefit analyses. We emphasise that this compensation need not happen but the potential is there; the compensation is a political decision, not an analytical one.

What, then, are social costs and social benefits? Social costs represent the value of the resources in the best alternative use, i.e. the opportunity value. If, for instance, a certain category of personnel is subject to unemployment or underemployment, then wages paid may overestimate the value of the production we lose by employing or using this factor. On the other hand the prevailing situation in many under-developed countries is that their currencies are overvalued to some extent. It is therefore necessary to correct for this by weighing up the foreign exchange rate by some factor for those inputs which are imported.

The market price can also diverge from the opportunity value of the resources because of subsidies, taxes or duties on the factors of production. In the same way this correction is also needed. The correction factors used in this analysis are discussed in the cost section (Chapter 6). The determination of opportunity costs for resources used is well known and the rules for so doing are discussed elsewhere. These are some of the difficult problems associated with the measurement of costs. But it is in the calculation of the social benefits of improving water quality that the greatest problems arise. In this analysis we confine the benefits to the health area, even if other benefits could result.

According to welfare theory, the benefits equal people's willingness to pay for better health due to improvement in water quality. We need not ask what people think. They gain better water if we know that they truly wanted this from the fact that they would pay for it. The willingness to pay is the direct evidence of preference. But the health effects are very difficult to identify and describe, and even if these difficulties were overcome, the problem of value remains.

Since willingness to pay is not revealed in traditional markets, it cannot be derived from calculations based on market prices. Because of the difficulties involved in direct estimates of willingness to pay for an improvement in health, several methods intended to provide indirectly a measure of the benefits have been developed[1]. Apart from the difficulty of handling the revealed choices to carry out the benefit-cost analysis this is an area where we can expect externalities, i.e. social costs not understood or accepted by the rural population due to ignorance, yet ultimately beneficial to society.

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1) There are three possible market observations that could bear on the question of preferences. First there is a market for water in some rural areas; however, in our observation of this market there is no discernable distinction between good and poor quality water. Second, we observe behavior of source preferences where the perceived quality of water leads people to travel further to fetch it. Finally, it is generally known in the villages that boiling drinking water will improve the quality, yet we find very little evidence that people do boil water. None of these market related observations is satisfactory to base analysis on.

The measures we devise here are estimates which are not necessarily perceived as relevant by the individual. The four most common methods of estimating indirectly the value of an improvement in health are based on:

(a) averted costs for medical care

(b) increase in production

(c) evaluations implicit in the political process

(d) the insurance principle.

(a) If certain medical care costs can be averted as a result of an improvement in water quality, resources will be saved and will be available for other purposes. The advantage of this method is that the resources saved have a market price which can be used for valuation of the saved resources. These benefits are quite beyond argument; their evaluation is sometimes rather difficult but this saving certainly releases resources available for other uses.

(b) An individual's death or ill-health reduces the supply of productive factors, assuming full employment and that the individual is gainfully employed. If his life can be prolonged or his health improved, production has the potential to increase. This method, however, equates social welfare with the size of GNP, a welfare measure often criticised. If we accept this method as providing a rough measure of welfare and assume a person's wage as equal to his contribution to production, the value of an improvement in health is quantified as the discounted value of the increase in earnings engendered by the improvement in health. Again this measures the availability of resources. Although this method is not supported by the economic welfare theory underlying CBA, it has become the predominant method of calculating the benefits from health projects. The method is easy to use and it sets a minimum value on health or life. The problem is that there is only presumptive evidence that these valuations represent what people would pay.

(c) The third method starts from the values implicitly assigned to health in the political process. By studying certain political decisions you could indirectly establish the value that is set upon a human life or a particular health risk. This method, however, has not been used very much, partly because it is difficult to find a consistent thread running through the various political decisions.

The political process usually fails to identify priorities except through the budget allocations. It is inevitable that the political discussions in a society will generate very ambitious goals all of which cannot be met by the resources available. The resolution of the relative importance of objectives only takes place when the budgetary process reveal just what Government is prepared to pay. The use of budget allocations however is rather close to the choice of an interest rate which will reduce selected projected to the level of resources available.

(d) The insurance principle formulates the problem so that the answer to the following question is wanted: how much are the members of the society prepared to pay to reduce the risk of death and illness. When one is sick or about to die one would pay a great deal to recover; the insurance question asks the realistic question of how much one is willing to pay to reduce risk. This method has the advantage of being the only method consistent with the Pareto base of welfare economics in reflecting an actual transaction price. On the other hand its use involves so many practical problems that empirical analysis based on this method almost certainly will fail, especially in underdeveloped countries with incomplete or non-existent insurance markets, particularly in rural areas.

In order to obtain an estimate of benefits from improvement in health and prolonged life we will, in this analysis, use the first two methods. However, the estimations must be used with caution. Details of the estimations made will be given in Section 7.4:"Estimates of the benefits of water treatment".

In brief we compute the released resources and compare with the utilised resources. We never ask:

(1) do people want the results obtained from potential increase in resources, and

(2) who benefits from the improvements.

7.2 Formulation of the Problem

The problem in this analysis is to choose among three different strategies of water treatment for the rural areas of Tanzania. These strategies are called low, medium and high levels according to the standard of water quality achieved. The following table (Table 7.1) shows what kind of treatment will be utilised for each different type of water sources for each strategy. A further description of the treatment activities is made in the engineering section. Table 7.1 is the same as presented in Chapter 6 and is repeated here for the convenience of the reader.

TABLE 7.1
REQUIRED TREATMENT FOR DIFFERENT COMBINATIONS
OF WATER SOURCE VERSUS QUALITY LEVEL TO BE REACHED

Quality Level	Water Source (1) Groundwater	(2) Turbidity <30 Low Pollution	(3) Turbidity 30-100 Slight Pollution	(4) Turbidity > 10 Moderate Pollution
Low	No treatment	No treatment	Storage	Storage
Medium	No treatment	Storage	Chlorination	Flocculation, Settling and Fillration. Chlorination.
High	Chlorination	Slow Sand Filtration	Flocculation, Settling and Chlorination	Source Recommended to be Rejected.

For each higher level of treatment the costs will rise and it is assumed that the corresponding benefits will also rise with the higher level of treatment undertaken. We assume that, independent of treatment level, the water treatment programme will be finished at the end of the 20th year if we start the programme in year 1. In order to evaluate and compare the different levels we calculate a present value of all costs and benefits for each level. If the benefits exceed the costs the project (the level) is socially worthwhile. If we accept that one level of treatment must be undertaken whatever the budget restrictions are (this means that the comparison of other projects with water treatment is not considered) we must rank the different water quality level according to their net benefits. The result will be that we choose that level which give rise to the largest net benefits.

Different actions taken in the water treatment field will have effects far in the future, and the costs will also be spread over several years. In this project we assume a 20 year planning period so that all the planned water schemes should be built within 20 years, i.e. at a rate of 5% per year. If we look at this as an investment process the characteristic feature is that the costs will appear in advance of the benefits or costs prevented. In some way it is therefore necessary to make the benefits and costs arising at different times commensurable. The most frequent method of handling this is to discount the costs and benefits at a special time at a previously determined discount rate. Generally this time will be the start of the project so that a present value is calculated. A positive rate of discount means that the costs and benefits are assigned a lower value the further in the future they occur. At a 6% discount rate the present value of 100 TShs arising 10 years from now will be 55.84 TShs. At a rate of 12% the present value is decreased to 38.55 TShs. The higher the rate of discount the lower the value assigned to future effects. If the discount rate is 0% the costs and benefits will have the same value whenever they appear in the future.

The reason for a positive discount rate are many. The most usual arguments rest on the assumption that per capita income will increase over time and that the individuals will have diminishing marginal satisfaction from consumption. An increase in production, and therefore consumption, of a certain amount is therefore less valuable the further in the future it occurs. Uncertainty of the future and the probability of death are other arguments in favour of a positive discount rate.*

In addition to the social time preference rate which the above discussion suggests should be positive it is necessary to take account of alternative uses of the capital - the opportunity cost of capital. In a country such as Tanzania the demand for investment resources for projects with 9-10% returns seems very large - in excess of anything that is likely can be financed. An appropriate interest rate to use for the present value calculation is that which brings down total investment requirements from projects with positive present value to equal the value of investable resources.

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* For a fuller discussion of these problems see Guidelines for project evaluation, United Nations, New York 1972.

7.3 The Costs of Different Levels of Water Treatment

The costs used in this analysis will only refer to the treatment cost and the costs for manpower requirements for operation of water treatment plants. The costs for boreholes, pipelines and so on is not included. In order to come to the social costs for water treatment we have the financial costs in 1978 prices as a base. The costs arising from use of local unskilled labour will be corrected for by a factor 0.9 and the costs referred to imported material and expatriate labour will be increased by a factor of 2.5 due to the assumption that forign currency is substantially undervalued, i.e.instead of using the official exchange rate of a dollar as about 8 shillings we use a value of 20 shillings per dollar. According to the calculations given in the cost section we will have the following present values for the selected water quality levels when we use a discount rate of 18%, 20 years planning period and a construction plan indicating a construction of 5% per year of the total designed water schemes. The costs are given as a summary for the whole rural population.

Low	47,218,000/-
Medium	191,862,000/-
High	937,077,000/-

The costs per each region are given in an appendix to the cost section. These costs are based on the assumption that the total rural water programme is achieved, covering the entire rural population.

7.4 Estimation of Benefits of Water Treatment

When water quality is improved it is assumed that the health standard also will improve due to the fact that the incidence of many diseases is related to polluted water. These relationships are fully discussed in Chapter 5 in this report and we will use the results of that discussion to arrive at an approximate figure of the potential benefits one can count upon if all waterborne (F O) diseases are eliminated. We are then able to determine tne percentage reduction in F O diseases, for each level of treatment, equal to the present value of costs.

The benefits estimated in this section can be divided into two main groups. Firstly, one has benefits due to F O diseases avoided, which would have caused illness but no deaths; and secondly one has benefits from deaths avoided due to the reduction of F O diseases.

Estimation of Benefits from a Situation where all Faecal-Oral Diseases are Avoided

The benefits will consist of costs saved when faecal-oral diseases are eliminated. These costs will include reductions in hospital costs for inpatients and outpatients, disease costs evaluated as lost earnings, costs for transportation and waiting time in connection with attendance at hospital and dispensary.

AFYA Costs

We have inpatient and outpatient attendances for FO diseases as percentage of all attendances for each region in the country. These can be used to estimate the fraction of AFYA expenditure going to each of these services in treating these potentially waterborne diseases.

The AFYA expenditure is 47/- per person per annum. This has been increasing rapidly and for the above estimate the 1978/1979 budget appropriation has been used. The allocation of this cost to hospitals is very difficult. Essentially we argue that all AFYA expenditures are associated with hospitals; dispensary costs are low in comparison and are neglected. The percent of inpatients and outpatients with FO disease is quite similar so it is enough to take this percentage and apply it to the costs of health service to get a per capita estimate of AFYA expenditures on FO diseases. The problem with this assumption is that the allocations to health have been changing rapidly so that the expenditures on the absence of the water quality programme may be much higher than we have assumed.

Disease Costs

We only consider FO diseases serious enough to cause the patient go to a dispensary. We do not have direct data on how many such persons there are but we have carried out investigations as reported in Chapter 5.

We estimate that the real incidence of FO disease (as recorded in dispensaries) is 1.6 times that recorded at hospitals. As each person goes twice per year to the dispensaries on an average, this means that the real incidence rate per person per year is about 3.2 times the proportion of hospital outpatients with FO diseases. This proportion was 12.07% in 1978. For the length of attack for each disease episode we use a figure of 4 days. Altogether the number of FO diseases totals .39 P.

Other AFYA costs

These costs are probably best estimated using the outpatient figures which we have taken to represent the real disease level. Thus it is included in the hospital costs.

Costs in Connection with Transportation to Hospital

With about 80 districts in the country each with a hospital, we estimate a rough average one way travel distance of 90 km. This can be costed at TShs 0.15 (15 cents) per km which is the government controlled bus fare. One-way-going-the patient is sick and we count the value of time that lost from the disease. We assume the patient is well when he returns and so his time must be valued. The cost of travel is therefore (2)(90)(.15) = 27/- per trip. We know that about 1/3 of the population go to hospital every year and further that approximately 15% of all visits are connected with FO diseases. The cost per attendance can then be converted to a per capita cost, and is 1/35. The time spent can also, in a similar way, be converted to a per capita cost and evaluated as lost earnings. If we assume the return journey take a full day including travelling and waiting and we count this as 3/42 per trip or -/17 per person. As only 60% of the population is working this becomes 1/45 per person.

Earning Lost

In order to estimate the production value per day and hour in the rural sector, we start with an assumption of 750/- as a value added per year and capita in 1978 prices. The best available estimate we have is for 1975 in 1975 prices where we have 520/- per person for agriculture. There is a substantial volume of non-agricultured activity carried out by rural population and making allowance for this and price increases we come to the estimate of 750/-. If we assume that 60% of the total rural population is in the labour force with full productivity we will have 750/0.6 = 1,250/- per member of the rural labour force per year. Although the production is spread unequally over the year (wet and dry season) we have not found a similar distribution of the incidence of FO diseases so there is no reason to introduce a weighing system for the average working day's production value; we divide 1,250/- by the number of days in the year (365) to get a daily production value of 3/42 TShs. If we assume 7 hours work per day we will have about 0/5 TSh per hour. These average values will be used to calculate the earnings lost.

The estimation procedure that will be followed divides the benefits into three categories:

- Reduced hospital costs
- Reduced losses in earnings from sickness
- Reduced deaths and hence longer productive lives

Hospital Costs

Sick persons go to the dispensaries and hospitals. Approximately 1/6 of all the sicknesses resulting in dispensary or hospital. (Each person visits a dispensary twice/year; and the number of hospital visits is 1/3 the population). The per capita expenditures of AFYA are taken at 47/- per person; on the average 15% of the hospital visits are for FO diseases (over the past six years). Thus the cost per person of hospital FO cases is 7/05. In addition, we estimate the value of time for transportation and waiting at hospitals to be 1/45 per person. The total cost in transport and hospital charges is then 8/50 per person.

The number of FO cases visiting the hospital for treatment is estimated at 12.8% (if P is total population there are .39 P FO cases and .05 P hospital FO cases i.e. .15 P/3. Hence the FO cases treated in hospital total 12.8%). We take this number of hospital cases will decline (compared to what it would have been in the absence of the water quality programme). The effectiveness of the programme is given by the parameter γ . This is the fraction of correct FO diseases that will be eliminated, i.e. the closer γ is to 1 the greater the reduction in FO diseases. The number of FO attacks per person on the average is:

$$n_0 \left(1- \frac{t\gamma}{20}\right)$$

At t = 0 before we start the programme this is just n_0, and n_0 = .39. At t = 20 the entire population is covered and we have n_0 $(1-\gamma)$ cases FO disease per person. In the calculation we use γ as a parameter.

The population increases at 2.7% per annum. Thus the reduction in the hospital costs at time t $(1 \leq t \leq 20)$:

$$(8/50)(.128)(.39)\ \frac{t\gamma}{20}\ P(0)(1.027)^t = .02122\ t\ \gamma(1.027)^t\ P(0)$$

- (8/50) → Treatment cost per attack
- (.128) → Proportion of attacks to hospital
- $(.39)\frac{t\gamma}{20}$ → Reduction in number of cases
- $P(0)(1.027)^t$ → Rural population

After the twentieth year the reduction in hospital costs are constant at .72294 γ P(0). We do not allow for the population covered to increase further.

Time Lost from Illness

The number of cases is .39P at the beginning (t=0).
There are 4 days lost per case.
The number of cases at time t ($0 \leqslant t \leqslant 20$) is:

$$.39\ (1 - \frac{t\gamma}{20})$$

with the water quality programme but into place over a 20 year period.

This gives the reduction in the value of time lost at time t as:

$$\underbrace{.6}\ \underbrace{(3/42)}\ \underbrace{(4)}\ \underbrace{(.39\ \tfrac{t\,\gamma}{20}}\underbrace{P(0)(1.027)^t} = .16006\ t\,\gamma\,(1.027)^t\ P\ (0)$$

- .6 → fraction of population working
- (3/42) → value of days work
- (4) → number of days per case
- (.39 $\frac{t\gamma}{20}$ → reduction in number of cases
- P(0)(1.027)^t → rural population

After the twentieth year this becomes 5.4539 γP(0).

Reduction in Deaths

First, we estimate the decrease in the number of deaths per person as a result of the water quality programme reducing the incidence of FO diseases. The estimate of the existing death rate is .002750 per person. We anticipate this will decline so that the reduction in the number of deaths at time t is: $.002750\ \frac{\gamma t}{20}$

where γ is the effectiveness of the water quality programme. The estimated productive years lost as a result of the FO disease deaths in 100 persons is 8.3368 (Annex 5.4, Chapter 5) and the number of FO deaths per 100 persons is .2750. Hence the productive years lost per death is 8.3368/.2750 = 30.3 years. This counts all deaths no matter what the age as we consider all persons are potentially able to contribute to society. We now use the 30 year period to estimate the net value of the life saving at the time the disease is avoided. The value attributed to the reduction in FO diseases is the present value of the stream of earnings net of minimum consumption. We take 1,250/- as the annual value of production of which 650/- is taken as the minimum subsistence expenditures or an annual net of 600/- per year surplus production over the minimum subsistence. The minimum subsistence per worker is equivalent to a minimum subsistence per capita of 390/-. The present value factor is:

$$\frac{1-e^{-30r}}{r}$$

where r is the relevant discount rate. Continuous discounting procedures are henceforth used to make the calculation tractable.

The value of a prevented death is then put at

$(600/-)(\frac{1-e^{-30r}}{r})$. Total savings are then:

$$(.002750)(\frac{\gamma t}{20})(600/-)(\frac{1-e^{-30r}}{r})\ P(0)\ (1.027)^t = .08250\ \gamma t\ P(0)(1.027)^t(\frac{1-e^{-30r}}{r})$$

After 20 years this becomes $2.8112(\frac{1-e^{-30r}}{r})\gamma P(0)$

Total Benefits

In Table 7.2 we summarise the expressions for the benefits arising from each of the three sources. Next we compute the present value over 40 years of these benefits. This is done for several interest rates leaving the effectiveness parameter unspecified. The base population is taken at 14,178,000 persons. Annex 7.1 explains the basis of the computation.

TABLE 7.2
SUMMARY OF BENEFITS

	Type of Benefit	Time: $0 \leq t \leq 20$	Time: $20 \leq t \leq 40$
1.	Hospital and Transport to hospital saving	$\gamma t\, P(0)(1.027)^t(.021)$	$.72\, \gamma P(0)$
2.	Lost earnings from disease	$\gamma t\, P(0)(1.027)^t(.16)$	$5.45\, \gamma P(0)$
3.	Value of deaths prevented:	$\gamma t\, P(0)(1.027)^t\,(.083)\, \frac{(1-e^{-30r})}{r}$	$2.81\, \frac{(1-e^{-30r})}{r}\, \gamma P(0)$

In estimating the benefits we calculate the population which is affected by the water quality programme; this population equals the total population at the end of 20 years. Then we consider the continuation of service to this same group - we ignore further population increases but consider that replacement costs must be met for the population as well as all operations and maintenance of the treatment facilities. The benefit estimates are given in Table 7.3.

Examining these estimates of benefits we observe the general structure: At 6% discount rate the benefits of the first 20 years approximately equal the benefits of the second twenty year period. For interest rates above 15% the second twenty years is 10-15% of the first twenty years. At the 18% discount rate total benefits are estimated at 300-350 million shillings.

That is, the present value of the total benefits from hospital cost savings, reduced diseases, and longer lifetimes comes to a total of 300 million shillings; of this only 3% comes from lower hospital costs; 25% from reduced diseases and 72% from longer lives. This indicates that hospital cost savings are not an important part of the total benefits.

TABLE 7.3
BENEFIT ESTIMATES FOR WATER QUALITY IMPROVEMENTS

PRESENT VALUES

$\gamma = 1$

(Thousand Shillings)

r	Hospital		Lost Earnings		Prevented Deaths		Total	
	P1	P2	P1	P2	P1	P2	P1	P2
.02	65,371	112,599	496,095	984,455	5,770,289	9,935,431	6,331.76	11,032.49
.04	50,145	63,035	380,549	478,340	3,427,812	4,307,323	3,858.51	4,848.70
.06	38,821	35,747	294,612	271,261	2,113,264	1,945,153	2,446.70	2,252.16
.08	30,344	20,522	230,281	155,735	1,349,517	912,372	1,610.14	1,088.63
.10	23,955	11,922	181,790	90,472	890,132	443,104	1,096.38	545.47
.12	19,104	7,000	144,974	53,123	605,915	221,956	769.99	282.08
.15	13,870	3,209	105,262	24,600	357,821	82,775	476.95	110.59
.18	10,307	1,508	78,215	11,444	223,011	32,621	311.53	45.57
.21	7,833	714	59,446	5,413	145,682	13,261	212.96	19.39

r: interest rate

P_1: Benefits for first 20 years

P_2: Benefits for second 20 years

7.5 Benefit-Cost Analysis

In Table 7.4 the benefit-cost ratio is calculated for the first twenty years of the projects for different treatment levels and different interest rates. The benefits shown in Table 7.3 assume complete cures from FO diseases and reduction of the deaths related to such diseases. In the benefit-cost ratio table we indicate the percent of cases which will just bring the benefits equal to the costs. Thus at a 12% discount rate with 100% cures of FO diseases is 2.6; as long as the cure rate is above 30% then the benefit-cost ratio is greater than 1.

From this table we can draw the following conclusions: the low treatment level will be acceptable for cure rates which are roughly the same as the discount rate. The expert judgement as to the acceptable cure ratio is that we should be able to obtain 10-20% reductions using the low level treatment approach. At an 18% discount rate a 15% cure rate or better is required to have discounted benefits equal to or greater than discounted costs. We can conclude that the low level treatment is justified on the basis benefit-cost analysis and expert judgement as to the FO disease cure rate that we can expect.

Turning to the middle level treatment we see that for low interest rates 2-4% the required cure rates are in the range 13-17%. For higher interest rates the cure rates go up to more than 60% for an 18% interest rate. The cure rates we can expect for the medium treatment will not be more than 20-25% and at such levels the benefit-cost ratio is less than one for acceptable discount rates.

Finally, it is clear that the high level treatment cannot be justified at any interest rate; we do not believe that cure rates of more than 50% can be achieved with the most elaborate methods.

The final conclusion is that the low treatment procedures are economically justified while the medium and high treatment levels are not.

The results of the benefit-cost analysis must be interpreted with some care. The value of labour is a fairly sensitive parameter. Essentially, the benefits are proportioned to this value so that the results can be readily adjusted to any different view. What value should be attached to the rural incomes is a complex question. The important question is whether the estimate of 750/- per person is appropriate. The 1975 estimate of value added per person in agriculture is 520/-. We have raised this to 750/- on the basis of inflation and non-agricultural work by the rural community.

TABLE 7.4

BENEFIT/COST RATIOS AND MINIMUM CURE RATE NEEDED

(20 Years Only)

Interest Rate	Treatment Level		
	Low	Medium	High
.02	41.7[1] (.02)[2]	7.7 (.13)	1.6 (.64)
.04	30.8 (.03)	5.9 (.17)	1.2 (.84)
.06	23.3 (.04)	4.7 (.21)	.94
.08	18.0 (.06)	3.7 (.27)	.75
.10	14.2 (.07)	3.1 (.33)	.62
.12	11.4 (.09)	2.6 (.39)	.51
.15	8.5 (.11)	2.0 (.50)	.40
.18	6.5 (.15)	1.6 (.62)	.33
.21	5.1 (.19)	1.3 (.75)	.27

1) Benefit cost ratio

2) Minimum cure rate needed

If this estimate is 50% too low (i.e. instead of 750/- we should use 1,125/-) then all of the cure rates (in brackets in Table 7.4) would be reduced by 50%.

Using an 18% interest rate this would still not change the conclusion. At an 8% interest the medium level treatment needs an 18% cure rate to break-even. We conclude that the results are robust against changes in the value of agricultural labour.

Changing the assumptions on the number of productive years from 30 to 20 years changes the benefits approximately 2%. Changing the number of productive years from 30 years to 10 years reduces the benefits by aaproximately 15%. This is sufficiently small that it does not change the conclusions. In our opinion the conclusion that the low treatment level is justified and the medium and high levels are not is soundly based, robust against major changes in assumptions and provides a sufficient basis for shifting treatment of rural water to storage for turbid, polluted waters, leaving other waters untreated.

CHAPTER 8

LEGISLATION AND REGULATION OF THE WATER QUALITY PROGRAMME

In this chapter we review the legislation dealing with water quality and make recommendations on the legislation and regulation. In Section 1 we give an introduction to the Legal Technical issues in Water Quality. Section 2 reviews the alternative approaches to Water Quality legislation. Section 3 reviews existing legislation and section 4 presents the recommendations.

8.1 Legal Technical Introduction

A program for water quality implies that there are one or many goals of the society relating to the quality of water which are to be achieved, one way or another. The goals are directly or indirectly laid down in terms of rules or standards; for example quality standards, standards for technical equipment, monitoring etc. Such standards can be implemented voluntarily by people, authorities etc. but usually an implementation program has to be backed with legal rules to be effective.

Constructing such rules poses many problems, which are technical in a specific sense, i.e. legal technical. Legal instruments must be created to enforce the implementation program. The choice of instruments is important in order to achieve the highest possible efficiency. Efficiency is here defined as how close one approaches a certain goal (for example drinkable water within a given period), given certain restrictions (for example: the costs must not be too high, land use must not be restricted too much, the freedom of people must not be restricted too much etc.).

In the environmental legal field (including legislation on natural resources), into which the Rural Water Quality Programme fits very well, the following two legal technical aspects are of basic importance.

- formulating the standards
- constructing the enforcement instruments

Formulating the Standards

Since the major aim of the program is to ensure that the water supplied to users is of satisfactory quality, it is necessary to formulate standards regarding what quality is to be obtained. How high the quality standards are set is not a legal problem, but hygienic and, ultimately, political. The legal technical problem is instead how to formulate the standards whatever these might be, so that they will be understandable and enforcable. This requires including in definitions of the standard regulations on how to take samples etc. in sufficient detail so that in the event of dispute it is possible to verify the quality of the water with a minimum of judgement. Such considerations and regulations form an integrated part of the standards. This can be called Water Supply Quality Standards, Drinking Water Standards, etc.

If need should arise for standards as regards the quality of surface or ground water (or for raw water as such) besides the Drinking Water Standards, the same legal technical problems exist. Other types of standards may include effluent standards, i.e. standards for the quality of pollutants that may be discharged into a source; and furthermore on siting of activities which may cause pollution. Effluent standards could also be called Standards of Performance, thereby clearly including standards for closed systems and manufacturing technology (where possiblities of "no-discharge technology" exists).

Standards must not necessarily - from the legal point of view, that is - be laid down numerically. Another method is what is sometimes called "narrative" standards, for example in the Tanzanian Water Utilization Act 1974 (WUA), section 17 (a) (iii): "(The water used under a water right)... shall not be polluted... to such extent as to be likely to cause injury either directly or indirectly to public health, to livestock or fish, to crops, orchards or gardens which are irrigated by such water or to any products in the processing of which such water is used...".

Such narrative standards pose some legal technical problems, however, since they are more "vague", thus making different interpretations possible to a higher degree than standards laid down in numerical rules. There may exist several reasons why narrative standards are used instead of numerical ones, the main reason being difficulties to determine which numerical standard would actually be the "correct" one with respect to the adopted goal. Sometimes, numerical standards, even when possible to lay down, would be so complicated that it is more efficient just to establish the goal directly by a narrative statement and then leave to the planners, the decision makers of the agencies etc. to decide how this broadly described standard should be met in individual cases. Also the numerical standards might be specified in regulation set down by the implementation agency and changed from time to time through an administrative rather than the legislative process. Furthermore, best judgement as to the water health relationship may change from time to time requireing changes in standards. The narrative rule specifies the real purpose of the water quality standards but permits precise formulation to be adjusted to the circumstances and the knowledge of the relationship between health and water.

Even standards of performance can be constructed as narrative standards, for example a rule that each industrial plant should use the best control technology that is available with certain costs, as found in the U.S. and Swedish environmental legislation. These broad standards can then be made more precise by adopting guidelines from time to time which translate the broad, narrative standard to numerical or other technical standards, as is done in Sweden among other countries.

Standards in the wide meaning used in this report correspond to the legal term <u>substantive rules</u>, as often used.

Constructing the Enforcement System

Substantive rules along do not ensure a high efficiency from legislation. Enforcement of the rules poses many problems, some of which are related to the construction of the substantive rules, i.e. the standards.

An efficient enforcement system must include at least four different types of rules, taken into legislation. They are:

- procedural rules
- economic rules
- rules on supervision
- rules on sanctions (punishment, fines, etc.)

Together with substantive rules, a legislation based upon these types of rules could very well be rather efficient (provided of course that each and every rule is well constructed). If, however, one of the types is missing, for example, there is no supervision or sanction against non-compliance, the legislation may easily prove inefficient however good the construction of the standards may be. Thus, each group of rules is like a link in a chain: If one link is weak, the chain may break. This also applies to environmental legislation.

Procedural Rules

Procedural rules are those which require specific actions, applications, documentation, etc. Such rules could include compulsory application for a permit to discharge water or to operate (cf the water rights of the WUA) and for notification of minor changes in operations. That way the agencies et al will know which activities are about to start. Furthermore, the authorities have the possibility to deem how the standards are met in each activity.

A more complicated system includes planning rules for water (for example river basin planning, implementation plans) and for land use as such, with special attention paid to water (for instance housing, highways, quarrying, agriculture, storing of hazardous substances and waste, etc.).

Another type of the procedural rule deals with who is to make the decisions concerning water quality in particular cases, who shall approve of plans etc. Also, what information, data etc. must exist before a permit is granted. Furthermore, specification of who shall produce these data?

As to the last problem, there is also an economic aspect dealt with under economic rules below. But it can be mentioned that more and more countries have adopted, or are considering, what is called Environmental Impact Statements of Assessments. These are to be prepared and reviewed before permission to carry out a major construction project or other activities which may affect the environment. Such a procedure is meant to ensure an as complete as possible understanding of the consequences of the decisions.

A balance should be sought between the costs of a complicated administrative system and the benefits from avoiding decisions made in ignorance which might cause water and natural resources to be destroyed or damaged unnecessarily.

Economic Rules

This type of rule lays down who shall bear the costs or suffer the losses arising from implementation of a programme. For example if the financial position of the government is weak, rules requiring a high compensation to land owners or others when restricting land use or compulsorily acquiring land will raise very severe obstacles for implementation.

It is indeed a political issue who is to bear the burden of the costs. But when taking a political standpoint one has to know the effects which will be brought about if, implementation is carried out.

Related to this problem, although also a part of the procedural problems, is which rights should be connected with a granted permit or a water right. As regards the latter, the WUA provides for restrictions of water rights, and even termination, sometimes with compensation for the holder of the right. A system which does not provide for such potential changes will be less efficient, at least as regards the costs for implementation.

Part of the economic rules, as well as part of the procedural, is the issue who shall have the burden of proof as regards possible effects from polluting activities and other activities that might affect water resources. If the burden is put upon the applicant (the land user, the entrepreneur etc.), then governmental finances will not be burdened by all the costs associated with producing data analysis. Furthermore, it is possible that the data produced by an applicant sometimes will be more valuable (provided false statements are made criminal offences, as is done in the WUA) than data produced by a governmental agency to a certain cost, especially as regards available technology, since the applicant in order to get a permit to operate has to satisfy the agency that his or her activity will not pollute the water excessively. That is, it is in the economic interest of the operator to get the best data. The data which are provided by the applicant must of course be thoroughly examined before a decision is made.

This shifting of the burden of proof in environmental issues is made in the Swedish Environment Protection Act, for example, and it is a part of the environment impact staement system at least in the United States (laid down in the National Environmental Policy Act 1969). This provides the best protection for the environment as projects can proceed only after a finding that whatever damage will be done is acceptable; positive action by the applicant and the regulatory agency is necessary rather than an action to stop a decision already taken.

Rules on Supervision

To ensure efficiency in legislation concerning water, supervision is important. It must be made clear, not only who is to supervise water quality but also how the supervisor shall (not just "may") proceed to make offenders comply with the law, and how the supervisor shall act when finding that a standard is not met because there are so many sources of pollution in the area (i.e. a need for revising granted permits and for further restrictions on land use etc.).

This type of rule, combined with clearly formulated standards, will reduce discretion and ambiguity to a fairly low level.

Another type of rule, necessary for efficiency, shall give access for supervising officers to all land and all works etc. including the internal technical and other reports of the industrial plants and others. This type of rule is already laid down in the WUA, and should, after sufficient experience has been gained be reviewed and, where necessary extended.

Rules of Sanctions

Even if it would be desirable to achieve such an understanding among people for the necessity of complying with the law, there must always be fallbacks to protect society from offenders by threatening appropriate sanction. How to construct such rules depends on national conditions. The WUA gives explicit recognition of the necessity for sanctions: Giving false statements, using water without a water right (if required) and non-compliance with conditions as ordered when the right was granted are, among others, made criminal offences. That section covers the basic needs for rules on sanctions and is far more sophisticated and well considered than for example the Swedish rules in their environmental legislation (or penal code).

There is also another type of sanction, which ought to be considered. That is confiscation of such profits which arise from non-compliance with the law, and restoring, when possible, of resources damaged due to the non-compliance at the costs of the offender (if restoring is possible, then the abovementioned profit is calculated upon the net after the costs of restoring are met). These sanctions should ideally be used beside the pure punishment like jail and/or fines.

Also non-compliance with the rules on supervision can be made criminal offences, to increase efficiency. That is, if a supervising officer - or an agency - willfully neglects their supervisory duties (for example neglects to revise a water basin plan or granted permits when the water quality is permanently below standards), then it is a criminal offence. Constructed cleverly, and carefully enforced, such a rule could be of great assistance to make the implementing agencies work efficiently. (Minor administrative failures should not be punished, since such a threat hanging all the time over the heads of the officers will probably paralyse action more than encourage it).

8.2 Approaches to Water Quality Legislation and Regulations

Approach No 1 Water Supply Standards (WSQS), or Domestic Water Standards

In this case only domestic water standards are set; the Government regulates the water delivered by water schemes but does not concern itself with effluents or the quality of the water source. If used alone, the total costs for achieving specified standards might be high compared with the total benefits. Focussing only on drinking water standards will direct resources and administrative effort towards raw water treatment. Industries may discharge without control contaminants into water sources used as inputs for water supplies thus creating a need for more expensive raw water treatment. It can work both ways since establishing new industrial plants may require the new plant to provide expensive treatment for the raw water used. Industrial water also must be of high quality for many processes. Construction of new housing areas and increased shipping in the large lakes are other examples of how the raw water quality (as well as supply of a given quantity) may be affected by manmade action. Man by his actions in polluting water may make the treatment costs for domestic water higher than would be necessary if we have a more balanced programme. Insome ways the situation is even more dangerous for industrial and sewer effluents may overwhelm existing treatment systems resulting in periods of great danger, or an industrial effluent may contain a toxic substance not previously in the water source and thus treatment is not provided and great damage may be done to the population before the situation is detected.

Thus we believe that regulation and legislation must be more comprehensive than simply establishing water quality standards for domestic water supplies. Attention must also be directed at the sources of contamination.

Drinking water standards are easily laid down in a special act, for example, a Drinking Water Act. A water works legislation should be included in such an act. There is a vast amount of information on such water standards.

Approach No 2: No.1 plus Effluent Standards

Under this approach the government would establish regulation on effluents from human habitations, factories, shipping, etc.

This approach would offer better possibilities for efficient allocation of resources to control water quality. The method for establishing effluent standards may be as follows:

- set individually for each discharger;
- set for special groups of dischargers;
- or both (i.e. standards are set by group, with legal possibilities for adjusting the standards in single cases provided certain conditions exist).

The first alternative demands the most expensive administrative system as applications for permits to operate (a permit system) must be reviewed and standards agreed upon for each discharger. This leaves the applicant somewhat in the darm as to his costs until he enters into negotiation with the authorities so as to determine what is expected. Even the third alternative requires a permit system that includes thorough examinations of which protective technique is to be used, but it can be made a little less complicated, since most of the applications for a discharge permit will end up in the requirement to comply with the general effluent standards and only few applicants will be able to show that special conditions exist that would allow them to go beneath the effluent standards.

The second alternative seems to be the simpler one, considering administrative costs with the benefits. A permit system, or notifying system, would emphasize the supervision part of th water control. The discharger notifies the appropriate authority which technique is to be used and that effluent standards will be met. A monitoring system will be set up to check the effluents and the operation of the activity. Failure to meet the effluent standards means reducing the activity or shuting down. In order to avoid this, the operator will normally do his utmost to meet the standards in order to be allowed to operate.

In the future, as the Government's administrative capacity grows, as well as the data concerning the capacity of the different recipient waters, it will be beneficial to switch to the third alternative mentioned above, or - even better - to the first one, being the only one where the best technique available at the time of the application for a given cost (which has been considered to be reasonable in earlier cases) can be required. (This can also be described as a legal framework for adjusting the requirements according to the level of technical and economic development.) In fact with increasing population, irrigation, and industry the pressures on water bodies will increase and make a more finely tuned effluent control system necessary. However, for the next decade a system of monitored standards should be satisfactory.

Disadvantages of This Approach

If there is no effective total physical planning for siting of polluting activities such as industry, villages, agriculture, livestock etc. effluent standards alone (combined with domestic water standards, that is) will not secure the best allocation of resources. For example, there may occur unacceptable contamination from many polluting sources emptying their effluents into one body of water even after the waste treatment being carried out in accordance with the standards resulting in higher treatment costs.

On the other hand, steering the location of polluting activities in order to avoid such a heavy load on a specific body of water, might be the most effective action; however, a comprehensive physical planning approach can be very expensive. Fortunately although ultimately necessary, the immediate problems facing Tanzania are rather simpler.

Another flaw with this approach is that it does not take into account the possibilities that other uses of water besides those covered by the effluent standards may change the conditions of the raw water as regards quality and/or quantity, (of the Water Utilization Act, WUA).

Legislative Measures

If this approach cf an effluent standards combined with drinking water standards were selected then these could be laid down in an environment protection act or as amendments to the Water Utilization Act (WUA).

Approach No 3: No 1 plus Receiving Water Quality Standards (RWQS)

This approach combines drinking water standards and controls over the receiving waters which prohibit pollution of such waters when specified standards are not met.

This approach might have some advantage as compared with the first. Meeting standards for raw water requires sometimes, though not always, protective measures when operating an industrial plant, as well as sewerage discharges and other polluting activities. Receiving water quality standards is an instrument for establishing the raw water standard.

Disadvantages of this Approach

This approach will often work poorly because once the recipient water body which is also the raw water supply is loaded up to the established limit, as specified in the RWQS, there is no room for further or other polluting activities, however, otherwise beneficial it be, whereas the activities already established might operate with minimal or no protective measures. Thus upstream or first entrants will have little costs for effluent treatment; later comers and downstream activities will be compelled to provide elaborate treatment methods. The issues here are complex; effluent standards introduced too early and leading to high investment costs will restrict economic activity; the RWQS approach penalyses the late comer when the level of polluting activity has risen to the point that it is necessary. Of course it is possible to draw the regulations to permit gradually tightening of the early polluters ordering such activities to take protective measures once a new activity applies for a siting at the same recipient. However, even with that provision, costs might be high since adding a treatment system to an activity already in operation is usually more expensive than integrating into the initial design. There are exceptions to this. Firstly, there are probably situations where it will be not more expensive. Secondly, it might prove more beneficial for the nation to have a plant in operation at low production costs even at the price of polluting the body of water (that is: the cost-benefit ratio may be better when postponing protective measures as compared with taking them from the start of the operation, even if the costs of constructing and introducing the measures will be higher later on), than treating the discharge from the start at high costs.

There are two problems which occur with this approach based upon WSQS and RWQS, namely:

(1) We may not get close to good resource allocation due to the unequal imposition of pollution control costs and the arbitrariness of some of the results.

(2) The construction of implementation instruments for the RWQS is difficult and requires much consideration. For example, the reason for the failure in the United States in the 1960s in their water and air pollution control was to a considerable degree due to their using the quality approach without constructing good legal instruments for implementing the adopted standards.

Approach No 4: No 2 plus Receiving Water Quality Standards

This approach is a combination of No. 2 and No. 3 described above. It eliminates most of the disadvantages mentioned in connection with the other approaches. It is also the most sophisticated and complex from the legal technical point of view. Furthermore, it is in general terms the approach proposed by the Tanzanian Effluent Standards Committee 1977.

The approach includes three sets of standards:

- Water Supply or Drinking Water Quality Standards (WSQS);
- Effluent Standards (or Standards of Performance); and
- Receiving Water Quality Standards.

The RWQS will be the instrument to check that the body of water is not too heavily loaded with pollutants. The effluent standards ensure that reasonable protective measures are taken with each polluting activity. Integrated with legislation on protective measures should be requirements concerning the siting of the activities.

The administrative costs of this system are high. It requires surveillance of the water supplies, surveillance of effluents, surveillance of receiving waters, and finally constructing models of the streams and lakes which permit reasonable estimation of the impact of effluent volumes and composition on receiving water quality so as to provide a sound technical basis for establishing the necessary rules and carrying out the day-to-day administration.

Conclusion

As can be seen, the most sophisticated approach of those mentioned also seems to be ultimately the most efficient method of achieving good water quality. However, we now must deal separately with the short and the long perspectives and examine which, if any, modifications are to be made to the observations above.

Firstly, we have the basic problem of achieving the water quality standards.

Secondly, there is the problem of maintaining these standards, once achieved. With growing population and industrialisation maintaining the standards means a permanent struggle in environmental control, as the situation will deteriorate steadily. This applies to all countries, but is probably especially relevant for developing countries which are experiencing rapid population growth (i.e. changes affecting the environment are likely to occur to a great extent due to the need for greater irrigation and use of chemicals for agriculture, increase in land under cultivation, industrialisation, etc.).

Tanzania has launched a Crash Program which has as its objective provision of good quality, accessible water to rural communities by 1980.

The problem of achieving these goals is tremendous and necessitates maximum resources be directed at the construction of schemes; thus water treatment should be held to the minimum consistent with acceptable quality. At the same time the basis for proper controls over future water use must be established - the legal base and the implementing organisations must be developed and tested to deal with the major environmental problems associated with water development in future years.

The discussion in this section has emphasised the need for a comprehensive approach in the control of water extraction and discharge. The immediate problems of Tanzania do not merit a crisis approach to environmental problems. But it is necessary to have a steady build up of skills and background information towards the time when the macro-regulation problems are serious. We judge that in several areas this will take place well before the end of this century; population growth, the need for irrigation, the industrial development program, and the rapid urbanisation of the society will result in high environmental problems during the next two decades. Our legislative recommendations are thus aimed at the immediate problems of raising water quality through appropriate surveillance and follow-up action as well as adjustment to provide the basis for handling the macro-regulation problems which are certain to arise in the future.

8.3 Existing Legislation

8.3.1 Existing Legislation - General

Water law in Tanganyika has, at least since the end of the 19th Century, declared water to be under government ownership. We do not know to which extent local customs and rules can be said to go, or have gone, together with these legislation. When the rules laid down in law have been applied, many forms of water use could be secured by being granted water rights.

Under German and British administrations, several pieces of legislation were passed. Among these were the Water Ordinance of 1933, of 1948 and the finally of 1959. In 1974, the now effective Water Utilization (Control and Regulations) Act replaced the 1959 Ordinance.

The ownership of water in Tanganyika is now declared to be vested in the republic. That means that the basis of former water law as regards ownership, water rights etc. are continued. The 1974 legislation is, however, in contradiction to former law, to a high extent based upon decentralisation as a principle, although centralised control will still be possible by means of declaring bodies of water as national water supplies.

The 1974 Act has not given any considerable legal practice so far.

The existing Water Works Ordinance/Act has not been found in official lists of legislation. Furthermore no indication of its legal use has been found by the Consultant.

It has thus not been reviewed. Of importance in the future will be the Public Health Law which is now being drafted.

8.3.2 Existing Legislation - Detailed Analysis

In this section we review the existing laws dealing with Water Quality: The Water Utilization Act (1974) and the Fisheries Act (1970).

A. Water Utilisation (Control and Regulation) Act 1974 (Annex 8.1)

(1) Introduction

This act (hereafter referred to as WUA) controls use of water, whether surface, ground or rain water as regards quantity as well as quality, the latter aspect, however, being considered to a lesser extent.

The WUA applies to, and is carried into effect by, i.a. governmental departments and all public and local authorities and others, including Water Authorities appointed under the Water Works Ordinance Cap 281, see § 3.

(2) Rights to Use Water

Basically, all water in Tanzania - be it surface, ground or rain water - is not subject to private ownership but is owned by the republic /§ 8/. Then, certain rights may be granted, or are laid down in the act itself, to use water.

The general rights under the act are the following:

For domestic purposes, abstracting water is allowed provided the abstractor has legal access to the water in question /§ 10/. This does not, however, include construction of any works /ibid/.

The owner or occupier of any land has a basic right to abstract 22 700 litres (i.e. 5 000 imperial gallons) in any one day /i.e. not mean value/ from a well or a borehole on that land. This right includes sinking or enlarging the well and borehole, as long as certain distances to other water supplies are met /see § 11-(1)(a)/. Furthermore, the same persons may construct works on the land to conserve rainfall and then use that water, as long as the works are not constructed in a river or a stream /§ 11-(1)(b)/. What is to be considered as a river or a stream as regards a specific watercourse, may be determined by a Water Officer /see below/ under § 11-(2).

These rights to limited quantities of underground and casual water may be restricted in individual cases /see below/. From technical point of view this might pose a problem since there is no need for an application, and thus no automatic examination of whether there is water enough in the area, before a water is abstracted within these rights.

For mining purposes, the act gives certain general rights to the holders of certain types of leases. These rights seem to be somewhat broader than was given to the land owner or occupier above /see § 12/.

Finally, the act also gives certain general rights to water for forestry purposes /§ 13/.

There are also what is called existing rights, i.e. rights which arose and/or existed under previous legislation. The existing rights are - as regards revision or termination etc. of water rights in general - subject to the same rules as are Water Rights granted under the WUA /§ 26/.

There is also a section, explicitly prohibiting use of water without being in accordance with an existing right or with a water right under the WUA /§ 14/, whether the use be direct or by diverting, damming, storing or abstracting. Nor is it allowed to construct or maintain any works except when in accordance with such rights, /ibid/.

To achieve a right that exceeds the general or the existing ones, an application for a Water Right is necessary. This means that the republic, through its appointed institutions /which will be described below/ gives certain rights to certain persons or types of persons. Thereby there is already the basis for a permit system, giving good opportunities for the nation to control the use of water; a system which could be reviewed and extended if deemed necessary.

So all in all, the rights to use water under the WUA can be split into three categories, namely:

(1) general rights laid down in substantive rules in § 10 through 13;

(2) existing rights;

(3) Water Rights.

(3) The Administrative Structure

At the central level, there is a Principal Water Officer /PWO/ /§ 4-(1)/. At the regional levels there are Regional Water Officers /RWO, ibid/. Other officers may be appointed as deemed necessary by the Minister /§ 4-(2) and (3)/.

To advise the PWO there is a Central Water Advisory Board /CWAB/ and as advisors for the RWOs there are Regional Water Advisory Boards /RWAB, § 5-(1)/.

The CWAB and the RWABs have an advisory role on matters concerning water use problems; such as apportionment of national water supplies; decisions on Water Rights; and measures necessary because of drought; as well as giving priorities from time to time in general for different uses of water in Tanzania. The Water Officers have to consider the advice of their Advisory Board before making most decisions creating or affecting Water Rights or affecting other existing rights /such as specifying of quantities under § 21/. Exceptions are decisions on suspension or variation of Water Rights because of drought under § 20 /§ 6-(2)/; for a Regional Water Officer, the provisions for drought being restricted to regional water supplies in the region in question /§ 7/.

The decisions are still entirely the PWO's and the RWOs. But hearing advice means there will be information to base the decisions upon. Furthermore, the possibilities to acquire useful information are increased by section 28, which entitles the Water Officers and the Advisory Boards to call upon any person to give information for purpose of the act. Refusing to give it without reasonable excuse is an offence under § 33-(5). The same goes for giving information knowing, or having reason to believe, it to be false.

The decisions of the PWO are appealed to the Minister and those of the RWOs to the Regional Commissioner /§ 32/.

(4) Level of Decisionmaking

Use of water is meant generally to be decided upon on the regional level. It seems that decentralisation is basic in the WUA. However, we must pay attention to the hard criticism by the Effluent Standards Committee in this respect, implying that the decentralisation has caused the water control to be much less efficient.

Even the WUA itself does not completely ignore the needs for central decisionmaking. The Minister may, under § 9; declare a source of water to be a National Water Supply, if he deems it to be in the public interest to regulate the use of water from that source on a national level. Then, when an application for a Water Right affects a National Water Supply, such application is examined by the PWO. In all other cases, Water Rights are granted by the RWOs.

Power to Make Rules and Regulations

As in most legislation everywhere, it has not been possible nor deemed necessary to lay down detailed rules on procedure and enforcement of substantive rules. Therefore, § 38 gives the power to the Minister to prescribe "anything which may be prescribed under this Act and for the better carrying into effect of the provisions of this Act...".

This seems to mean that there is already today, by means of the WUA, possibilities to prescribe most rules necessary for allocating water resources, or for shifting the use of water.

This does not, however, necessarily mean that there is no need for reviewing the legislation. For example, the WUA will probably not include general rules on effluent standards and siting of industries, nor Receiving Water Quality Standards. But even if it does, there is a need for more distinct and easily interpreted rules for these matters. Furthermore, Water Basin Planning with necessary enforcement rules, requires that the legislation be changed.

(5) Granting of Water Rights and Exercising the Rights

Water Rights (which are equivalent to permits to use water) can be granted by a Water Officer. The right can be to divert, dam, abstract or otherwise use water. The Water Right may specify the source, quantity, purpose and period (even indefinite).

Water Rights are normally given to a person /equivalent/ but it may also be declared as oppurtenant to certain land /this also applies to existing rights/. This declaration may be made not only when granting the right, but also at any time later. The right in question can be enjoyed or exercised by the person who for the moment being owns the land /§ 26-(2)/. If more than one person is entitled to the land, then proportions are to be set, see § 16-(3) through (5).

As can be seen, a Water Right is required to use water outside any general, or existing right. But there might be other obstacles to using the water. Thus, in order to exercise a Water Right, the holder can acquire legal access to land by means of easement. § 27 gives power to the Water Officer to create easements for this purpose and to decide the compensation, to which the land owner or other injured parties are entitled under § 27-(6). Certain procedural rules are laid down in § 27-(1) through (5) and (8) through (9).

This means that there are legal means within the WUA to get the necessary access to land in order to use a water resource. This is a parallel to the general compulsory acquisition of land.

Deadlines for Exercising a Water Right; Inspection

When a Water Right is granted for a construction of works and the works are to completed within a specified period, an inspection and certification is to take place. The Water Officer may extend the period. But once the period(s) has expired, the works shall be inspected by an officer approved by the Principal Secretary, who then issues a certificate that the works have been satisfactorily constructed.

This certificate is rather procedural, though, and has explicitly no evidential value /see § 28(s)/.

(6) The Substantive Rules on Use of Water in the WUA

As pointed out before, one of the critical links in a legislation, which aims at quality /or with specific goals as in a whole, for that matter/ are the substantive rules /i.e. standards/ on how and when certain acts and uses are allowable. In the WUA, § 17 lays down standards. They are constructed as narrative standards.

These standards are to be implemented by the Water Officers when granting Water Rights for mining, forestry or industrial purposes, and also for generation of power. It is unclear whether this was meant to include oilfired power /discharge of cooling water/ or hydroelectric power only. However oilfired power could alternatively be construed as an industrial activity.

This enumeration as to when the standards are to be applied indicates that there are no legal standards as to which protective measures are to be taken with sewerage discharge etc.

at least not in the WUA. Here attention should be paid also to the Fisheries Act /below 8.3.2B/.

The basic principles of the act are:

Returning of Water	(1)	The water shall be returned to the same water system (narrowly defined from which it was taken. The Water Officer may however authorise any other water system as recipient for the discharge. So the main principle is really only a guideline for the Water Officer.
Quality of Water Returned /discharge/	(2)	The water discharged shall substantially have the same quality as it had before being used. No numerical standards are set for the interpretation of this rule. Since it is very strict, it will probably not be possible to enforce as written. The content of it, interpreted by means of the normal meaning of the words used, is that for example all industrial plants discharging water shall have such a good protective equipment as to have virtually clean water to discharge. This is beyond the strictest standards of the industrialized countries and may not be technically feasible. Having a rule as strict as this one, with no explicit room for variations due to the local circumstances and the technical feasibility of the protective measures, might do more harm than good as compared with other legal technical methods. This will be discussed in a special section later.
Protective Measures as Regards Quality	(3)	The water receiving the discharge shall not be too much polluted. The limits are set as narrative standards, implying the pollution must not be "... likely to cause injury either directly or indirectly" to - public health - livestock - fish - crops - orchards or gardens which are irrigated by such water - products for which such water is used.

Protective Measures as Regards Accumulation — The Water Officer shall also require other protective measures to be taken, namely to prevent accumulations anywhere of silt, sand, gravel, stones, sawdust, refuse, sewerage, sisal waste or any other substance likely to affect injuriously the use of such water.

(7) Variation and Termination of Water Rights

One important factor for efficiency, mentioned earlier, is obviously well provided for in the WUA, that is instruments to change or terminate Water Rights after they are granted. As a whole, it seems possible within the WUA to adjust the rights however much, provided there is a public interest requiring it. The following situations are explicitly regulated.

Permanent Inadequacies /§ 19/ — When the quantity of water is not high enough to satisfy all rights granted, the Minister may direct the Water Officer to review the water use situation and revise the water rights.

One basic principle for this revision is stated, i.e. that when the whole right has been maintained beneficially, reduction or cancellation of that right shall be made only in proportion with all the other rights in the same area /though not clearly stated this probably means all other rights which are used beneficially/. This rule on equity between beneficial users might pose problems for the WO, however understandable such a rule may be. The rule will namely prevent the WO from the best over all solution, if that solution includes different reductions of water rights in different parts of the area in question. It seems that the critical point here is the definition of the area within which the review is to take place. It is up to the Minister to specify the area /§ 19/. Thus, much consideration must be paid by the Minister when specifying it, in order to achieve the best possible solution.

A better way would be changing the section as to set this principle of equity as a guideline, but not mandatory principle, for the WO. /I have interpreted the existing rule as mandatory, the WO "shall have regard to the principle.." (of equity as defined above)/.

Drought

When a source become, or is likely to become, insufficient for the needs of its consumers, the WO may suspend or vary all or any right to abstract or use water from that source for a suitable period.

Here, no rules on equity are laid down /cf § 19/.

When the quantity is not specified in existing rights

The WO may at any time /no special conditions are required for this/ specify the quantity of water to be used within an existing right.

This possibility seems appropriate as an instrument to restrict existing rights without a specified quantity, if needed for water use planning. Here, no burden is put upon the WO to justify the restrictions. However, no existing right can be terminated completely under this rule /but under the rule of permanent inadequacies and the rule mentioned below on public interest/, but only restricted. The rule of equity is not explicitly mentioned in this context.

Thus, existing rights from earlier legislation do not necessarily become legal obstacles if and when planning for water use, particularly since there seems to be no rule under which the holder of the existing right is entitled to compensation /cf § 25-(2)/ in this case. However, we do not know whether this rule of specifying quantities was actually meant to be specifying in order to prevent uncontrolled increases in the water use in the future, i.e. specifying the right to the quantity used at the time of considering it.

With consent from the holder of the right

A rather natural rule is that the WO may, with the consent of the holder of the right, diminish or terminate it /§ 22/. There is at least one situation, when this rule can be useful when planning for water use. Suppose someone applies for a Water Right which, if granted, would be beneficial for the population or the nation and especially more beneficial than are the Water Rights already existing in the same area. Then the WO could inform the applicant, that the application cannot be be granted as long as the existing Water Rights remain, but if the applicant, perhaps with the help of financial agreements with the holders /including delivery of water from the applicant's source to them/, can get the consent of the holders, then the application could be granted. That way, the WO could use the initiative of the applicants /powered by their prospects of economic benefits for themselves/ to "clean up" the water use situation in the area at the same time.

More interesting however are the conditions under which rights may be affected without the consent of the holder.

Breach of conditions /illegal use/

First, there is the situation when a condition is not fulfilled /§ 23/, i.e. when using the water illegally. Then the water right may be terminated, namely if the default is not remedied within a specified time.

When full beneficial use is not made

Secondly, a Water Right may be terminated or diminished if the holder during the last three years neither has made "full beneficial use" of the right, nor has showed cause why the right should not be terminated or otherwise modified /§ 24/. Certain procedural rules for this are laid down.

Such a rule can assist in efforts to maintain a highly beneficial use of water resources and thus adds to the efficiency of the WUA from legal technical point of view.

Public purpose

Thirdly, and perhaps most interesting for the programme, there is the Public Purpose Clause in § 25. A WO may, if he or she deems water to be required for "a public purpose", diminish or terminate any water right as much as is required for the purpose in question. What will be defined as a public purpose is /entirely, it seems/ put in the hands of the Minister under § 25-(3).

However, the holder of a right being affected this way is entitled to compensation for "all loss resulting from the determination or diminution of the right". If the parties do not agree upon the compensation, it is /upon application/ decided by the High Court. cf 9 below.

Dangerous works — Forthly, a Water Right may be suspended for a period, during which repairs etc. are to be carried out, if the works are considered to be dangerous and therefore requiring repair or modifications etc. /§ 29-(2)/, cf under 8 "Inspection", and 9 "Compensation".

(8) Inspection and Supervision

As regards access for inspection, the rules seem to be functional /see § 29-(1)/. The same goes for the possibilities to require repair or modification of works which endanger "life, health or property" /cf above/.

When any works are, or turn, illegal a WO may require the works to be modified or destroyed etc. /§ 30-(1)/. Certain procedural rules are laid down, including the rule that the WO may execute the order and recover the cost for that from the person in default /§ 30-(2)/. The same power is given to the WO for such situations when a Water Right has come to an end for whatever reason, and provided that the works exist to exercise this right.

§ 31 gives power to the Principal Secretary and to persons authorise by him/her to make surveys for water use and to establish hydrographic stations. Compensation is paid only for damage done and land occupied for the construction, but not for the entry as such /§ 31-(2)/.

(9) Compensation

As mentioned, § 25-(2) entitles the holder of a Water Right to compensation when a right is restricted or terminated because of a public purpose.

Furthermore, compensation is paid under § 31 for damage and for land occupied for the construction of works. The same section states clearly that no compensation is paid for the entry as such on the land.

Then there is the situation when § 29 is applied, i.e. when ordering repairs or modifications of dangerous works. The act does not say anything about compensation here. Probably that means that no compensation will be paid. At least it is common in most countries that no one is entitled to compensation for measures meant to avoid damages due to this person's doings /cf "police power" of government/.

As regards compensation for restrictions etc. under the Public Purpose Clause, we do not know whether the compensation for "all loss" means loss as equivalent to actual existing values diminished or destroyed, or loss as equivalent to the profit the holder could have made if exercising his/her right as efficiently as legally possible. The first level we can call "actual use" of the right, the second "possible use".

The interpretation of this compensation rule will be important when implementing a water supply programme (cf on economic rules above).

(10) Sanctions

Offences are listed in § 32. We do not have to go into details on them. Suffice it to say that not only breach of certain procedural rules but also of substantive ones are punishable. No penal rules are laid down, however, on negligence from public officers when applying and enforcing the rules of the act.

(11) Registry

There is to be a central registry of all Water Rights registered under the WUA /§ 34-(2). Registers also are to be kept by the Water Officers, and they shall cover grants, renewals, variations etc. /§ 34-(1)/. Everyone is entitled to an extract from a Water Officer from such register of Water Rights which is administered by the WO in question.

B. The Fisheries Act 1970 No. 6

Under this act, regulations can be made by the Minister of Agriculture preventing the obstruction and pollution of territorial waters /§ 7-(2)(o)/, i.e. all surface waters in Tanzania and all sea waters within 12 nautical miles /§ 2/. Regulations may also provide for the protection of spawning areas /§ 7-(2)(n).

However, these regulations are to be "for the better carrying out of the objects and purposes of this act" /§ 7-(1)/. This means that regulations under the Fisheries Act cannot be made only to achieve high quality raw water. But on the other hand, this Act could prove rather handy when fisheries aspects and raw water aspect combine.

Here, attention should be paid also to the power in the same section 7 under (x) to establish marine parks, sanctuaries or reserves "for any purpose whatsoever". In spite of this wording it is clear, however, that the purpose has to lie within the objects and purpose of the Fisheries Act /cf sub-section (1)/.

8.4 Legislative and Regulatory Recommendations

8.4.1 Introduction and Overview

This section on recommendations contains four parts: (1) The recommended procedures for handling the rural water supply quality problems; these recommendations include immediate acceptance of the Tanzanian Temporary Water Quality Standards as now formulated with some slight changes and promulgation of the enforcing regulations suggested here after appropriate reviews and identifications. (Annex 8.2) (2) The recommended environmental protection program through amendment of the Water Utilization Act and establishment of the associated reorganisational arrangements to implement the amended Act. (3) The recommendations for extension of the surveillance program to cover the effluents from sewers and industrial establishments and monitoring of receiving waters. (4) Recommendation on a national resolution to reduce schistosomiasis.

First, we turn to a brief discussion of institutional and jurisdictional questions then to a detailed description of the recommendations. Recommendations on changes in responsibility, either increasing or decreasing the responsibilities of an organisation are always controversial and what is said here should be no exception. Tanzania is at an interesting point in facing environmental problems - the population densities and the level of industrial development are such that there is only mild degradation of the water environments. There are of course some very polluted waters but in comparison to the problems that have been faced in industrialised countries the situation is hardly serious. Nevertheless, there is every interest in an appropriate response - neither continuing to neglect environmental problems nor moving so rapidly that either unrealistic and non-enforcable laws and regulations are formulated nor that incremental costs levied on industries and human communities are so large as to reduce the rate of industrialisation.

The gest of our organisational recommendations are as follows:

(1) We recognise the existence of an Environmental Protection Group within ARDHI. However this organisation has no capacibility of surveillance of effluents etc. The proposed surveillance organisation can gradually grow in size and experience to handle surveillance of water supplies, sewage and industrial effluents, irrigation effluents and receiving waters. The surveillance system would serve all ministries that have functional responsibilities which concern water quality.

(2) An organisation would be established with a section for each major drainage basin of Tanzania to collect, organise data on water extractions, water discharges, receiving water quality, hydrological and meteorological matters. This organisation would assist the Principal Water Officer, carry out analytical investigations, and ultimately investigate water development projects for the various ministries concerned. (See Section 8.4.2.)

(3) The Regional Water Officers should be abolished and instead the entire process of granting water rights, etc. should be handled nationally on a drainage basin basis.

8.4.2 Recommendations for Domestic Water Quality Legislation

We recommend three legislative steps on domestic water quality:

(1) Passing an act dealing with domestic water quality which establishes a framework for issuing regulations.

(2) Promulgate the Temporary Tanzanian Standards with some changes as given below.

(3) Promulgate implementing regulations - our recommendations on this are set out below.

In addition the Consultant recommends the establishment of an Emergency Water Quality Revolving Fund to provide resources for the emergency cases where the action level indicates that immediate action is necessary to protect the health of people.

We review in the remainder of this section the recommendation on how this should be done. The temporary standards as formulated cannot be strictly enforced at this time. To do so would close down most rural water supplies and drive people to traditional sources that are normally more polluted than the improved water supplies. To reach the temporary standards quickly would be too expensive and too demanding in trained staff.

Obviously immediate enforcement is totally unrealistic. One possibility is to ignore completely implementation of water quality standards, publish the targets for standards and wait until the national resource base is sufficient to finance and operate treatment plants. However, in the Consultant's opinion this would be an error; water quality problems are fairly serious and becoming more so with the shift of population to larger human settlements and the rapid increase in the rural population. People are getting diseases because of the water quality and some are dying. There is a growing risk of epidemics of communicable diseases where water plays an important role in transmitting the disease. The example of the recent cholera outbreak indicates that once established waterborne transmission can increase sharply the number of cases. To neglect the water quality problem is to permit continuation of dangers to health and welfare which can be reduced by appropriate action. However, Tanzania's financial situation is not strong and all the goodwill in the world will not overcome the fact that resources and manpower for a water quality program are desperately short and the costs must be taken into account in reaching a judgement on what is to be done.

The idea behind the implementing regulations recommended is that these should move the water quality standards to a consistently higher level at a rate determined by the availability of funds to do so successfully. The proposed system provides for problem identification, for systematic evaluation and recommendations as to what should be done, for resources for action, and for sanctions if there is failure to act in a reasonable manner. It calls for actions now at a level consistent with resource availability.

In order to enforce legislation with Drinking Water Quality Standards rationally, non-compliance must be dealt with according to: (a) each specific water quality parameter and (b) the severity of the non-compliance, i.e. how much the actual quality deviates from the standard. (c) The possibility of taking action, one must do as much as possible, but concentrate on the most serious cases.

Proposed Domestic Water Quality Legislation

Legislation on domestic water quality should be submitted to Parliament. In the Consultant's view this legislation should be general and provide for the following:

(1) Authorise the Principal Secretary, MAJI to issue water quality standards, non-compliance and enforcement regulations, and establish appropriate organisations for surveillance of water quality.

(2) Establish narrative standards on domestic water quality to the effect that such standards should provide safe level of chemical and biological pollution taking into consideration the costs of achieving such standards.

(3) Authorise the Principal Secretary, MAJI to close water scheme when he deems them unsafe and to delegate the authority to suitable officials.

We recommend against acts which set out very detailed rules on quality standards. This should instead be handled in separate regulations.

Temporary Standards of Quality of Domestic Water (Annex 8.3)

The Consultant recommends these be issued as Tanzanian water standards with the following adjustments:

(1) The frequency of sampling for testing be reduced. Specific proposals on this are set out in Annex 9.6.

Comment

Existing requirements for sampling would be extremely expensive and far beyond the capacity of any surveillance organisation that could be practical in the next ten years. Furthermore, we believe low sampling frequencies are technicially satisfactory and will provide adequate protection to the public.

(2) The fluoride standard set at 8 mg/l is satisfactory for the moment; the suitability of this level must be confirmed otherwise it should be reduced to 6 mg/l in 1984 unless research on the effects of fluoride contamination indicates that the 8 mg/l level is safe (see Sections 5.1 and 9.8).

Comment

The available data on fluoride concentrations and health was discussed in Chapter 5. This evidence is sufficiently uncertain that we believe that no immediate action to reduce the fluoride standard should be taken. Instead we recommend a research program on impact (see Section 9.7) to be initiated as soon as possible. This would provide the basis for a decision before 1984 of the health impact of high levels of fluoride in the Tanzanian environment. The literature indicates there is no simple relationship between fluoride content and fluorosis, that there are other factors intervening which determine the severity of the impact of a particular fluoride content in the water. Thus it is not feasible to simply transfer results from other areas to Tanzania.

However, should it prove not feasible to carry out the necessary research then we recommend that the standard be reduced to 6 mg/l in 1984.

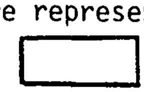
(3) The standards for iron and manganese we believe are too high to enforce as a rigid condition of water quality; the standards should be met but there is little health danger from violation of the standards.

Regulations for Enforcement

As we discussed in detail in Section 8.1 it is important that water quality standards be real - that there is a system for enforcing the standards. After all, the objective is to protect the health of the population by raising the quality of water consumed. The fact that it is impossible to reach the ultimate standards immediately does not mean that action should not be taken to improve the situation. We recommend a set of regulations that are quite detailed which will permit progress towards achievement of the Temporary Standards.

For water schemes designed for more than 300 m^3/day (about 10 000 persons) WHO standards should apply. The approach that we follow is to specify Action Standards and Rules for bacteria, fluoride, nitrates, and chemical contamination. These rules specify exactly what is to be done at what levels of non-compliance with the standards. We describe the procedures in three parts: (1) Bacteriological; (2) Fluoride and nitrate ; (3) Toxic chemicals. For all other aspects of the Tanzanian Temporary Standards the Water Hygiene Engineer may make such recommendation as he feels appropriate to permit water sources to meet these standards. However, we are proposing strict, mandatory regulations only for the above three categories.

Bacteriological Contamination

The problem of controlling and reducing bacteriological contamination depends upon: (1) A proper surveillance system (See Section 9.4 and Annex); (2) A capacity to identify problems and recommend practical solutions (see Section 9.2 for organisation and 9.3 for engineering; also Chapter 7 for analysis of the correct level of treatment to try to reach; (3) Finally, systematic rules and procedures. The rules and procedures are presented as a flow chart in Figure 8.1. The associated Table 8.1 indicates the non-compliance levels and the time phasing of this levels. The basic idea is to start with the schemes with the greatest violations and improve these using the skills and financial resources available; then the level to be enforced (compliance level) is steadily reduced until the national standards are met. First, we explain the proposed system for the first period and then we describe how the compliance regulations adjust. In the flow chart  represents a question which can usually be answered "yes" or "no". The actions of the zonal Water Hygiene Engineer are represented by a box: 

Reports to the National Water Hygiene Committee (see Section 9.2) are indicated by: 

TABLE 8.1

PHASING OF ACTION PROGRAMME

Channel numbers refers to Figure 8.1

NON-COMPLIANCE LEVELS

Level	Faecal Coliform Count: Schemes designed for ⩽ 300	Faecal Coliform Count: Schemes designed for > 300 m^3/day
NC4	1000	10
NC3	100	1
NC2	10	1
NC1	1	

Tanzanian Standard

Period	Channel			Estimated period length at a construction programme of: 20 years	30
	First	Second	Third		
I	NC 4	NC 3	NC1, 2	3 years	3
II	NC 3	NC 2	NC 1	6 years	9
III	NC 2	NC 1	-	11 years	18
IV	NC 1	-	-	Tanzanian Temporary Standard for Domestic Water Reached	

There are five levels for schemes below 300 m^3/day for evaluating the bacteriological purity of the water:

a. F-coliforms >1
This corresponds to the Tanganyika Temporary Standard.

b. F-coliforms >1
We designate this non-compliance level 1.

c. F-coliforms >10
We designate this non-compliance level 2.

d. F-coliforms >100
We designate this non-compliance level 3.

e. F-coliforms >1000
We designate this non-compliance level 4.

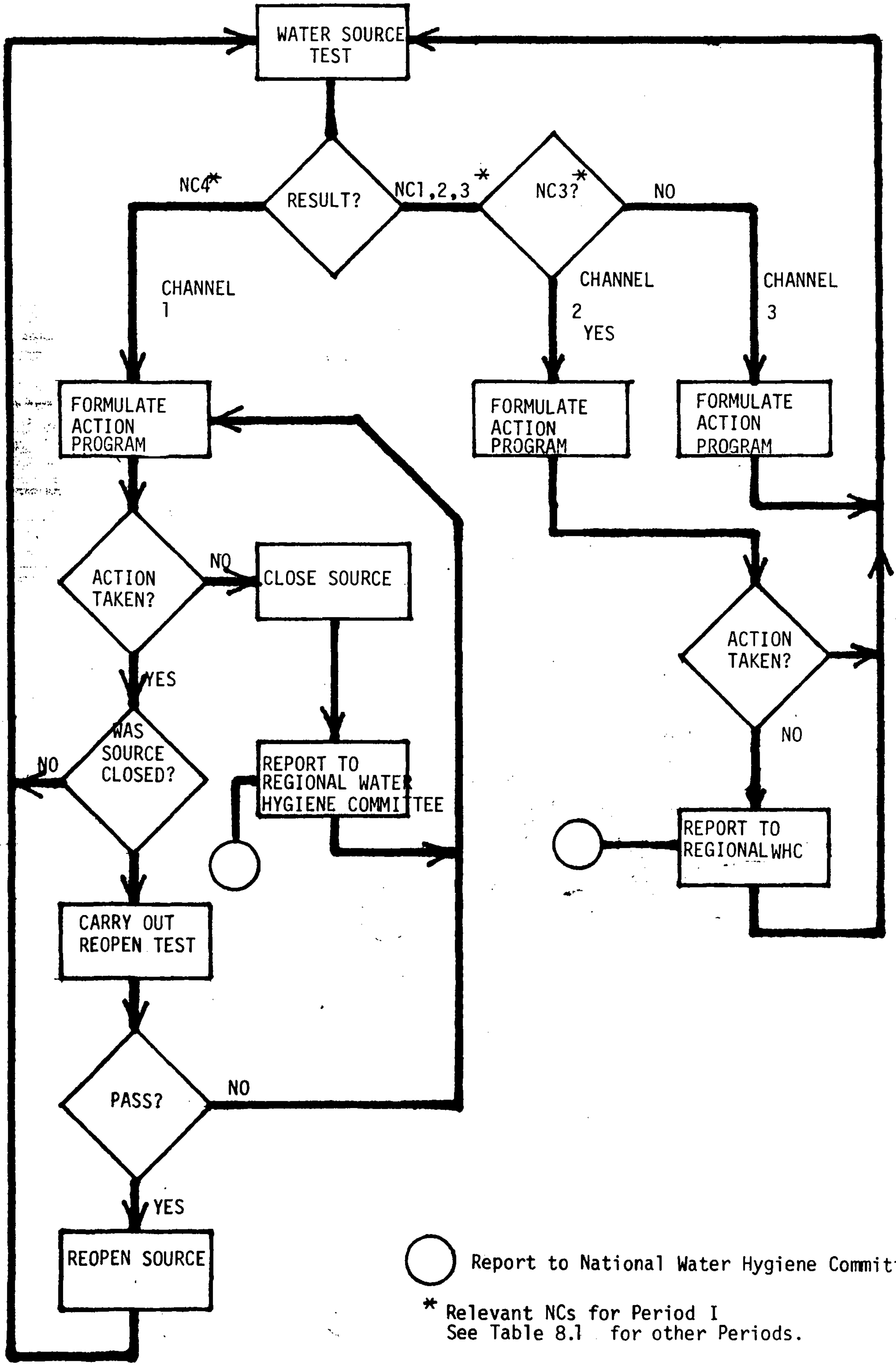
The Zonal Hygiene Engineer carries out a test on a source. This is the box designated "Water Source Test" in Figure 8.1. The result of the tests fall anywhere into the five categories listed above. If the scheme reaches the level NC 4 (F-coliforms >1000) then enforcement falls into Channel 1; if NC 3 then into Channel 2; finally for the other three levels into Channel 3. We describe what happens in each of these channels. The NC 4 level of non-compliance is a rather serious health hazard and requires fairly prompt attention. We estimate some 2% of the MAJI sources fall into this category; that is about 50 schemes are providing rather dangerous water to the population. The proposed sequence of steps is as follows:

The tests are taken according to the established procedures. These require that on every visit to a water scheme at least three samples should be taken for testing. From the test results the NC level of the scheme is determined. (See Table 8.2.) Subsequent action depends on what NC level has been reached and what period we are in. We next discuss the steps in Channel 1. We number these steps 1.1, 1.2 etc. When we consider Channel 2, we will number the steps 2.1, 2.2 etc.

Step 1.1

The zonal sanitary engineer formulates on action program. This is based on his observations in the field and laboratory analysis; he sets out what is necessary to reduce the non-compliance level at least to the third NC level and if possible lower. The purpose of the heavy training requirements

FIGURE 8.1
FLOW CHART OF ACTIONS IF BACTERIOLOGICAL STANDARD IS VIOLATED



Report to National Water Hygiene Committee

* Relevant NCs for Period I
See Table 8.1 for other Periods.

TABLE 8.2

SCHEDULE FOR DECIDING CLASSIFICATION OF SCHEME
NC LEVEL FROM TEST RESULTS

1. Tests are ordered from worst to best and classified according to NC level.

2. Then consult following table to determine scheme NC level.

Sample number		Non-compliance level										
Test Results	1	4	4	4	4	4	4	4	4	4	4	4
	2	4	3	3	3	3	2	2	2	1	1	0
	3	*	3	2	1	0	2	1	0	1	0	0
Conclusion NC		4	3	3	3	3	2	2	2	1	1	0
Test Results	1	3	3	3	3	3	3	3				
	2	3	2	2	2	1	1	0				
	3	*	2	1	0	1	0	0				
Conclusion NC		3	2	2	2	1	1	0				
Test Results	1	2	2	2	2							
	2	2	1	1	0							
	3	*	1	0	0							
Conclusion NC		2	1	1	0							
Test Results	1	1	1	0								
	2	1	0	0								
	3	*	0	0								
Conclusion NC		1	0	0								

* Anything

for the zonal hygiene engineer is exactly to ensure that he is able to make recommendations which are feasible and economic.

After formulation of the action program the Zonal Water Engineer (ZWHE) submits it to the RWE. This action program details (1) The evidence for the violation; (2) The recommendations for action including cost estimates; (3) The time allowed for the RWE to take the recommended or equivalent remedial action; (4) ZWHE's advice on whether the Emergency Fund should be used. In general this report should be submitted to the RWE within one week of the sampling date.

Step 1.2

The RWE takes action to improve the water quality. If the source was not closed then after the remedial action the source is considered satisfactory but the ZWHE should retest it within a month. Thus if action by RWE is prompt and conforms with the tunes required by the ZWHE the source will not be closed. We emphasise that the intent of the regulation is that all of this mandatory and room for judgement as to appropriate action be kept to a minimum.

Step 1.3

If action is taken but source had already been closed then a reopening test is carried out. This comprises two separate sampling runs of three samples each (except in these instances where procedures require more than three).

All three samples (or four out of five) samples on these two occasions should give results below the NC level controlling Channel 1 before a source can be opened. It is compulsory that actions have been taken to eliminate the source for degrading the water.

Step 1.4

If the closed scheme passes the reopening test, then it is reopened and retested in the normal sequence. If it does not pass then it remains closed and the ZWHE must formulate another action program and the steps are repeated.

Step 2.1

The scheme is classified as at the NC level appropriate to Channel 2. Then the ZWHE formulates an action program for the RWE engineer. This program contains the same components as described in Step 1.1 above.

Step 2.2

If the RWE takes action no further steps are necessary.

Step 2.3

If the RWE does not take action then the ZWHE reports to the Regional Water Hygiene Committee and the National Water Hygiene Committee.

The objective of this procedure is to provide an opportunity to correct the schemes which are deficiencies in Channel 2 but without closing schemes.

Step 3.1

If the scheme is classified at the NC level appropriate to Channel 1, then the ZWHE prepares appropriate action program and submits it to the RWE. In many cases corrective action in these cases can be undertaken by the village. It is hoped that RWE would forward these recommendation to the appropriate DDD for action.

The suggested phasing of the program is as follows:

Period I 3 years in length; during this period Channel 1 will deal with the NC 4 level i.e. the extremely dangerous sources with F. coliform counts above 1000. Obviously correcting these sources is a matter of some urgency for water with this degree of pollution is hazardous to human beings. We hope that this period can be completed in less than three years but it will take some to identify and eliminate the high pollution level. We judge with available resources it will take three years to complete this.

Period II The second period concentrates on improving all NC 3 sources. Some sources may degrade to NC 4 during this period and must be handled promptly. In this period Channel 1 covers NC 3 (and any schemes that retest at NC 4); Channel 2 covers NC 2 and Channel 1 NC 1.

Period III The third period concentrates on improving the NC 2 sources, etc.

Fluoride and Nitrate Contamination

The flow chart showing the steps and decision is shown in Figure 8.2. The ZWHE carries out a test for a source; if the source exceeds the fluoride or nitrate standard three times within one year and this is the first time the source has so failed then the ZWHE prepares an action program. If the source has previously failed three times in a year the ZWHE closes the sources, reports to the Regional Water Hygiene Committee and the National Water Hygiene Committee and formulates an action program.

The action program specifies the same items as described in the bacteriological section. However, the time allowed for remedial action should be one year.

If action is taken within the time period and the scheme was not closed then the scheme is tested according to ZWHE's overall schedule. If action was taken but the scheme is closed then a reopening test will be made:

When two samples out of three taken at different visits with a minimum of two weeks between each visit, meet the standard then the source may be reopened.

If the scheme fails the reopening test another action program is prepared by the ZWHE.

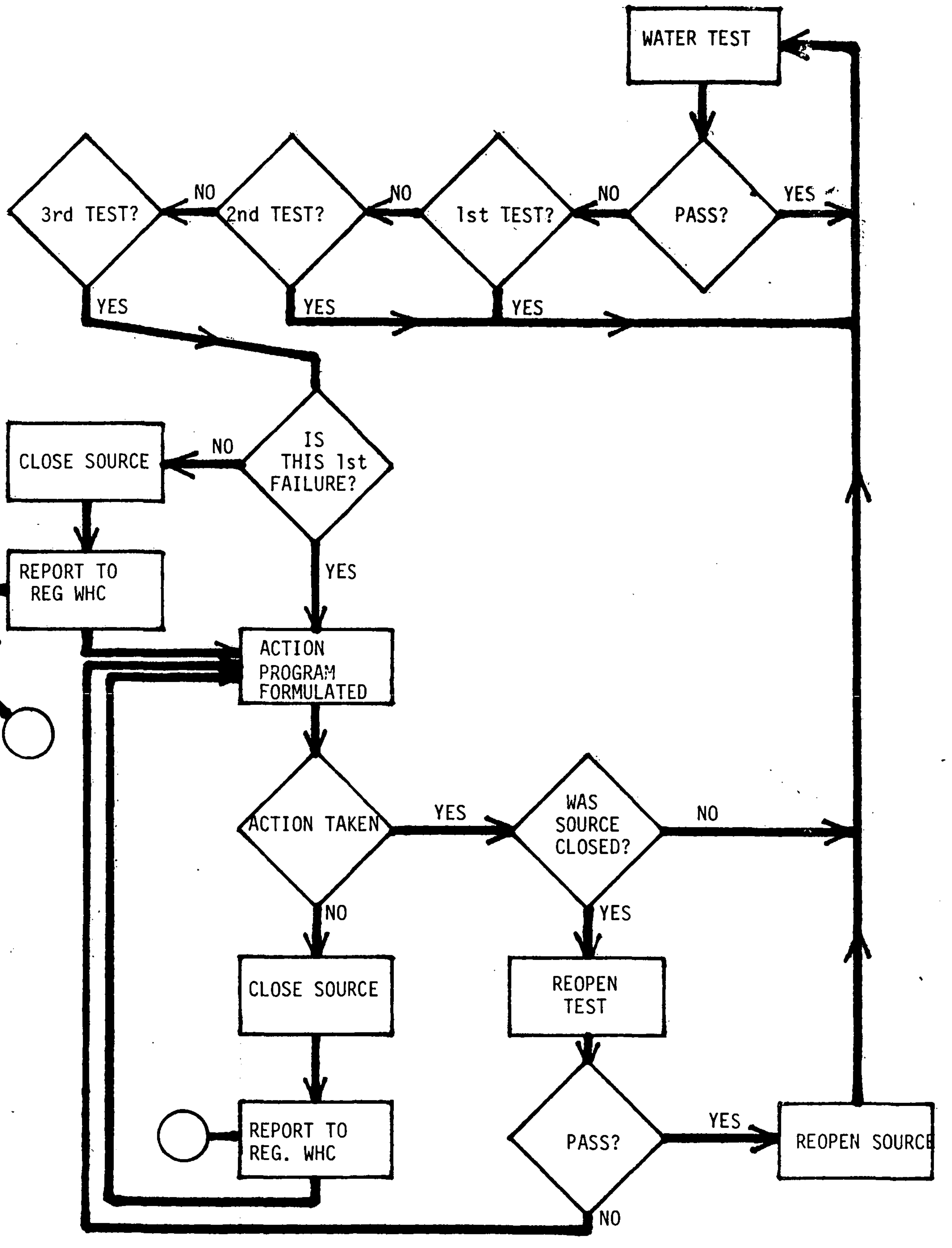
If no action is taken within the period specified by the ZWHE in his action programme then if the source is open he is required to close it and report to the Regional Water Hygiene Committee. The National WHE, and to resubmit his action program to the RWE.

Toxic Chemicals

The flow chart for action controlling toxic chemicals is given in Figure 8.3. The ZWHE carries out water test and if the source violates the standard for a toxic chemical or if the ZWHE suspects a toxic chemical violation he should forward a sample to the central laboratory (Ubungo) for complete analysis. If the standard is violated and industrial pollution is suspected the Regional Water Officer and the Principal Water Officer should be officially informed that there is a suspected violation of the Water Utilisation Act.

FIGURE 8.2

FLOW CHART OF ACTIONS IF FLUORIDE OR NITRATE STANDARDS ARE VIOLATED



 Report to National Water Hygiene Committee

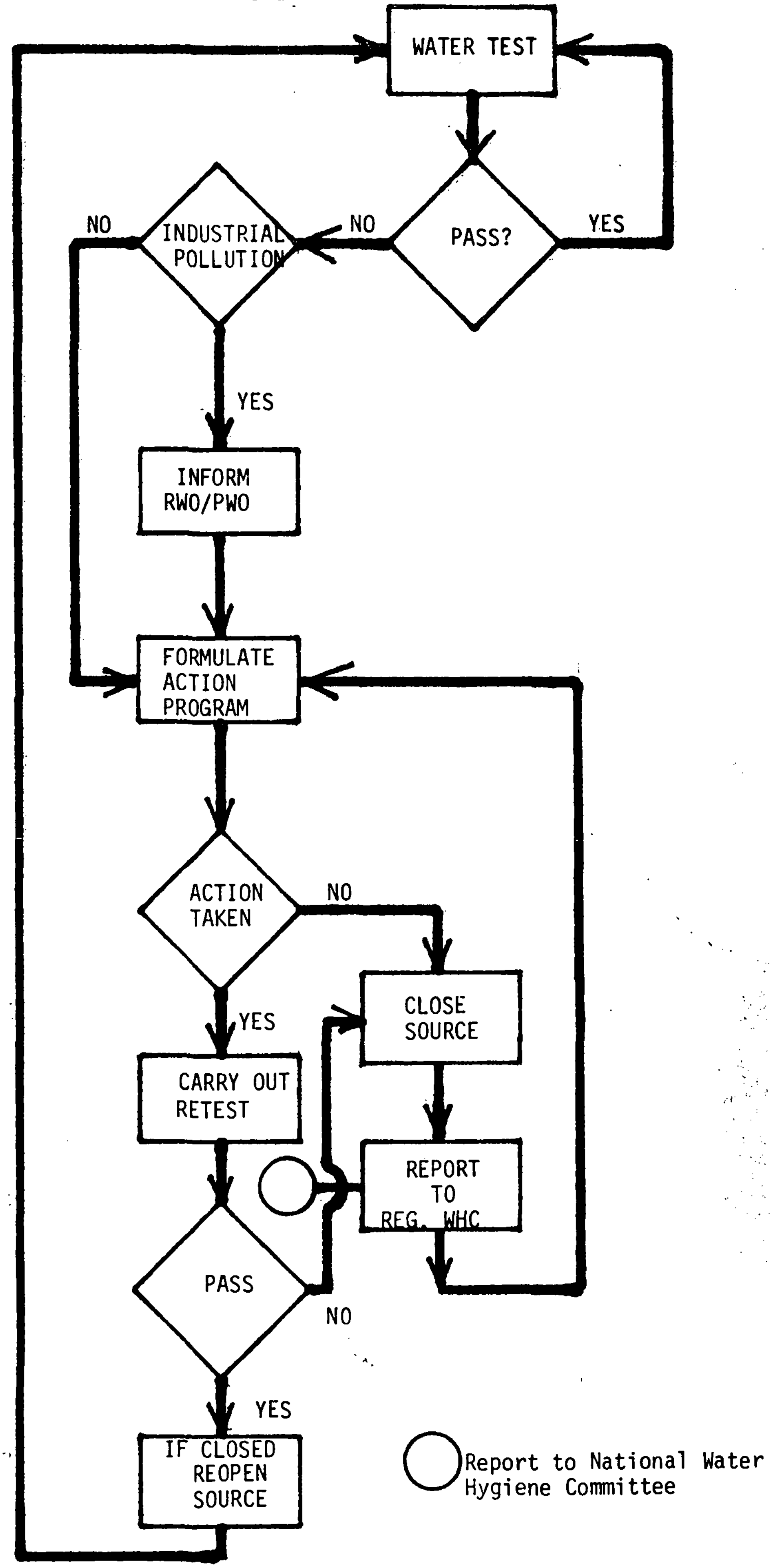
The ZWHE then formulates an action program. With toxic chemicals the time period allowed for action will vary with the seriousness of the pollution and the ZWHE must make a determination of how dangerous the situation is.

If action is taken the ZWHE retests the source and if it is closed reopens it. If the scheme fails the retest then the ZWHE must close the scheme, report to Regional and National WHEs and formulate another action program.

If no action is taken the ZWHE closes the source if it is not already closed, etc.

FIGURE 8.3

FLOW CHART OF ACTIONS IF STANDARDS FOR CHEMICALS CAUSING TOXIC EFFECTS ARE VIOLATED



8.4.3 Proposals for Amendment of the Water Utilisation Act

The Water Utilization Act (WUA) is the existing major legislation dealing with water in Tanzania. The Act is reviewed in detail in Section 8.3.2 and reproduced in Annex 8.1. In this section we propose a rather far reaching revision of this Act which we believe is both suggested by experience with the WUA to date and also provides an appropriate framework which can incorporate the major elements of planning and controlling water quality and quantity. Although there is a tendency to discuss water quantity and quality separately, once water demands increase substantially - as human population densities increase significantly and there is widespread industrial development - then it is not really feasible to deal with quality and quantity as separate elements. The framework we are suggesting here, to use the drainage basin or water basin as the geographical organising area for water programs, is, in our view, the only approach that will permit national water planning in Tanzania. The point is discussed below but essentially there is no alternative to planning water use on a drainage basin basis since this is the zone or geographical unit which permits the full interrelationship among users to be taken into account. This of course has been well recognised in the Ministry historically. The implications of this observation are developed in detail in this section.

We recommend that water control and planning should be handled through two separate pieces of legislation. The first is the proposed Domestic Water Quality Act which we have discussed in detail in Section 8.4.1. The second is the WUA with appropriate amendments. In Annex 8.2 we set out an outline of these amendments. The remainder of this section describes the concepts and intentions of the recommendation.

The objective of the WUA is to provide for systematic control of the volume of extractions and also to provide a legislative basis for water quality control for effluents. We have argued for separation of the domestic water standards and enforcement procedure, a here and now problem discussed at length in 8.4.1, from the effluent, receiving waters, and water quantity problems. In fact as Tanzania develops there are two problems of a quite different type but closely related. First, the water quality standards to be maintained in the supply of water to people (domestic water). Second, the management of the water sources taking account of extractions and effluents so as to provide maximum benefits to the nation. We are concerned in this section with the legislation issues for the second just as is the WUA. This problem is less acute than the domestic water quality problem but it is becoming more pressing everyday, and so, in our view, needs in the near future a significant reorganisation of the water planning approach and the directly related quality and quantity controls. We feel it is not enough to leave water quality controls with the recommended domestic water quality program but must consider the wider problem of the effluents and extractions (see Section 8.2).

After provision of regulatory methods for handling domestic water supplies we must turn to the question of water pollution and alternative water uses. How should control of the water resources be organised? A purely national approach is not very useful; a regional approach will not be very successful since the major water sources are usually far larger than one region. The best way to handle this is to establish controls and planning for the major drainage basins; this permits a comprehensive estimate of water availability to be made from hydrological analysis; demands to be determined from the demographic data plus the Water Rights issued. Finally, the Water Rights plus surveillance data should provide the requisite information needed for analysis of quality standards. Effluent and receiving water standards should ultimately be set for particular drainage basins.

When we turn to the problem of managing a water source such as a river or lake it is obvious that in trying to control water extractions and set effluent standards one must consider the entire drainage basin of the river or lake. If a river traverses several regions then the regional water officers are helpless in making intelligent judgements on permitted extractions; furthermore, whoever has responsibility for the water quality of the source (receiving water standards) must also consider the entire picture of the effluents into the source, the extractions, the relationships among them, the variations in the volume of water available, etc.

From these considerations we believe that it is desirable to shift the control of water extractions (issuing of Water Rights), control over effluents and sewerage to the water basin (or equivalent drainage basin) as the basic administered unit. It is rather inconvenient to do this since the drainage basins do not correspond to any of the political administrative units and for Tanzania some of the important drainage basins extend across national boundaries involving one or more additional countries.

According to the WUA the appropriate authorities would issue Water Rights to applicants upon request whenever requirements exceeded 22,700 litres per day (5,000 gallon); this would be done by the Regional Water Officer when the source concerned was not a national source; if the extraction was from a national source then the Water Right is issued by the Principal Water Officer in the Ministry of Water, Energy and Minerals. The WUA has a great deal to say about Water Rights which are of course valuable assets and the PWO is basically concerned with the legal issues surrounding these Water Rights and the inevitable adjudication that will arise as this system is implemented. As Water Rights are issued the RWO and PWO can, in principle, monitor extractions and compare what is technically feasible (basically a hydrological issue) with what is permitted. Given the extreme variability from year to year of water conditions in Tanzania it is necessary to have some way to control extractions when the available water is low. This is provided for in the WUA by the drought clause which permits reductions in approved Water Rights when there may be insufficient water. Obviously the more extraction there is from a source the more frequently the drought clause must be invoked and enforced for the public welfare.

As for water quality, obviously something must be said in Water Rights as to the quality of the effluent which the user returns to the source. The WUA specifies this must be the same as the quality of water that is extracted. This is not a very useful standard as it is impossible to require this of users and virtually every water user in Tanzania stands today in violation of this aspect of the WUA. As noted in the detailed textual review this is far more severe than the most stringent condition of Environmental Law in Sweden; in the United States where a similar condition has been legislated, it has proved unenforceable.

We have reviewed in three regions what has been done by the RWE in his position as RWO and the answer is essentially nothing. As far as we are able to determine at the regional level there is no systematic procedure for issuing Water Rights; there is no readily available documentation as to what Water Rights have been issued and we doubt that there is any feasible way to use the regional data to determine total extraction from a source. In brief we suspect on the basis of our very limited review that the RWO is presently not an effectively functioning position. This is not meant critically, since the RWE is already overburden with the tasks of supplying water, with new construction and with running the schemes that are his responsibility. In the day-to-day pressures of his job operating a systematic Water Rights register etc. is of rather low priority. It is no wonder then that this is probably not working so well (we are cautious on this conclusion because our observations were limited). Furthermore, most major water sources have been designated national water sources and fall under the jurisdiction of the Principal Water Officer. In brief we see that with the present system as it has developed over the past four years, a very limited role for the Regional Water Officer. In fact we feel that this position should be abolished.

The main amendments for the WUA would provide for the following:

(1) A new organisation assignment for planning. This is discussed below in detail. The regions would no longer participate in the control of water quality except for domestic water use. The regional participation would be through the Water Basin Boards as set out below. The amendments would establish Water Basin Boards for each major drainage basin.

(2) Planning now spread through the Ministry of Water, Energy, and Minerals and the regions would be reorganised for drainage basins. Major projects using water would be handled through the Water Basin Board; minor projects by the RWE but with a data base provided by the Water Basin Board. Water quality regulations for effluents and receiving waters would be established by the Boards.

(3) Surveillance of receiving waters and effluents would rest with the proposed Water Hygiene Division in MAJI.

(4) Legal matters pertaining to Water Rights, adjudication over such Rights, including Water quality issues, would rest with the Principal Water Officer.

(5) Water planning would be carried out by Water Basin Board secretariats which would be operated and coordinated by MAJI. All aspects of exploitation of water resources would be included, thus irrigation, water transport, hydroelectric water uses would be incorporated.

(6) The water quality rules covering Water Rights would be reformulated to provide greater flexibility and to provide enforceable standards with respect to treatment economy.

Organisation

It is not the purpose of the investigations here to propose a new planning system for water resources. Nevertheless, there are certain aspects of the Water quality programme that are strongly linked to the question of who should plan what for water resource development. We are arguing here that in the years to come the planning for water resource development can best be organised around the drainage basins.

The approach that we recommend is to organise PPD (MAJI) along drainage basin lines. Water Basin Boards would be appointed (see below) under the proposed legislation and PPD would establish and operate secretariats for each Board. The information on meteorology, hydrology, geohydrology, and water demands would be organised by drainage basin. The secretariat would regularly up date the information, maintain the registry of Water Rights issued, maintain records of water quality (receiving water and effluents), carry out studies of the water quantity and quality situation and perform such work as the Water Basin Boards would from time to time direct. The secretariats would work with Ministry of Health on public health aspects; with Kilimo on irrigation; with Ministry of Lands on sewerage effluents; with Ministry of Industry on industrial effluents; with the Ministry of Foreign Affairs where the drainage basin includes other countries, with the Principal Water Officer where there are legal questions.

The Water Master Planning work would be integrated into drainage basins.

Through this procedure the hydrology, hydrogeological, Water Master Planning, and project preparation would be restructured within Project Preparation Division. Specification of a full programme for this is beyond the scope of this study and we have given only indications here of what should, in our view, be undertaken.

The Water Basin Board

The Water Basin Boards would be established at a rate consistent with the availability of the staff necessary for the secretariat. The Water Basin Board would usually be chaired by the Principal Secretary, MAJI and the secretary would be Director, PPD. The Principal Water Officer would be a member. The Board would comprise the RDDs from the regions included in the drainage basin and representatives from other Ministries as appropriate. The Board would meet from time to time to receive reports from the secretariat and to set assignments to the secretariat.

The Board's power would be:

(1) To issue through the PS, MAJI, effluent and receiving water standards for the Water Basin;

(2) To prepare water resource development plans and to submit such plans for approval of the Government; implementation would rest with the Ministries or the regional authorities as was appropriate for particular cases. The secretariat would serve as a monitoring organisation to the Board during implementation keeping the Board informed as to progress;

(3) To request the Principal Water Officer to take appropriate legal action when there was a serious water quality problem that the RDD could not have resolved to the satisfaction of the Water Basin Board.

Should these recommendations be accepted then we feel that at the start only a few Water Basin Boards should be designated.

Effluent and Receiving Water Standards

The amended WUA should provide the basis for the Principal Secretary, MAJI to issue standards and regulations for effluents and receiving waters. These ultimately should be specific to each drainage basin but at the start there would be national standards established (see Section 8.4.3.) Whatever standards are promulgated a comprehensive set of regulations for enforement should also be provided. We are opposed to legislation of a highly detailed nature; instead we think that the legislation should provide a frame within which detailed regulations can be issued and changed without having to amend the legislation.

As we have previously noted the relevant language of the WUA establishing the standards is unrealistically demanding and cannot be enforced. We have suggested in Annex 8.2 different language on this point.

Principal Water Officer

This position would remain the key officer for all legal actions dealing with matters covered in the WUA. He and his staff would work with PPD's Water Basin secretariats in all aspects of quality and quantity control. He serves as the legal action agent for the Water Basin Boards. However, according to our recommendations the general secretariat for the Water Basin in responsible for the registry of Water Rights, maintenance of appropriate files and records on water conditions in the basin, and keeping up to date on conditions and problems of the Water Basin. The Principal Water Officer would require a deputy to handle the legal aspects of international waters.

Development Projects

We sketch here briefly how we visualise development projects being identified, prepared, and implemented. The development of projects for the basin requires coordination with all water extractors and effluent dischargers. Project ideas and concepts will be identified by the secretariat by interviews, literature reviews, discussion with the regional authorities, review of Water Master Plans, etc. These project ideas should be summarised and approximate cost estimates made. Guidance should be sought from the Treasury as to the level of resources that should be considered feasible for Water Basin Plans including such foreign assistance as may be appropriate. Then the Water Basin secretariats would prepare projects to feasibility level; these projects would be reviewed and approved by the Water Basin Boards. After comprehensive discussion by the Boards the final project proposals would be submitted to the Treasury. The plan would specify the implementing organisation. In preparing the plan explicit consideration would be given to water quality problems. The Water Board secretariats would monitor the progress on the projects, reporting regularly to the Water Basin Board on these matters.

Priority Areas

We recommend three particular Water Basins which require priority attention:

(1) Pagani River Basin which drains Arusha, Kilimanjaro, and Tanga. This area is characterised by considerable industrial development, large scale agriculture using chemicals inputs, and large towns.

(2) The Ruvu Basin through Morogoro and Dar es Salaam. This Basin is rather polluted now with the substantial industrial development and large concentration of people.

(3) Lake Victoria although not as of now polluted there is a great deal of industrial development underway and use of the Lake will increase steadily in the future using water for irrigation, expansion of transportation systems using the Lake, and a rising volume of extractions for domestic water use. Furthermore, there are rather complicated international problems that must be faced for Lake Victoria.

When experience is gained from these water basins may the list be expanded to include the Rufiji and Ruvuma basins.

International Problems

In several cases the water basin extend into other countries resulting in potentially rather complex water resource planning water quality issues. Lake Victoria, Lake Tanganyika, Lake Nyasa, and the Ruvuma River (Mozambique) are all instances of drainage basins which are partly in other countries. The Principal Water Officer requires a Deputy for International Relations as there will be a growing number of legal questions on this aspect and it is necessary to begin to develop background and to review thoroughly all existing agreements. The question of international agreements covering water quality and quantity control is one of extreme complexity and must be approached on a case by case basis. We believe that the most appropriate starting point for these international agreements is for the Ruvuma River Basin; at present there is little industrial pollution of the Ruvuma and there is sufficient water for present extractions. Consequently, the problems to be resolved are relatively straightforward and would provide experience for the Principal Water Officer in international agreements. The second priority area is Lake Victoria where the industrial development by the three riparian countries is quite sufficient. The volume of water extractions from the Lake should not prove a problem but the water quality will need surveillance, agreements on effluent and receiving water standards, monitoring facilities, and finally enforcement and corrective procedures.

8.4.4 Effluent and Receiving Waters

The legislative recommendations is two-fold:

(a) To rpovide a ligislative framework for issuing effluent and receiving water standards.

(b) To issue as the initial step an administrative regulation promulgating the effluent and receiving water standards prepared by the Government Committee which has been considering these points, supplemented by specific regulations as to testing responsibilities, testing procedures and follow up regulations to deal with violations.

Discussion

The proposed revision of the WUA discussed in 8.4.2 contained an explicit framework in the legislation for issuance of effluent and receiving water standards. In the Consultant's view it is important to avoid putting detailed standards directly into an act. First, proper definition of the standards require fairly detailed specification of procedures for taking samples, frequency of sampling, time specifications for testing, chemical and bacteriological methods used for the work etc. This type of detail is not appropriate for legislation, yet without such specification the numerical standards are quite meaningless. Second, the scientific and medical views as to what is acceptable may vary from time to time and hence it should be easy for the responsible authorities to change the standards as is considered appropriate based on accumulation of research results and experience in Tanzania and other countries.

The effluent and receiving water standards proposed (reproduced in Annex 8.4) by the Effluent Standards Committee are now under scrutiny by the Government. The Consultant has reviewed the proposed standards and find these generally well drawn and appropriate. We recommend that detailed rules which specify surveillance and action responsibilities should be defined and included with the standards.

In the discussion of section 8.4.2, where we outlined proposal amendments to the WUA, the use of effluent and receiving water standards in maintaining water quality was discussed. There is no need to repeat here that discussion the essential points were:

(a) Current Tanzanian problems are not yet critical with the possible exception of the Morogoro - Dar es Salaam area but that deterioration is continuing;

(b) The analysis and planning for water utilisation must cover both quantity and quality. This leads inevitably to complex administrative systems and difficult technical problems both of which must be faced. The recommended approach is to organise control by drainage basins, which we have designated as Water Basins.

8.4.5 Schistosomiasis

The Consultant's legislative recommendation on schistosomiasis are that there be included in the proposed Public Health Act or appropriate legislation a subtitle with two sections. The first section would declare that reduction of schistosomiasis represented national policy and that Government organisations would insure that development programs did not lead to significant increases in prevalence. The second section would require the Ministry of Health to prepare a perspective plan aimed at significant reduction of the incidence of schistosomiasis by the end of the century and a five year initial action plan. Financial guidelines for the initial action plan would be provided by the Ministry of Finance to insure that planned activities were at a level consistent with available funds.

Discussion

The findings reported in Chapter 5 on the impact of schistosomiasis on the public welfare are strongly indicative of the need to undertake systematic eradication programs. The case for control and reduction of schistosomiasis is strongly debated and there are views which suggest that the public health impact is not very great and that the costs to the society are too low to justify significant expenditures on control. However, it is the Consultant's conclusion that there is sufficient evidence in hand that there are marked negative effects on the human population leading to discomfort, lassitude, and kidney and urinary problems requiring medical intervention. Also it is unlikely that the data on impact of the disease in Tanzania will improve significantly over the next few years. Thus we believe the time is appropriate to recognise that the problem is severe and must be handled by the Government. The first step is a clear statement of national policy on this so that there need not be further debate on whether but only on how schistosomiasis is to be attacked.

The first part of the recommendation is that an appropriate legislative vehicle be found for making such a statement of public policy. Of course, the question must first be studied and discussed by the CCM and the Government and all salient aspects of the question considered. If following such deliberations, the conclusion is reached that schistosomiasis reduction is a significant national goal then we recommend such conclusion be incorporated in an appropriate legislative format. One possibility is the Public Health Act which is currently under consideration.

The second part of the legislative recommendation is to require AFYA to prepare and present to the Government a perspective plan and an action plan on schistosomiasis control. The perspective plan would use available information to estimate prevalence (for this study we present a review of the available data in Chapter 5.4); the types of actions that may prove effective; a strategy for control; and estimates on costs, time, and manpower required. The purpose of the perspective plan is to provide the Government with a detailed overview of what is necessary to reduce schistosomiasis and to provide the basis for the five year action program. The five year action program is to specify particular schistosomiasis control activities that should be undertaken by the Government in the immediate future.

The legislation should also specify that water resource development projects should provide for the assessment and control of schistosomiasis within the project. This is particularly important for irrigation projects and water supplies based on reservoirs. In each case intervention by man is increasing snail habitats and directly increasing the exposure of man to schistosomiasis.

PART THREE
A PROPOSAL FOR A WATER QUALITY PROGRAMME

CHAPTER 9
RECOMMENDATIONS

9.1 Overview of Recommendations

This chapter presents the basic conclusions of the Consultant and the recommendations on the Water Quality Programme. The recommendations are given as alternatives for the surveillance organisation and treatment construction. Section 2 sets out the organisation of the Water Quality Programme and is independent of the two alternatives A and B. Section 3 reviews the engineering recommendations. These are general in nature and describe the approach to treatment as well as providing comments on alternative methods. Section 4 presents the detail programme for the water quality surveillance system. The choice between alternatives A and B effects the level of the water quality surveillance programme. Alternative A establishes six water hygiene centres at the start; alternative B reduces this to only four centres. Section 5 summarises the legislative recommendations. Section 6 proposes an emergency water quality fund. Section 7 reviews the manpower and training programme. Next in Section 8, four research concepts are presented which are directly relevant to the water quality programme. Section 9 deals with schistosomiasis recommendation and Section 10 public education campaigns.

Alternative A calls for total expenditures over the six year period 1980/81 to 1985/86 about TSh.36 million while alternative B requires TSh.29 million. These costs cover the total costs - start up, capital and recurrent - of the Water Hygiene Division including the technical assistance considered necessary in the early years, a research programme, a training programme, and establishment of an Emergency Fund to provide flexibility in implementation. The cost of treatment of rural water supplies is given in Table 9.3. If the treatment programme is to be completed in 20 years, TSh. 42 million are needed during the first six years (1981/82 to 1985/86). This will largely be in increments to the regional rural water supply programmes; such increments would total approximately 5%. If the treatment programme is stretched out over 30 years the cost during the first six years is TSh. 28 million over the same period.

Before examining these recommendations in detail it is essential to review the purpose and justification of the Water Quality Programme and its relationship to other aspects of the rural water supply programme. The Government of Tanzania has embarked on a major programme to provide better quality water, available close to homes, and drawn from reliable sources which do not fail in the dry season. At present the human effort in obtaining household water is enormous and probably takes more energy than any other activity of the Tanzanian rural household. The effort becomes particularly strenous in the dry season. Finally, the quality of water from unimproved sources is generally extremely poor leading to disease and death from waterborne and waterrelated diseases. In essence the rural water supply programme seeks to supply more and better quality water.

The first question that must be discussed is the extent to which resources should be devoted to water treatment. An improved source with no treatment raises water quality above traditional sources; the extent of this improvement varies with the source type but has been clearly established in the bacteriological testing carried out in the Water Master Plans and in this study. Thus providing an improved source will already improve the quality of water.

To what extent should additional expenditures for water treatment be incurred? We have three observations to make on this question. First the question can be restated as follows: Should some of available resources be directed to treatment resulting in a slower rate of construction of improved water supplies? The Government faces a choice on this point: Costly, sophisticated treatment methods may be utilised which results in a lower rate of construction of water schemes; alternatively no treatment may be provided, resulting in the maximum rate of scheme construction (the actual rate of course depends on the availability of resources). Where is the correct choice? Our second comment is to point out that the per capita cost of the water scheme is much greater than the treatment per capita costs. Scheme costs (capital costs) are in the range of 200/- to 400/- per capita; treatment costs (capital costs) are in the range of 1/- to 10/-. (This range reflects the treatment costs recommended and discussed.)

In our view the question of whether there should be water treatment or not cannot be answered in terms of the impact on the water scheme construction. The inaccuracy in the scheme cost estimates is greater than the treatment costs and even if the costs were exact the impact on the provision of water supplies would only be a question of delay of completion of the construction programme by 1 or 2 years.

Consequently, the impact of provision of water treatment on the scheme construction programme is in our view so small that we need not consider this in the decision as to the type of water quality programme to have.

Third, we base the recommendations on treatment methods on the absolute question: What methods will be economic, measuring the benefits in reduced disease and deaths? Our analyses indicate that a low treatment level as prolonged storage is justified, while higher level do not improve the health situation enough to justify the expenditure.

In presenting the recommendations on Water Quality we consider the following possibilities:

1. Water surveillance system Level A;
   No water treatment programme.

2. Water surveillance system Level B;
   No water treatment programme.

3. Water surveillance system Level A;
   Water treatment programme which catches up to entire population in 20 years.

4. Water surveillance system Level A;
   Water treatment programme which catches up to entire population in 30 years.

5. Water surveillance system Level B;
   Water treatment programme which catches up to entire population in 20 years.

6. Water surveillance system Level B;
   Water treatment programme which catches up to entire population in 30 years.

The basic argument we make is as follows: The Ministry should expand its water surveillance programme. This can be done at Level A or Level B; we believe Level A is more appropriate.

In addition the Government should provide the recommended water treatment through prolonged storage. The rate at which this should be installed depends upon the availability of funds and the rate of construction of new water schemes.

This can be financed either through the higher costs (approximately 5%) of the ongoing rural water supply programme or supplementary funds made available to the regions from the Ministry. In effect the Government imposes water quality standards and the regions must provide the funds to construct sources which meet these standards.

We present in Tables 9.1 and 9.2 the budgets for alternatives A and B respectively of the Water Quality Surveillance System. In Table 9.3 two different levels for the total treatment costs are given, corresponding to a 20 or 30 years target period for the provision of water. The calculations of these budgetary costs for the proposed treatment are based on preliminary results from the 1978 census. The census results have been recalculated to give estimates for the rural population allowing for a 5% annual increase in urban population since 1967. These population figures form the base for a revision of the calculations of the number of schemes proposed to be constructed with increased storage e.g. those with source categories 3 and 4. The results are shown in Table 9.4 and are about 10% higher when compared with those given previously in Table 6.5.

The cost of each of the six alternative programmes specified above can be obtained by combining the appropriate lines from these Tables. We emphasize, however, that the direct budgetary implications of a Water Quality Programme are given in Tables 9.1 and 9.2.

It must be kept in mind that the treatment method recommended will not provide water which meets the present Tanzanian temporary standards. Thus, for example if the 20 year programme is selected then at the completion of the 20 years all schemes then constructed should test at not more than 10 faecal coliforms under ordinary conditions. A subsequent stage would then commence to install higher level treatment methods which would permit the Tanzanian temporary standards (less than one f-coliform) to be met for all sources. Of course, many water schemes would meet the Tanzanian temporary standards when the source is very good and adequate protection of the source is carried out.

Under the recommended programme the Water Surveillance Programme would regularly identify and act upon violations of the enforcement levels set up; additionally there would be recommendation and advice on water quality for existing and new schemes. We recommend strict limitation on treatment methods but there are other steps that can be taken to support the programme of raising water quality which would arise from the work of the zonal water hygiene engineers.

TABLE 9.1
RURAL WATER QUALITY PROGRAMME EXCLUDING TREATMENT
ALTERNATIVE A

(Thousand TSh)

	80/81	81/82	82/83	83/84	84/85	85/86	86/87-95/96
Water Hygiene Division							
Total		2,980	2,360	2,520	2,670	2,880	54,200
Foreign		1,330	777	836	896	956	20,670
Local		1,650	1,600	1,680	1,570	1,920	33,530
Research Programme							
Total	500	1,900	1,200	400			
Foreign	250	1,000	700	200			
Local	250	900	500	200			
Training Programme							
Total	654	283	283	376	376	376	4,092
Foreign	336	112	112	168	168	168	2,408
Local	318	171	171	208	208	208	1,684
Emergency Fund							
Total		3,000			1,000	1,000	
Foreign*		750			250	250	
Local		2,250			750	750	
Technical Assistance							
Total	1,440	2,520	2,160	2,160	1,440	1,440	1,440
Foreign	1,248	2,184	1,872	1,872	1,248	1,248	1,248
Local	192	336	288	288	192	192	192
TOTAL	2,594	10,683	6,003	5,456	5,486	5,696	59,732
Foreign	1,834	5,376	3,461	3,007	2,562	2,622	24,326
Local	760	5,307	2,559	2,376	2,720	3,070	35,406

* Assumed to be 25%

TABLE 9.2
RURAL WATER QUALITY PROGRAMME EXCLUDING TREATMENT
ALTERNATIVE B

(Thousand TSh)

	80/81	81/82	82/83	83/84	84/85	85/86	86/87-95/96
Water Hygiene Division							
Total		2,370	1,910	2,020	2,160	2,330	37,990
Foreign		1,010	718	730	790	850	14,960
Local		1,360	1,190	1,290	1,370	1,480	23,030
Research Programme							
Total	500	1,900	1,200	400			
Foreign	250	1,000	700	200			
Local	250	900	500	200			
Training Programme							
Total	562	283	283	283	376	283	3,163
Foreign	168	112	112	112	168	112	1,848
Local	394	171	171	171	208	171	1,315
Emergency Fund							
Total		3,000			1,000		1,000
Foreign*		750			250		250
Local		2,250			750		250
Technical Assistance							
Total	1,440	1,800	1,440	1,440	1,080	1,080	720
Foreign	1,248	1,560	1,248	1,248	936	936	624
Local	192	240	192	192	144	144	96
TOTAL	2,502	9,353	4,833	4,143	4,616	3,693	42,873
Foreign	1,666	4,432	2,778	2,290	2,144	1,898	17,682
Local	836	4,921	2,053	1,853	2,472	1,795	25,191

* Assumed to be 25%

TABLE 9.3
TOTAL COST OF RECOMMENDED TREATMENT
PROLONGED STORAGE
(Thousand TSh)

		81/82	82/83	83/84	84/85	85/86	86/87-95/96
1.	20 year programme	7,377	8,191	8,470	8,757	9,052	112,039
	Foreign exchange*	738	819	847	876	905	11,204
	Local cost	6,639	7,372	7,623	7,881	8,147	100,835
2.	30 year programme	4,918	5,461	5,667	5,838	6,034	74,700
	Foreign exchange*	492	546	567	584	603	7,470
	Local cost	4,426	4,915	5,100	5,254	5,431	67,230

* Foreign exchange costs of storage tanks taken at 10% of total cost.

Note on Method of Calculation:

1. The number of schemes is estimated in Table 9.4. This provides an estimate of how the 1978 population would be covered. It is assumed that the number of schemes will remain fixed but the population served by each scheme will increase.

2. The number of schemes constructed in any year is 1/20 or 1/30 of the total number so that all schemes are constructed after 20 or 30 years. The design population for a scheme is the population 20 years after the time of population. Thus as time passes the design population of the schemes to be constructed increases.

3. Additional treatment costs of large schemes providing more than 300 m^3 per day are not included; these are mainly urban supplies and the majority already have treatment facilities although most require rehabilitation.

TABLE 9. 4
PROJECTED DISTRIBUTION OF POPULATION ON WATER SOURCE TYPE
COMPARE WITH TABLE 6.5

Water Source Types

Region	Total Rural Population 1978* x 1000	3			4		
		No. of Scheme	Population per Scheme	% of Pop.	No. of Scheme	Population per Scheme	% of Pop.
Arusha	879	264	1,500	45	44	1,000	5
Coast	517	121	1,500	35	52	1,000	10
Dar es Salaam	50	7	1,500	20	-	-	0
Dodoma	932	47	2,000	10	47	2,000	10
Iringa	886	89	2,000	20	30	1,500	5
Kigoma	612	31	2,000	10	21	1,500	5
Kilimanjaro	865	238	2,000	55	-	-	0
Lindi	512	31	1,014	6	43	1,666	14
Mara	700	7	1,000	1	19	1,500	4
Mbeya	1,057	106	2,000	20	-	-	0
Morogoro	896	90	2,000	20	30	1,500	5
Mtwara	737	100	1,561	21	76	1,177	12
Mwanza	1,384	42	1,000	3	-	-	0
Rukwa	443	104	1,500	35	45	1,000	10
Ruvuma	564	85	2,000	30	38	1,500	10
Shinyanga	1,325	199	1,000	15	133	1,500	15
Singida	616	42	1,500	10	62	1,000	10
Tabora	785	184	1,500	35	79	1,000	10
Tanga	927	163	2,000	35	62	1,500	10
West Lake	995	55	2,000	11	7	1,500	1
TOTAL	15,680	2,005	1,670	21	788	1,380	6

* Based on calculations based on preliminary results from the 1978 census.

9.2 Organisation of the Water Quality Programme

In this section we give the outline of the proposed organisation to carry out the Water Quality Programme. It comprises three major components: (a) National Water Quality Committee; (b) Regional Water Hygiene Committees; (c) Establish a Water Hygiene Division of MAJI. (This is discussed in detail in Section 9.4.) The relationships of Ministries to the Water Quality Programme are shown in Table 9.5.

National Water Quality Committee

The Water Quality Committee is the basic point of coordination and policy making for the Water Quality Programme. The proposed membership comprises:

Principal Secretary, Ministry of Water, Energy and Minerals (Chairman)

Principal Secretary, Ministry of Health

Principal Secretary, Ministry of Lands, Housing and Urban Development

Principal Secretary, Prime Minister's Office

Principal Secretary, Ministry of Agriculture

Principal Secretary, Ministry of Industries

Head of Water Hygiene Division of MAJI (Secretary)

The Ministry of Health obviously should be a member; Lands, Housing and Urban Development is included as they have responsibility for sewerage; the PMO is included since the RDDs and other regional authorities are of central importance in the programme; Agriculture is included since we anticipate increasing investments in irrigation with significant impact on water quality; and Industry is included as we anticipate that industrial effluents will have an increasing effect on water quality.

It is understood that the Principal Secretaries may designate an officer from the Ministry to represent them, although the Consultant believes that participation of the Principal Secretaries is essential to satisfactory operation of the Water Quality Committee.

TABLE 9.5
RELATIONSHIPS AMONG MINISTRY ORGANISATIONS

Ministry - National Level	Description of Proposed Relation to Water Quality Programme
1. Water, Energy and Minerals (MAJI)	
1.1 Principal Secretary	- Chairman of National Water Quality Committee
1.2 Water Hygiene Division	- Establishment recommended in this report; incorporates Water Quality Laboratory, Ubungo. This division has the major responsibility for the implementation of the Water Quality Programme and its activities and organisation are discussed in detail in this chapter.
	- Division Director is Secretary of National Water Quality Committee.
1.3 Project Preparation Division	- Establish, coordinate, and direct the Water Basin Boards and participate in international committees or organisations dealing with water basins shared with Tanzania's neighbours. (Increasingly it will be necessary to control water quality, extractions, and effluents on a comprehensive basis and the natural geographic coverage of such control is the the catchment area of major rivers.)
1.4 Principal Water Officer	- Responsible for all legal aspects of the Water Quality Programme. This particularly deals with water quality legislation; establishing monitoring, reviewing and revising the enforcement programme.

Table 9.5 cont'd

2. Health (AFYA)	
2.1 Principal Secretary	- Member of National Water Quality Committee; coordination of AFYA's participation in Water Quality Programme.
2.2 Government Chemist	- Handles all special physical-chemical water tests which are beyond facilities of MAJI's Ubungo.
	- Consults with and advises Director Water Hygiene Division on physical-chemical water testing methods.
	- Participates in training of water laboratory technicians. (As part of overall training programme for laboratory technicians.)
2.3 Central Pathology Laboratory	- Consults with and advises Director Water Hygiene Division on bacteriological testing methods.
	- Participates in training of water laboratory technicians.
2.4 Preventive Services Division	- Provides technical support to Director, Water Hygiene Division on health aspects of the Water Quality Programme.
3. Lands, Housing and Urban Development (ARDHI)	
3.1 Principal Secretary	- Member of National Water Quality Committee; coordination of ARDHI's participation in Water Quality Programme.
3.2 Drainage Division	- Responsible for sewerage and effluent treatment. Coordinates on relationship of sewerage effluents on water quality.
3.3 Environmental Protection Group	- Responsible for investigations and recommendations on environmental protection relevant to the Water Quality Programme.

Table 9.5 cont'd

4. Agriculture (KILIMO)	
4.1 Principal Secretary	- Member of National Water Quality Committee; coordination of KILIMO's participation in Water Quality Programme.
4.2 Irrigation Division	- Responsible for effluents from irrigation projects and impact on water quality.
5. Prime Minister Office	
5.1 Principal Secretary	- Member of National Water Quality Committee; coordination of PMO's participation in Water Quality Programme.
6. Industries (VIWANDA)	
6.1 Principal Secretary	- Member of National Water Quality Committee; coordination of Ministry of Industry's participation in Water Quality Programme, particularly with regard to industrial effluents.

Responsibilities:

- Receive biannual report of Water Hygiene Division; review and where appropriate recommend action.

- Prepare Annual Report to Ministers on Water Quality Programme.

- Review Annual Plan of Water Hygiene Division and make recommendations to PS, MAJI.

- Review and recommend on all legislation and regulations dealing with water quality.

- Review research proposals and approve.

- Review use and level of the Emergency Water Quality Fund.

Meetings should be at appropriate intervals.

The Committee will have fairly a heavy work load the first three years of the programme with the establishment of the zonal centres and the initial impact of their work. There is also a considerable number of regulatory issues that the Consultant recommends be resolved. Once the programme is organised and functioning then the work load of the Committee should largely deal with any disputes on action taken to close water schemes that cannot be resolved on the regional level.

Water Hygiene Division in MAJI including Zonal Water Hygiene Centres

The organisational details are given in Section 9.4. Basically this division will control the central laboratory (which also acts locally as one zonal water hygiene centre) and additional zonal water hygiene centres.

Responsibilities:

- Operate national, zonal, and special water quality laboratories. Special laboratories comprise those associated with large water treatment plants.

- Carry out surveillance of water schemes (urban and rural).

- Carry out tests and consult on proposed new sources.

- Prepare recommendations to correct violations of water quality standards in both urban and rural water schemes; advises RWEs on implementation of corrective actions (zonal water hygiene centres).

- Carry out surveillance of sewage, waste water and receiving waters (see Comment below).

- Carry out water tests relating to groundwater investigations (not geochemistry for mineral investigations - if added to responsibilities - additional staff and equipment are required above what is described herein).

- Prepare the research programme and conduct or supervise approved research related to water quality problems.

- Prepare recommendations on specific treatment methods based on research and literature review.

- Prepare recommendations on source protection methods based on field observations and literature review.

- Prepare recommendations on design of intakes, storage and domestic points relevant to water quality.

- Review and prepare estimates of water treatment costs.

- Review and evaluate different treatment chemicals.

- Review, comment upon, and prepare recommendation, guidelines, regulations, and legislation dealing with water quality.

- Make recommendations to Principal Secretary on approval of drawing from special Emergency Water Quality Fund.

- Organise seminars on Water Quality for RWEs and RMOs.

- Advise Manpower Division, MAJI on training of laboratory technicians, water hygiene engineers and water technicians.

- Prepare support material for public education campaigns.

- Prepare biannual report of Water Hygiene Division for submission to National Water Quality Committee.

- Prepare Annual Plan for Water Hygiene Division.

Comment

We have recommended that surveillance of effluents and receiving waters be handled by the Water Hygiene Division. We recognise that ARDHI has primary responsibility for sewerage effluents, however we make this recommendation because we believe it is far more efficient to have one water laboratory organisation covering all types of water surveillance. With the acute shortage of manpower and laboratory facilities we urge that for economy a single responsible organisation be established.

Regional Water Quality Committee to be established in every region

The Regional Water Quality Committee is the central point for presenting action recommendations, raising violations of non-compliance levels and presenting follow up reports. The proposed membership comprises:

Regional Development Director (Chairman)
Regional Water Engineer
Regional Health Officer
Regional Lands Officer
Regional Planning Officer
Regional Agricultural Officer
Regional Industrial Officer
Zonal Water Hygiene Engineer (ZWHE) (Secretary)

Responsibilities:

- Plan water source surveillance for region covering new schemes (ongoing surveillance of operating schemes is specified by regulation as proposed in this study and is not subject to review at regional level).

- Receive findings of ZWHE on water quality of schemes. Particularly important are deficiency findings requiring corrective action according to regulation will be submitted (see Section 8.4.1). Review necessary actions, instruct organisations to take appropriate actions, generally follow actions being taken and reporting on corrective measures. RDD's office to be informed of recommendations of the committee.

- Prepare annual report on regional water quality programme for National Water Quality Committee. This should cover remedial actions taken, problems encountered and recommendations.

- Initiate public campaigns on water quality.

We anticipate that in a properly run programme there would be considerable difference of view. The compliance regulations we have suggested will result in some difficult situations when ZWHE closes a water scheme due to lack of prompt or appropriate action by the regional authorities. It is in the Regional Water Hygiene Committee that these conflicts will be resolved. Nevertheless, it is the intention of the proposed system that the ZWHEs will be following regulations which determine appropriate action in different circumstances. There is room for the ZWHE to use his judgement in preparing recommendations but he must close the scheme when the conditions arise which are specified in the regulations. Notice that the authority to close a water scheme is vested in the ZWHE. He does not need higher authority but of course he must have a reason for doing so as set out in regulations.

It is mandatory that the ZWHEs maintain close contact with the Regional Water Hygiene Committee. The ZWHE is also expected to work with the Regional authorities through the committee to promote source protection, to carry out public education programmes, etc.

9.3 Engineering Solutions and Recommendations

In this Section we review the Consultant's conclusions and recommendations on the engineering aspects of water quality. First, we discuss the general approach for small and large water supply schemes. Then we summarise the results of the benefit cost analysis on the appropriate level of water treatment that should be undertaken. Next we turn to recommendations on specific treatment methods, source protection, source selection, and design. In all of these factors we are interested in the affect on water quality. Inevitably quality considerations are mixed up in overall design. Finally, we make some comments on water quality considerations on the use of rain water and for rural institutions.

The discussion in this section is based upon careful assessment of the financial situation of the regions and the availability of technical manpower.

General

The problem taken up in this section is what practical measures should be undertaken to improve water quality. Other recommendations in the report deal with the administration, surveillance, manpower development, and finance needed to improve quality. Ultimately, however, what counts is the actual things that are done at water schemes. The dimensions of the problem are immense: First, we distinguish between large and small rural water supplies. Most rural water supplies in Tanzania are small serving a single village; the core recommendations deal with this case. But there are also large schemes and these are discussed below as the handling is rather different. Second, we repeat the necessity for practical, low cost solutions to the question of raising water quality. Furthermore, the recommendations and designs must be based on a realistic assessment of the day-to-day operating problems facing rural water systems. Third, one cannot approach water quality engineering without concern for the acceptability of water to the user. Rural communities have well developed ideas about what is good water and these views may not correspond to the scientific analysis. There are many cultural reasons why a source is rejected even though the laboratory analysis indicates it is of satisfactory quality. For instance, during the cholera epidemic along the Pangani River many new, safer, protected shallow wells with hand-pumps were installed by the health authorities. However, the local inhabitants still preferred the potentially lethal river water because it tasted better to them, and reverted to using such sources as soon as the health officers left the villages. Another relevant case was described by the water treatment plant operator at Misungwi (Mwanza Region): As instructed he had been adding the required amount of chlorine to the public water supply, but received complaints that the taste was too strong. In response to the public protests reduced the chlorine dose to a level where it was ineffective, not leaving the residual chlorine concentration high enough to ensure bacteriological purity on leaving the plant and passing through the distribution system.

Consumer acceptability is important, for without it the effect of any investment in water quality may be negated by refusal of the population to utilise the improved water. The solution lies in continuing education on health and water which is a prerequisite for the people of Tanzania to achieve higher levels of health and development.

Acceptability must also be considered by the water supply authorities in planning water schemes. Such factors as excessive chlorine, turbidity or salinity, or low pH may not be viewed by the water authorities as public health problems, but such characteristics tend to reduce the willingness of the population to use the water supply, even if the water is of good bacteriological quality. If such problems arise, the cheapest solution is likely to be selection of a more suitable water source.

Regional Water Engineers all have experience of this scheme rejection due to superstition, or other cultural reasons. There are no hard and fast rules; the effective RWE will try to understand such cases and use this knowledge to improve source selection and planning of future schemes.

A popular solution to water quality problems is to ignore quality considerations completely in designing water schemes and then suggest that people should boil their drinking water. This procedure is so often suggested that it is worth brief consideration of the economics. We estimate that 0.6 - 0.8 m^3 of firewood is needed to boil one cubic meter of water. The cost of gethering firewoodis 4/- shillings per cubic meter for a haul of 2 kilometers. In many areas with poor forest cover the handling distances will be much longer. Thus at a minimum we expect 2/50 - 3/- per cubic meter as the treatment cost for boiling water. This is far higher than the treatment costs by the methods covered in Chapter 6. We do not feel therefore that it is sensible to encourage the rural population to use firewood to purify their drinking water. Furthermore, although Tanzania has on the average plenty of wood to permit this method of water treatment there are many areas with shortages of firewood so that the effective cost would be much higher. Finally, we anticipate that universal boiling of drinking water would have some marked effect on reducing the quality and perhaps quantity of forest products.

Benefit-Cost Analysis

The benefit-cost analysis was carried out for three treatment levels (see Chapter 7). The conclusion of that chapter is quite sharp: The low level treatment is what is justified under the existing economic conditions in Tanzania. At an 18% interest rate the requirement for break-even (benefits equal costs) is that the low level treatment will prevent 15% of the F-O diseases. The medium level treatment requires approximately 50% prevention for break-even; we judge this to be unrealistic. The benefit-cost analysis is clearly indicative that a low level treatment of water is preferred and furthermore, more expensive treatment methods are not justified. The conclusion is robust and holds even if large shifts are made in the assumptions. In the Consultant's view there is a strong case for pegging the treatment at provision of extra storage for those surface sources which are judged to have poorer quality than protected shallow wells. All other sources are not treated.

Recommendations on Specific Treatment Methods

In this section we draw together a number of observations on different treatment methods. These are based on the Consultant's experience in Tanzania, elsewhere in the world, and in particular on the observation of existing treatment plants in Tanzania. Basically, we find that existing treatment plants are in poor to fair condition. Many of the plants were not functioning at the time of survey. We believe it is important to be quite practical in preparing recommendations on treatment. We will comment on how each treatment method should be handled and briefly on its usefulness. We reiterate that this recommendation holds for small rural water supplies (for large schemes see Section 9.3.7). Cost estimates and engineering details are found in Chapter 6.

(a) Storage

Storage has been discussed in Chapter 6; it comprises retaining the water in storage for a long period; our initial recommendation is for 48 hours.

Although this method has not been widely utilised in the past for water quality improvement, it has many advantages which should not be overlooked. Current knowledge on the precise efficiency of the process is limited, but the following effects can be assured if water is stored for 48 hours:

(1) Bacterial removal in excess of 90%.

(2) Removal of suspended matter, variable according to the layout of the tank, but again in the region of 90%. This includes helminth eggs and protozoan cysts, and inorganic matter. which probably adsorbs the majority of virus particles present.

(3) Death of schistosome cercariae

The very important advantage of the system is that it does not require any chemicals or other supplies, and demands virtually no maintenance. It is also the only process which improves its performance in the presence of high turbidity. This is because sedimentation is a faster process than the death of bacteria and particularly viruses. A greater fraction of these will be adsorbed onto the sediment when the turbidity is high, and thus removal by sedimentation will be increased.

The technical performance of storage systems is more fully discussed in Annex 9.11.

Although we are confident in obtaining substantial water quality improvement from storage, we believe that additional research is necessary to permit the determination of an optimal design for the storage tanks. The research programme (Section 9.7) sets out how we recommend this should be achieved.

There are some particular aspects of maintenance of storage tanks that need to be mentioned: First, the tank should be sterilised with chlorine before accepting into the water scheme; or if this is not possible it should be chlorinated as soon as possible. Second, the tank should be cleaned from time to time and the sterilisation should be repeated after each cleaning. We also note the necessity to keep the storage tanks properly secured to keep people from contaminating the water. We have noticed instances where storage tanks have not been properly secured. With the larger tanks being recommended this is a rather important point for the RWE and the village authorities to ensure.

b. Chlorination

This is the classical method of water disinfection. When properly applied it gives a complete removal of bacteria, although it does not guarantee the elimination of viruses. A further advantage is that presence of free chlorine residual will protect the water against minor pollution in the distribution system or regrowth of bacteria. This is a very important advantage, especially in large systems. The disadvantages are also important. Firstly, the dosing equipment is relatively delicate and requires moderate skill to operate and maintain. The dosage may have to be adjusted several times a day as the organic content of the water (which uses up the bulk of the chlorine) varies. This adjustment must be quite closely controlled, as too little chlorine renders the process ineffective, whilst too much causes taste complaints from the consumers, especially those previously used to untreated water.

We note that for supplies for more than 10,000 persons chlorination of some form or another should be used. A water scheme serving 10,000 persons is considered to supply 300 m^3/day. The handling of larger schemes will be discussed in more detail in Section 9.3.7. For small supplies, we generally recommend that chlorination not be used as we do not believe that the results are worth the cost. There are several additional reasons why we believe that this type of water treatment should be avoided for small rural water supply schemes:

(1) Proper use requires regular testing to ensure there is residual chlorine in the system. This can be done (see discussion under surveillance), but it calls for a higher level of training than is usually provided to the pump attendant.

(2) For rural areas it is important to have good quality, robust drip feeders for insertion of the chlorine into the water supply system. We observe frequent instances when the equipment has proved too fragile; this equipment is not particularly expensive and in the conditions found in rural Tanzania, it is worth purchasing the most robust equipment that can be obtained even if it is more expensive.

(3) We have examined the chemicals available and recommended either sodium hypochlorite or chlorinated lime as the cheapest sources of chlorine.

(4) The operators for chlorinators must be trained. This is not a particularly difficult course but it is absolutely necessary that the operator be allowed to learn to operate the equipment, be taught to assess the dosage requirements, and to check for residual chlorine.

(5) The chemical supply must be reliable and regular. So far this condition has not been met and existing treatment plants often run out of the chlorine source.

(c) Sedimentation, Flocculation, etc.

In this treatment method there are three stages: flocculation/coagulation, sedimentation, and filtration. This is a more expensive and complex treatment than either storage or chlorination often necessary for raw water with high turbidity.

Flocculation of raw waters, followed by sedimentation is occasionally pratised in Tanzania. It appears to work quite well, when alum is available at the plant. From a technical point of view, the effect is similar to that of 48 hours' storage except that schistosome cercariae can pass through the process. Sedimentation tanks may present some problem as sometimes the precise setting of the effluent weirs to the horizontal is badly effected, thus greatly reducing efficiency. The corrosive environment created by the coagulants may also cause holes in the weirs, again reducing efficiency.

Upward flow filtration is a simple and effective method of removing the residual flocs from sedimented water. After passing this stage, water can be very clear, although not pathogen-free. Operation is simple. Once the the filter becomes clogged, it is simply drained and refilled 2-3 times. Maintenance is also simple and hence makes the process attractive for small plants.

Rapid gravity filtration is another type of sand filtration for flocculated water. It has the same effect as upward flow filtration. Its only advantage over upward flow is the smaller surface area required. Operation is much more difficult, backwashing being accomplished by pumping filtered water and compressed air upward through the bed. The extra pipework and pumps are expensive and complicated and demand skilled operation.

From observation of these systems in Tanzania, we recommend as follows:

(1) It is necessary to use soda ash to adjust the pH. This requires that the operator be able to carry out the necessary tests.

(2) We recommend use of the most robust dosing equipment.

(3) The supply of chemicals is obviously critical to successful operation. As is the case for chlorine we find repeated instances of treatment plants out of operation for protracted periods due to non-availability of chemicals.

(4) The operators of these systems must be carefully trained in all aspects of operations including simple chemical testing to adjust dosage as necessary.

(d) Slow Sand Filtration

Under this process the water passess through a sand filter; the effect of the filter is biological rather than physical and the biological film that develops on the surface of the sand filter serves as the means of removing the bacteriological contamination.

This is a highly effective treatment method, with virus and bacterial removal in excess of 99.9%. It is in fact the best way of removing viruses from water. Removal of helminth eggs, protozoan cysts and schistosome cercariae is effectively complete under normal operating conditions.

The disadvantages of the system are also well known. The main one is that it demands skilled operation. This aspect is overlooked again and again, and what could in principle be a cheap, simple and effective treatment method turns out to be very expensive as it does not function effectively. Although technologically simpler than flocculation - sedimentation - filtration - chlorination processes, it is equally sophisticated in operation. The most important aspect of slow sand filter maintenance is the periodic removal of the surface biological layer (the Schmutzdecke) where much of the purification occurs. An even 2 cm layer must be scraped off when the pressure drop across the filter becomes too great. The water must then be run to waste until the Schmutzdecke is re-established. It thus requires considerable skill both in performing this operation and timing it correctly. Mistakes like allowing the filter to dry out must also be avoided, or the Schmutzdecke will die.

A major technical drawback is the inability of the process to handle large sediment loads, which are common in river waters, especially in the wet season. Present Tanzanian design policy seems to be to overcome this by a flocculation and sedimentation stage before filtration, but this should be viewed critically, as the low pH created by the coagulants may upset the delicate biological process in the filter bed. Likewise, the effect of prechlorination in heavily polluted waters may also adversely affect performance.

We did not find any of the constructed slow sand filters operating successfully in Tanzania. Although this is a good treatment method we believe that there are several points which condition proper operation.

(1) Slow sand filters should be avoided in conditions of high turbidity. This is a rather difficult condition since surface sources in Tanzania are typical rather turbid during the rainy season resulting in serious problems with SSF. Work is going forward now to investtigate the extent to which turbidity reduces the effectiveness of SSF in the typical working conditions of rural Tanzania. But as of this time, the SSF must be restricted to sources where the turbidity is low throughout the year.

(2) Practical methods of operations, particularly careful scraping and cleaning need to be developed. At this time there is no practical, proven experience in Tanzania. The exact methods of handling the SSF need to be established and proven. What is needed at this point is a very simple, understandable handbook for operations which would explain all of the rules and operating methods. This must be based on actual successful experience in running a slow sand filtration.

(3) Operator training is extremely important. As noted above considerable skill is needed to carry out the day-to-day operations. The person responsible for the operation of a water scheme utilising a SSF must receive instruction and guidance on exactly what is required.

In brief reviewing the three existing advanced methods of treatment - chlorination, sedimentation and slow sand filtration, we find similar problems in each. The operations of the systems have proved difficult with frequent breakdown due to: (1) Unsatisfactory design and construction; (2) Fragile equipment; (3) Shortage of chemicals; (4) Insufficient training of operators in control of the treatment systems. Having noted these points it is of course easy to set down the solutions but it is very hard to achieve these solutions. Although we have pointed out the things that are necessary to make these treatment methods work more successfully we repeat that the basic finding of the benefit-cost analysis is that it is not justified to utilise these advanced treatment methods for small rural water supplies. When we add to this basic finding the list of problems actually observed in operational conditions, the case for shifting to a low level treatment system requiring little operations or maintenance is greatly strengthened.

Recommendations for Source Protection

In this Section we discuss recommendations for protecting water sources. Source protection is an obvious way to try to safeguard water quality and the rural population is basically aware of the advantages of this. Traditional rules about water use provide for source protection and separation of sources according to use. However, in actual practice there is a great deal more that can be done to protect the source from contamination. The different sources are reviewed individually and source protection rules listed. This is such an important aspect of a water quality programme that we recommend that the Zonal Water Hygiene Engineer should prepare a report on every scheme he visits, recommending the source protection measures that should be instituted.

In the operation of the surveillance system the Zonal Water Hygiene Engineer is required to visit the schemes, carry out appropriate quality tests and observe the source and how it is protected. Based on the field observe the zonal laboratory prepares a report for the RWE and RDD; even if the source complies with the NC levels there may still be protection measures that the village can put into effect. Providing advice to the village leadership and working systematically over time, the Zonal Water Hygiene Engineer should be able to achieve major improvements in source protection.

(a) Boreholes

Access to the physical area around the borehole should be restricted for a radius of 25 meters. A concrete apron around the borehole will prevent pollution from going down the outside of the casing. Livestock should not be permitted in this area; people should be kept out as much as feasible. The village should establish a combination of physical restraints and social discipline.

Boreholes should be carefully protected between drilling and construction of the scheme. We have found a great deal of pollution of boreholes takes place if these are not properly protected. Although such pollution is essentially temporary once the borehole is being utilised it is proferable to prevent any pollution from entering.

With care around the borehole itself, the only pollution could be nitrates carried through groundwater; these can originate almost anywhere depending on the relation between recharge area and borehole and there is no satisfactory way to protect the borehole source from such contamination.

Generally the borehole is a very satisfactory source at least as far as bacteriological contamination goes and source protection requirements can bekept to a minimum.

(b) Shallow Wells

The shallow well protection methods have been set out in the Shinyanga shallow well project reports. These are all well thought out and as much as possible should be followed. The problem with a shallow well is that there are a lot of people around the well engaged in drawing water. Water is extracted either by hand pumps (occasionally motirised pumps) or by buckets or similar containers lowered into the well. Further difficulties occur as, in the dry season it is often necessary to excavate material from the bottom of the well leading to people actually going down in the well. The chances of pollution of the well are therefore quite high unless strong source protection measures are instituted. We divide these problems into those associated with physical conditions around the well and the problems of water extraction.

The well should be provided with a concrete apron sealing the rim of the well and preventing water from returning immediately to the well from the surrounding area. The area should be properly drained to prevent water from accumulating. The bush should be cleared around the well and ideally sanitary facilities (pit latrines) constructed on the downstream side of the shallow well. Animals should be kept out of the area around the well. (See Figure 9.1.)

The shallow well should be covered but this of course requires a satisfactory extraction method. Ideally a reliable handpump is installed which will permit the well to be closed. However, it has proved difficult to install and maintain satisfactory handpumps and realistically one must expect that in the next few years extraction from shallow wells will largely be based on buckets etc. If unrestricted use of buckets is permitted then the pollution in the shallow well will increase sharply and be kept at a high level with every extraction another source of pollution. This problem can be minimised in open wells by installing a windlass and bucket which would never leave the well and would prevent dirty buckets from entering. (Figure 9.2) However, we are cautious about how well this or similar system will function until there have been extensive field investigations. Finally, should it prove impossible to operate a closed well then we recommend that the village organise extractions so as to use only one bucket.

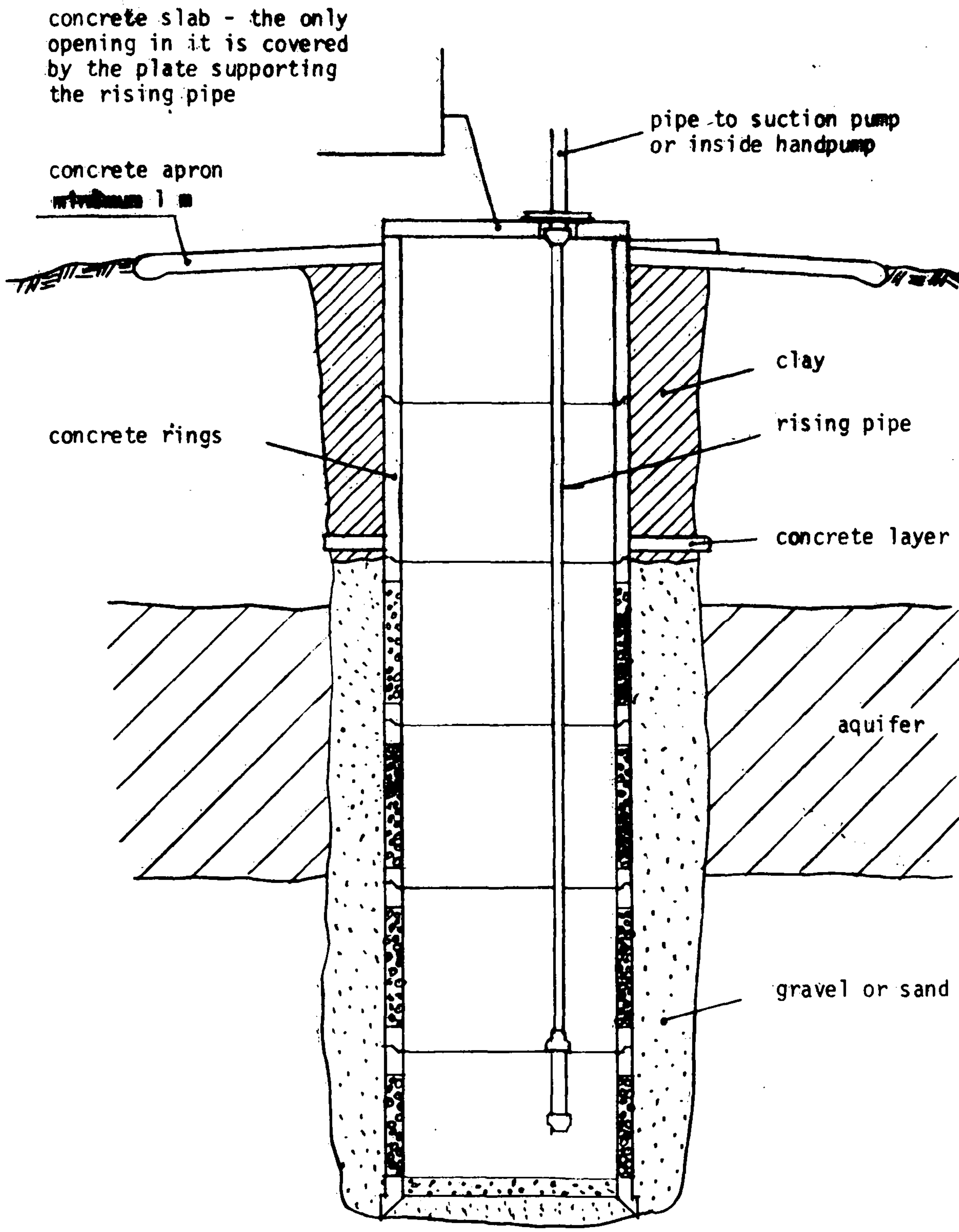
The problems of source protection of improved shallow wells are so complex that the village should appoint a well attendant who would be responsible for keeping the areas around the well clean and supervising the use of a communal extraction bucket or handpump. Where there are several improved shallow wells the Zonal Water Hygiene Engineer should encourage appointment of such an attendant and should train and advise such persons. The importance of source protection cannot be overstated. The shallow well is an adequate water source but the water quality will deteriorate rapidly without proper controls over the users. This is an area where public education, social discipline, and enforcement of understandable regulations can have a considerable impact on water quality.

(c) Springs

Springs are a good water source providing bacteriologically clean water. These sources are highly favoured by the rural population and are used whenever available. However, there is rarely much provision for protection of springs; the RWE has no defined responsibility for this and the village may have only limited ideas as to what is necessary. As an example of what can be done, Figure 9.3 illustrates how a spring can be protected. First the area around the spring is fenced and a drainage ditch constructed. This protects

FIGURE 9.1

PROTECTED SHALLOW WELL



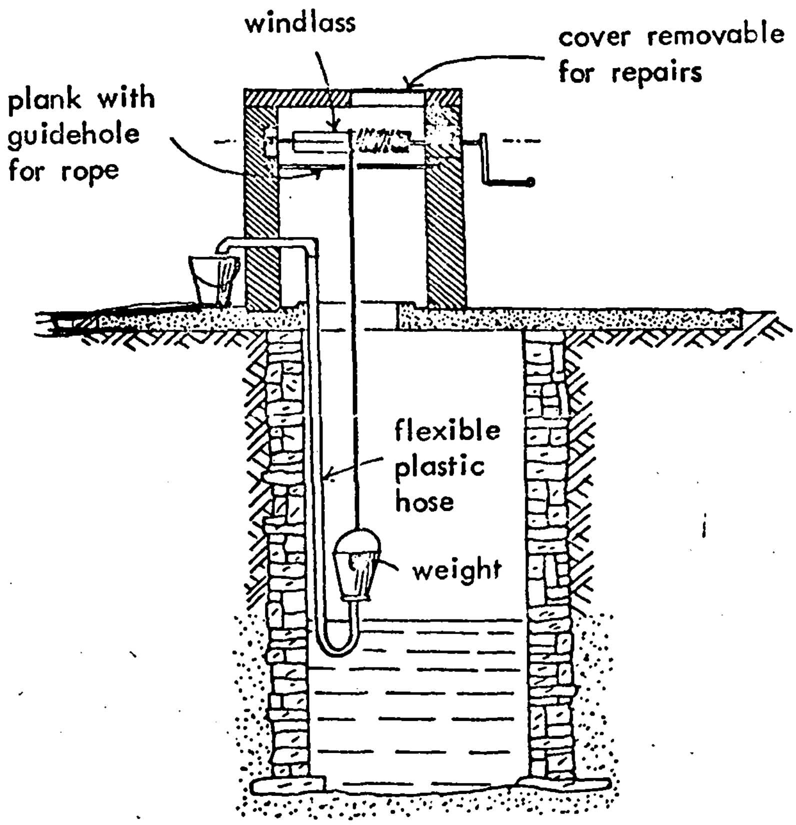
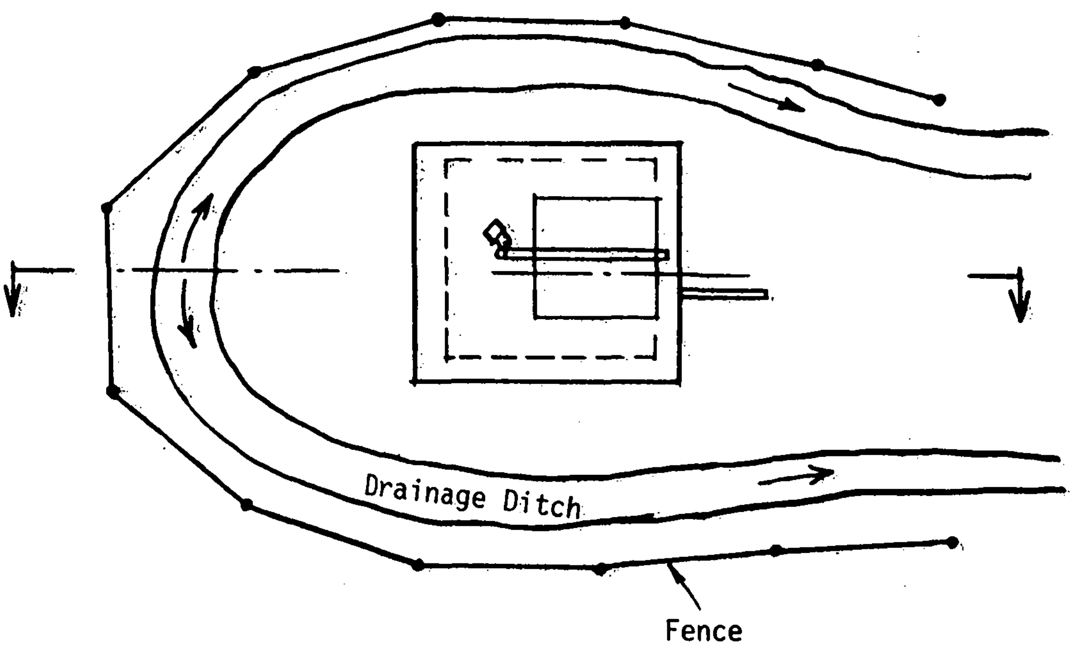


FIGURE 9.2: Shallow Well Protection Method

One method of protecting a well from pollution. No methods of this kind have yet been adequately tested in the field.



Plan Section

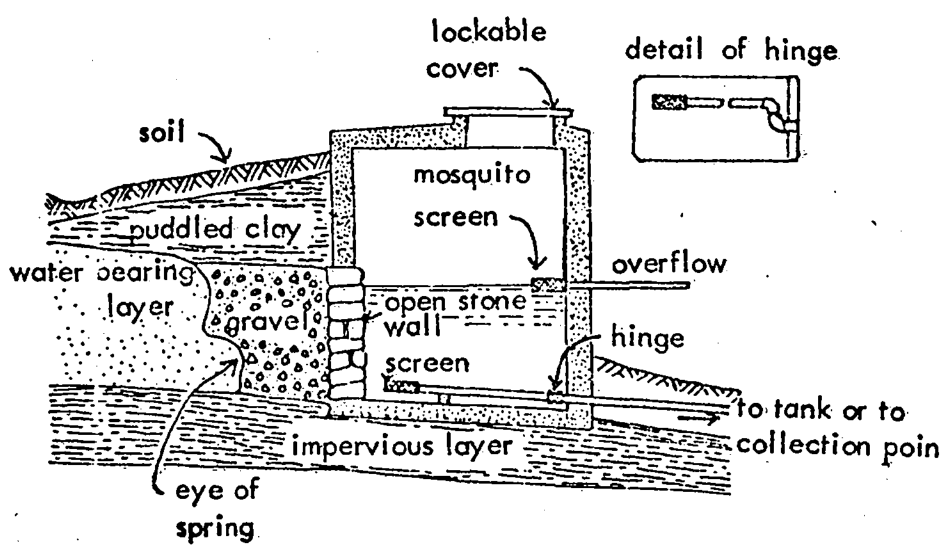


FIGURE 9.3: Protection of Springs. A spring box; the inset detail shows a hingemode with two pipe bends, enabling the screen to be lifted above the water for cleaning.

The spring area from surface pollution flowing into the water. People and livestock must be kept out of the area around the spring box. Second, the spring box collects the water and it is led away to a collection point or a storage tank. (Springs produce of the order of 3-7 m^3/day on a continuous flow basis and so storage can be utilised; for balancing 1.5 - 3.5 m^3 storage is required and for treatment 6-14 so that we need very small storage tanks of the order of 10-20 m^3.) By protecting the spring in this way we preserve the quality of the water.

When the Zonal Water Hygiene Engineer finds spring sources in villages he should encourage the village authorities to undertake construction of this or similar types of source protection. The costs are quite low and the improvement in the quality of consumed water can be quite substantial.

(d) Reservoirs

Water taken from reservoirs is usually of extremely poor bacteriological quality. This can be somewhat improved by better source protection but it must be admitted that the difficulties in achieving real improvement in water quality are immense. Nevertheless much can be done. First, the village must try to achieve the social discipline to keep animals and people out of the reservoir and away from the immediate vicinity (say 200 m from the shore). Second, maintenance is required to clean out such vegetation as may develop. Although obvious, this may require a considerable effort from the village. As part of this programme the RWE should provide simple water works to permit extraction of water for human and animal consumption without people actually entering the reservoir. In this case the water works can be considered part of the treatment since without them it is not possible to reduce the pollution. There are alternative ways to extract water from reservoirs noted below in the discussion of design. However, for existing reservoirs cooperation of RWE, Zonal Water Hygiene Engineer and the local authorities should permit improvements in the quality of the water used.

(e) Streams

Protection of stream sources is made difficult by the fact the water collects pollution far upstream of the intake. Although one can propose upstream protection this is quite ineffective. There is no way to avoid the upstream pollution so that source protection must concentrate on local measures. The obvious thing is to restrict laundry and bathing activities to points downstream of the intake. Alternatively, the intake should be positioned so as to minimise the amount of human activity upstream. Watering of animals should also be controlled and kept downstream of the water intake. This is largely a matter of social discipline and provision of facilities to make downstream use of the stream more convenient. There are no general rules; the village authorities must be encouraged to find ways and means to achieve these ends.

In all of these cases where we recommend source protection, it must be emphasised that this is a complimentary activity to the treatment system. These must go together the effort to improve polluted turbid water from surface sources through longer storage will be much more effective if good source protection measures are implemented.

Source Selection

We mention briefly the importance of source selection in the achievement of water quality. If chemical contamination is not excessive, then ground water is usually the best quality source. All other things equal we should prefer to use ground to surface water sources. Among the ground water source deep boreholes are the cleanest bacteriologically; shallow boreholes and shallow wells should be fairly clean if there is proper source protection Springs are in the same category. Very large surface water sources such as the large lakes in Tanzania are normally very clean sources. As we move towards other surface water sources then higher levels of contamination can be expected. The investigations of water quality carried out in the Water Quality Programme and various Water Master Plans have all produced results on water pollution of sources in the order mentioned. This is, of course, precisely what common sense would suggest. The evidence is clear that from the source viewpoint, the water quality preferences are for ground water and for the large lakes.

Choice of source will and should be made on the basis of cost. However, when the cost of alternative sources are close then the preference should go to the cleaner source. In the Consultant's views the cost choices are really rather close; a well run drilling programme will produce rather cheap water; in the case of the Mwanza, Mara areas the conclusion was that boreholes were the cheapest type of water supply and provided water at lower cost per cubic meter than did shallow wells. Using the cost estimates in Chapter 6 for the recommended low level treatment programme we estimate that it takes 35-40 cents per cubic meter to treat water by extra providing storage. Hence, we should prefer a good source - ground water or lake - to surface water so long as the cost difference without treatment is less than this cost difference of treatment by storage.

Design Recommendations Effecting Water Quality

In this section we summarise the design recommendations dealing with water quality. We present these briefly and without extensive detail. The basic objective is to draw attention to design features which will safequard water quality; additional expenses over alternative designs and it is possible to consider these increments as treatment costs. However, this seems to us to be a somewhat forced formulation and in consequence we refer to these matters as design recommendations which safequard water quality.

(a) Intakes

Intake structures can have considerable influence on the quality of water depending upon their location and position with respect to pollution sources. There are many examples of interest and we discuss lakes, streams, reservoirs (charco-type). For lakes it is important to site the intake fairly far out from the shore and well away from villages or other polluting sources. Intakes are recommended to be sited not less than 100 metres away from the shoreline. The incremental cost (annual cost of capital at 18% and pumping for an extra 100 metres we estimate at -/40 per cubic metre). That is the cost of the improved siting of the intake raises the cost of water by -/40 per m^3. If there is pollution along the shore then there can be substantial improvement in the quality of the raw water by better siting. There is no available evidence of the extent of the increase in water quality as we move further out or to deep depths. Nevertheless, there is surge pollution in the lakes and the better placed intake will provide protection against this. An alternative is an infiltration well on the shore of the lake. If there is sufficient permeability in the soil, this can work very satisfactorily. It is obvious that the intake should be kept away from the village or from factories but the Zonal Water Hygiene Engineer should take nothing for granted and for lakeshore villages with improved water supplies the intake site should be checked.

For streams the intake should be positioned as far upstream of domestic water using sites - not drinking - as is possible. We recommend the construction of infiltration galleries when stream sources are used and where suitable sites can be found. Using the natural filtration of the earth will have some beneficial water quality aspects. This is to be preferred to direct intakes which remove water from the source by say pumping. The infiltration gallery is not particularly expensive to construct.

Reservoir intakes can take two forms: First, for the small dam we recommend a charco type of collection system where collector wells are constructed down stream of the dam and

and infiltrating water collects in such wells from which it can be extracted. Some so-called charcos are fed by pipe from the reservoir; this delivers a greater volume of water but it is of poor quality. There should be considerable improvement from allowing the water to collect by infiltration. Second, for larger dams we recommend intake systems built within the reservoir and which will permit water to infiltrate into the intake even after sedimentation has taken place. By packing sand around the well we can keep it from clogging with silt. If the silt is not too fine such an intake can even obtain water from the sediments deposited in the reservoir. In general, we observe a lack of proper intakes in reservoirs and many of those that have been built are not designed to provide improved raw water over the usual high pollution found in reservoirs.

(b) Distribution Systems

The second category of design features which are important for maintaining water quality are properly designed distribution systems. The main points to be noted are fairly obvious but nevertheless important. First, the distribution system should have interconnections so that leakages arising from the water surge effect from water hammer will be kept to a minimum. Second pipes must be layed with care to minimize leakages and chances for contamination through water seeping into the distribution system. Third, we recommend considerable care be directed at design of facilities around domestic water points. This should include proper drainage, sanitary facilities, and special facilities for laundry and bathing to encourage use of the improved water supply. Finally, washouts should be placed at the low points in the distribution system to permit removing of sand and silt that have entered the distribution system.

Large Water Schemes

The discussion up to this point has dealt with small schemes with design size less than 300 m^3/day. Next we discuss large schemes. Rural water supplies serving several villages over a large area present two special problems. One is the risk of infecting a very large number of people if the water becomes contaminated by pathogens. The other is the existence of very long distribution mains.

The risk of large epidemics means that higher quality levels must be maintained than for small schemes. Here it is a matter of designing to a specified water standard and then overcoming, by some means, the operational difficulties this creates, rather than the reverse which applies for smaller systems. For these large schemes treatment systems must be included in the design so that the Tanzanian Temporary Standards are met. It is far too dangerous to permit these schemes to operate with contaminated water. The non-compliance levels defined in Chapter 8 are thus deliberately more strict for large schemes. The large distribution systems demand proper design, regular maintenance and that efforts to be made during operation to ensure adequate positive pressure at all points throughout the system. Chlorination is also essential to protect the water during its long journey to consumers.

This corresponds more or less to the medium level of treatment as defined in Chapter 6. However, the use of flocculation, sedimentation and upward flow filtration should be preferred to storage as the initial treatment stage, since the large storage tanks which would be required are too expensive. Following filtration, chlorination should be carried out, to a final, regularly measured level of around 2-3 mg/l.

It is felt that the use of slow sand filtration should be very critically considered, since the present record of operation of this type of plant is very poor. Although a good system in principle, the frequent failure of these plants in operation makes them generally unsuitable. Until MAJI has successful, protracted experience with SSF we recommend against their use.

The distribution system requires a full-time maintenance staff. An essential aid to their job will be the regular measurement of residual chlorine at points throughout the system, several times daily. It may be found necessary to install additional chlorinators at break-pressure and distribution tanks in the more distant parts of the system.

The large size of the distribution network means that the cost of piping is high, and designers may well be tempted to make many dead ends in the system. This should be avoided as far as possible creating reticulated subsystems.

The Use of Rain Water

Although there can be no question as to the generally high quality of rain water there are definite problems regarding the feasibility of using it.

Firstly, it relies on improved housing, with corrugated iron roofing and a guttering system. However, this is beginning to appear again following the resettlement of most of the population, and certainly applies to rural institutions such as schools and dispensaries.

Secondly, the total rainfall must be sufficient. If a typical improved house is say 5 m x 8 m, and houses 6 people, their requirements at 15 litres/person/day will be 15 x 6 x 365 = 32,850 litres per year. With a roof area of 5 x 8 = 40 sq.metres and allowing 20% for evaporation, the rainfall required to obtain this amount of water is 32,850/(40 x 0.8) = 1,027 mm. In round figures, then, a total rainfall of about 1,000 mm per year is needed to supply a typical household. Population figures show that about 40% of the population live in areas receiving at least this amount of rainfall.

Perhaps the most serious problem, though, is due to the distribution of rainfall over the year. Storage is required to last out the dry season. In areas of high rainfall this needs not be prohibitive. For example, in Tukuyu, with an annual precipitation around 2,500 mm, the monthly rainfall is sufficient (indeed), at least twice what is required) from November to May, whilst the total shortfall for our typical household would be about 3.3 cubic metres over the five dry months. Thus, allowing for dry years, a tank of 5 cubic metres capacity should suffice in this very wet area. However, in less wet areas, such as, for example, Songea, the storage required is much greater. The average annual rainfall is only just above the minimum required (around 1,170 mm) and monthly precipitation is only sufficient from December to April. If all the excess can be stored, enough water can be made available for the seven driest months by providing 15.8 cubic metres of storage - perhaps 20 cubic metres should be allowed for dry years. This would be very expensive and certainly beyond capabilities of an individual family to buy or construct. In the driest areas there is simply not enough rain. In Dodoma a family of six would be able to store all the excess rainwater in a tank of 5 cubic metres, but this would only last until mid June, with no chance of appreciable rainfall before November, with a surplus only from December to March. This means, in effect, that rain water would only be sufficient for just over half the year.

Thus, in summary, rainwater can be seen as useful adjunct to other sources, but not generally sufficient all the year round in all but the wettest areas. Because of its high quality it can be used in all domestic and most medical applications. To take the most advantage of this quality it should be reserved for drinking and cooking when available. Because it is generally insufficient for year-round use, a piped water supply will still be required even if the whole population uses rain water. The only potential saving in terms of water supply would be a reduced pumping requirement during the wet season.

Water Supplies for Rural Institutions

We believe that the provision of good quality water of dispensaries and schools in rural areas should be considered as an immediate problem requiring solution, these institutions cannot wait for the completion of the rural water supply programme. The necessity for clean water for schools and dispensaries is clear: These are high risk areas with many people using the water supply with resulting transmission of diseases. For schools we suggest some type of rain water collection system that will collect rain water, store it and deliver it for use. Notice this system accepts a clean source and stores it for a fairly long time so that any pollution arising from the collection should be reduced by the storage period. Although such systems are expensive their importance is considerable. These rain water systems should suffice for schools since the school holidays conform approximately to the dry season. For the dispensaries the provision of raw water is rather difficult until the improved water supply is provided by the Government. Again rain water collection systems are useful for the rainy season and the early part of the dry season. However, some further purification method is needed: Either use of filter candles or chlorination.

The Zonal Water Hygiene Engineer should examine the water quality conditions in dispensaries and schools from time to time and advise the regional authorities an appropriate action.

9.4 Water Quality Surveillance Programme

In this section of the report we present detailed recommendations on the organisation, manpower, and finance of the surveillance programme. The objectives of the surveillance programme are reviewed; then the recommended organisation specified. This leads to requirements for buildings, staff, transport, and equipment. Next we review sampling test procedures, and record keeping. Finally we estimate the costs of establishing and operating the surveillance system.

Objectives

The surveillance organisation should guide the relevant authorities so that the health of people is not endangered by water. This is accomplished by:

(1) Advising on improvements of water quality.

(2) Checking water quality.

(3) Initiating actions when the required water quality is not met.

The WHO Manual Surveillance of Drinking Water express these objectives as follows:

"The elements of a surveillance programme include engineering and the physical, biological, chemical, and institutional examination of water supplies. The engineering examination or sanitary survey is an on-site inspection and evaluation by a qualified person of all conditions, devices, and practices in the water supply system that could present a health hazard to the consumer. Physical, biological (generally bacteriological), and chemical examinations include testing of water samples in both the field and the laboratory. Institutional examination concerns those elements of operation and management that may result in health hazards to consumers, e.g., incompetent operators".

Organisational Structure

This subsection details the recommended organisation for water quality surveillance. Our basic recommendation is establishment of a Water Hygiene Division within the Ministry of Water, Energy, and Minerals; the summary functions of this division were given in Section 9.2.

Surveillance requires an on-site inspection and evaluation of the water scheme. Consequently an organisation able to cover the whole country must be decentralised. In this section we review the proposed organisation. Subsequent sections will take up the components of the organisation.

As surveillance implies control and even criticism of authorities in charge of water schemes, the surveillance agency status must have the power to protect the public from dangerous water conditions and to enforce corrections of deficiencies found. For the organisation to be able to do this in an effective and active way several requirements must be met:

(1) Independent organisation and budget.

(2) Skilled manpower staffing the organisation.

(3) Legislation and administrative regulation supporting necessary action to enforce remedial actions.

(4) Capability to carry out on-site inspection.

These are discussed in turn.

Independence

It is necessary for the organisation to be able to advise directly as well as criticise authorities engaged in planning, operating, and maintenance of water schemes. This can only be achieved with an independent organisation. Such an organisation could be assigned to another Ministry such as the Ministry of Health to ensure such independence. However, the advisory aspect of the organisation's service would, in the Consultant's view, be more effective if a close relationship is maintained between the surveillance system, and those engaged in the planning etc. Within MAJI headquarters these functions are performed on a division level; thus nothing less than a parallel division status would be adequate for a surveillance organisation. We recommend then the establishment within the MAJI of a "Water Hygiene Division". This "Water Hygiene Division" will be responsible for the Water Quality Programme and will cooperate with other divisions within MAJI to improve water quality in rural water supplies. A second requirement for maintaining an independent and effective organisation is establishment of an independent budget; i.e. the Head of Division must be able to allocate funds to achieve the rural quality programme goals. Failure to fulil such a requirement may lead to financial sanctions against the organisation when "unpleasant" remedial actions are required.

Manpower

Skilled manpower is required for the organisation, the training of the staff is discussed in Section 9.6. Only some general points will be made here. As the possibilities for improvement of water quality are diverse and usually highly technical solutions are out of the question, the staff should have a broad background to be able to evaluate and choose among unconventional solutions.

Legislation

Legislation and regulation supporting the work of the organisation are mandatory. Of course, the organisation should ideally work by informing and guiding, but legal power must be available to enforce the objective of improved drinking water quality. Detailed recommendation for such supporting legislation are presented in Chapter 8.

Inspection

The requirement that the surveillance organisation should perform on-site inspections, including sampling for bacteriological and physical-chemical testing will most effectively be fulfilled by a zonal laboratory organisation supplied with proper means of transport. Without some decentralisation, transport requirements would become far too expensive; yet the number of laboratories that can be established is certainly limited during the early years by the availability of manpower and funds.

Based on these requirements a Water Hygiene Division is proposed to be organised as shown in Figure 9.4.

The proposed Water Hygiene Division has sections for the following activities:

(1) Planning and reporting.

(2) Surveillance and research (Ubungo Laboratory and Zonal Water Hygiene Centres).

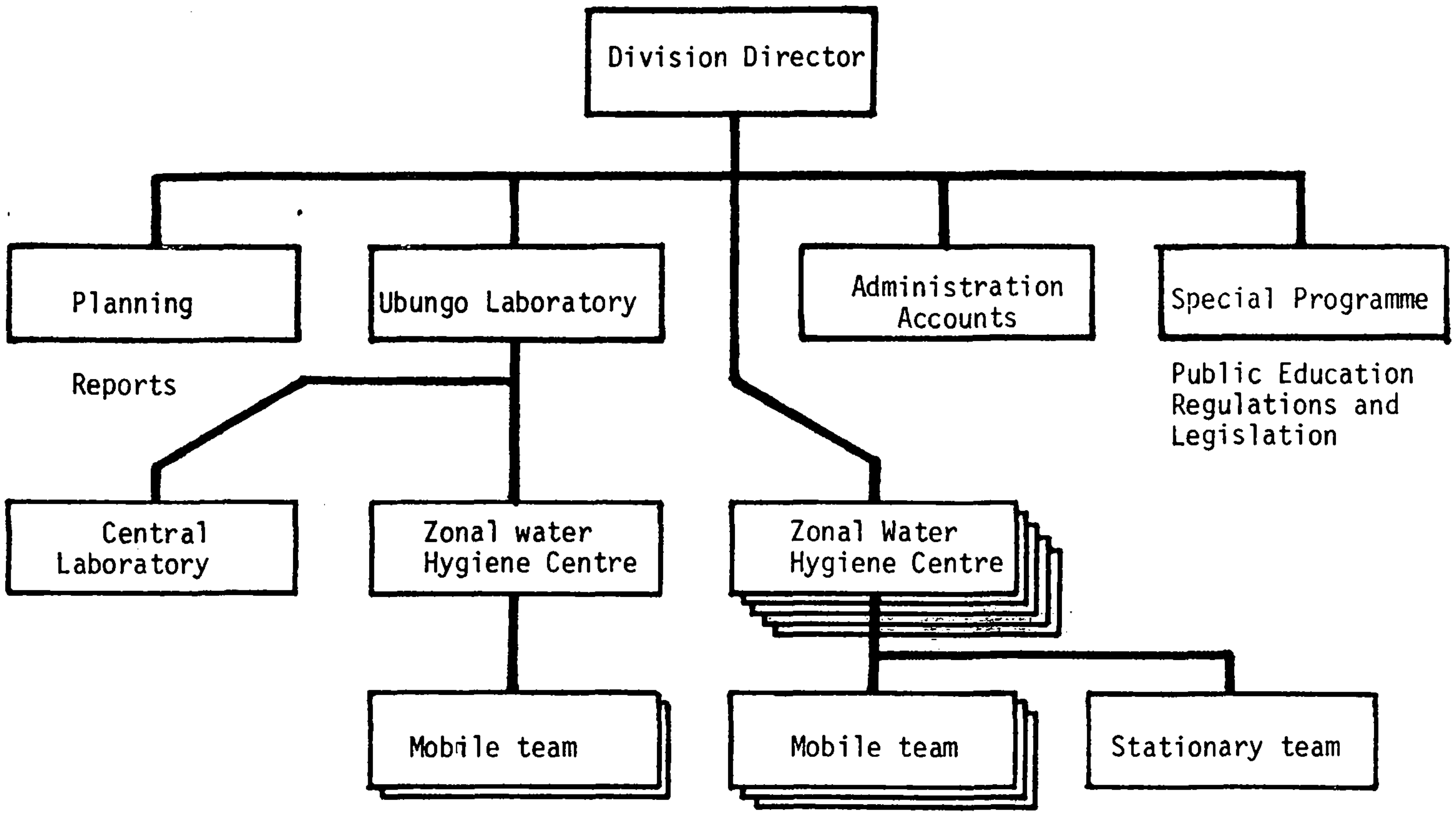
(3) Special programmes as legislation and public education.

(4) Administration and accounting.

Procurement and planning, special programmes are proposed to be handled by the central administration.

FIGURE 9.4

ORGANISATION CHART FOR PROPOSED WATER HYGIENE DIVISION



The Ubungo Laboratory is proposed to serve both as a central laboratory and as a Zonal Water Hygiene Centre for Dar es Salaam.

The Zonal Water Hygiene Centres are considered the core of the Water Surveillance Programme.

The functions and composition of three parts are discussed below.

Central Administration

The central administrative unit has the control and management responsibility for the Water Quality Programme. It comprises the following sections:

(1) Director of Division.

Overall control of the Division and its operations.

(2) Plans and Reports.

The section carries out normal planning functions to support the Director. In particular this section handles the reporting from the Zonal Water Hygiene Centres and provides support to the National Water Hygiene Committee. The planning section also maintains records on the Water Quality Emergency Fund and proveds the Director of Division with recommendations on approvals for use of the Fund etc.

(3) Administration and Accounts

The administration and accounts section handles all administrative metters and accounts for the Central Administration and Ubungo Laboratory. We assume that the RWE's accounting section will handle the Zonal Water Hygiene Centres. The section will be responsible for procurement and any necessary store keeping for the Central Laboratory and Zonal Centres with respect to the consumables and equipment needed by the laboratories.

(4) Special Programmes

The special programmes section has a wide range of responsibilities ofr various supporting aspects of the Water Quality Programme.

The tasks to be achieved by this section as given below are quite extensive. It is expected that much of this work can be carried out in cooperation with other Divisions of MAJI, Principal Water Officer, other Ministries and appropriate Departments of the University of Dar es Salaam.

- Prepare reports and recommendations on treatment methods based upon the technical literature, research reports, etc. The section should keep track of the extensive research and development work taking place throughout the world on water quality; identify approaches, equipment, techniques that may be of interest to Tanzania and circulate from time to time summaries of this for use by the ZWHEs. Where appropriate the section may recommend pilot studies of treatment methods.

- Prepare recommendations on source protection and scheme design: we have attached considerable importance to the matter of source protection and design to achieve water quality. The experience of the Zonal Centres and the RWEs should be reviewed from time to time and recommendations made on design and source protection. This is an area of great importance and much can be learned by careful study of actual experience and problems encountered.

- Prepare regular revision estimates of treatment costs. In this study we have prepared cost estimates for different treatment methods. These need regular revision according to price changes, better information on required labour inputs, cost accounting information, etc. This material must be made available to RWEs and Zonal Centres on a regular basis.

- Review and advise the Director of Division on legislation and regulations relevant to water quality problems. The legislation and regulatory aspects of the water quality programme are of great importance and the Director will be actively involved in formulation, revision, and interpretation of the regulations. He will receive support on these matters from the Principal Water Officer.

- Prepare seminars with the RWEs and RHOs on the Water Quality Programme (see Section 9.6). The seminars are meant to share experience on water quality problems, solutions that have been tried and the results, and the relationship with public health.

- Prepare materials for the public education campaigns. (See Section 9.9). The use of public education campaigns directed at different groups is of great importance for the Water Quality Programme and preparation is the responsibility of the special programmes section.

The staff requirements for the central administrative group are given in Table 9.6. Job description for some of the positions are found in Annex 9.1. The total staff emoluments budget is estimated at TShs 130,000/- per annum. We have kept the central administration staff to the minimum in order to direct resources to the Zonal Centres.

Ubungo Laboratory

The Ubungo Laboratory has two functions:

(1) To serve as MAJI Central Laboratory.
This involves:

- Technical Supervision for the Zonal Water Hygiene Centres.
- Laboratory for priority group III analysis (see Annex 9.8).
- Research laboratory on water quality aspects.
- Participate in training of laboratory technicians and treatment plant operators.

(2) Laboratory for Dar es Salaam Coast Zonal Water Hygiene Centre.

The present Ubungo Laboratory has been evaluated and discussed in Chapter 4. The main conclusion is that it has an overcapacity with the existing staff and equipment compared to the volume of samples submitted for analysis.

It is proposed that present staff levels remain basically the same with only minor changes. Thus an additional research officer is proposed and one SWT and one WT now at the laboratory would be assigned to the DSM Zonal Water Hygiene Centre. The recommended staffing is set out in Table 9.7.

TABLE 9.6

WATER HYGIENE DIVISION

CENTRAL ADMINISTRATION

Proposed Staff

	Title	Salary Scales	Estimated Salary
1.	Head of Division	MS 10	3,705/-
2.	Planning Officer	MS 5	2,625 - 3,110/-
3.	Clerk	MS 2	855 - 1,315/-
4.	Special Programmes Officer	MS 3	1,470 - 1,780/-
5.	Personal Secretary	MS 2	1,250/-
6.	Typist		600/-
7.	Driver		450/-
	TOTAL		10,955 x 12 = 131,460/-

TABLE 9.7

CENTRAL LABORATORY, UBUNGO

Proposed Staff

		Salary Scale	Estimated Salary
1.	Head of Laboratory	MS 7-9	3,450 - 3,600
2-3	Research Officer	MS 3	1,420 - 1,780
4.	Chief Technician SWT II	MS 3	1,420 - 1,780
5-12	Senior Water Technician SWT III	MS 2	855 - 1,315
13.	Water Technician WT I	MU 2	600 - 830
14-15	Water Technician WT III	OS 3	500 - 590
16.	Typist 2)	MU 2	600 - 830
17.	Driver		450
	TOTAL 1)		18,430 x 12 = 221,160

1) Present Salary estimation

2) Additional typing facilities is available at Central Administration.

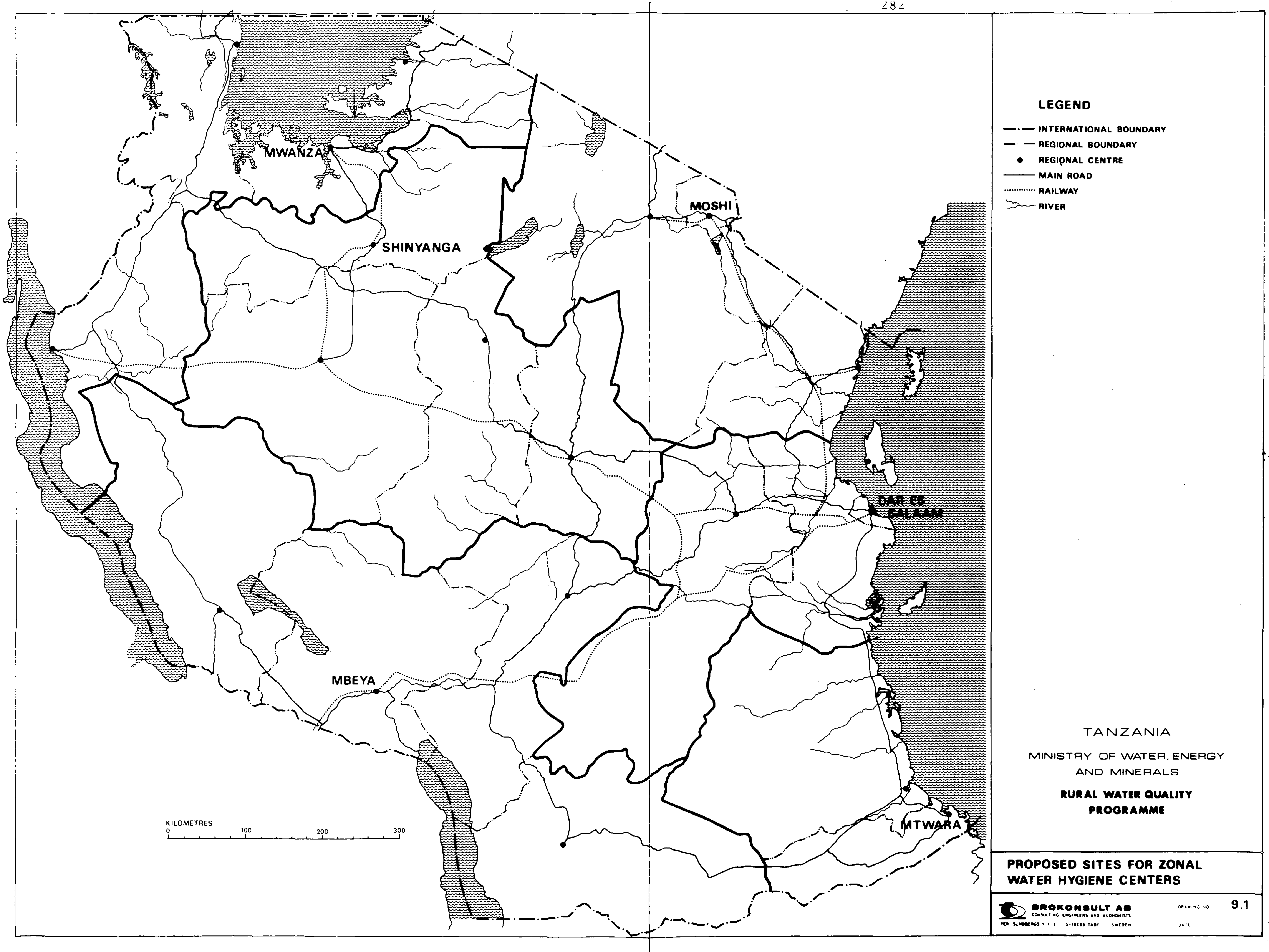
The reduction of the number of samples to be tested and water source recommendations to be made together with the strengthening of senior staff, will then permit the central laboratory to take on other duties, such as sewage testing supervision of the laboratory work of the Zonal Water Hygiene Centres and research work. One officer from the laboratory should make yearly visits of about two days to each Centre. Such supervision will require initially about 20 days per year including travel.

Zonal Water Hygiene Centres

The Consultant proposes Zonal Water Hygiene Centres to be established. These Centres are to serve as the core of the surveillance organisation. These are to be composed of one stationery and one to three mobile units. The stationery unit will function as a base for the mobile unit and be able to carry out physical-chemical testing of water samples. The mobile unit performs the surveys and samplings required. It is also equipped with facilities for bacteriological testing. The mobile team, headed by a water hygiene engineer, constitutes the core of the Zonal Hygiene Centre System. He is responsible for all parts of the surveillance; planning, survey, testing and evaluation. A job description is found in Annex 9.1. An outline of the working procedures he should follow is obtainable from the Form for Rural Water Hygiene Survey, Annex 9.2.

We consider two alternative schedules for establishing ZWHCs called alternatives A and B. Alternative A calls for the more rapid expansion of the programme and initially six Zonal Water Hygiene Centres to be set up in Dar es Salaam, Mbeya, Moshi, Mtwara, Mwanza, and Shinyanga. Their respective working areas are shown on Map 9.1. The scheduled expansion is shown in Table 9.8.

Based on the Consultant's experience, it is possible to visit about three water schemes a day, assuming 100 days in the field per year, 300 schemes can be covered annually by each mobile team. With the proposed six Water Hygiene Centres, each initially with one mobile unit, 1,800 visits could be made in one year as compared with the 4,958 visits required according to proposed sampling programme with the present number of water schemes. Thus we propose a successive expansion of the Zonal Water Hygiene Organisation. The alternative A expansion will ultimately lead after 15 years to 11 Zonal Water Hygiene Centres, each with three mobile units. In total these units are supposed to cover


MWANZA
SHINYANGA
MOSHI
DAR ES SALAAM
MBEYA
MTWARA
KILOMETRES
0
100
200
300
LEGEND
INTERNATIONAL BOUNDARY
REGIONAL BOUNDARY
REGIONAL CENTRE
MAIN ROAD
RAILWAY
RIVER
TANZANIA
MINISTRY OF WATER, ENERGY AND MINERALS
RURAL WATER QUALITY PROGRAMME
PROPOSED SITES FOR ZONAL WATER HYGIENE CENTERS
BROKONSULT AB
CONSULTING ENGINEERS AND ECONOMISTS
9.1

about 35 000 visits by 1994-95. That implies 1 000 visits per team per year, i.e. an increase from 300 initially planned. This higher figure can be reached as travel distance and time decreases, information on and quality of water schemes increases as well as experience and skill of the teams.

Alternative B implies initially four ZWHCs to be established in Dar es Salaam, Mbeya, Mwanza and Shinyanga. The scheduled expansion is shown in Table 9.9. After 20 years the number of Centres and mobile units reaches approximately the same level as that reached in alternative A after 15 years.

The Zonal Water Hygiene Centre would carry out surveys of water schemes, in particular doing the water testing necessary as part of the surveillance programme. The ZWHEs would implement the regulations on domestic water quality (see Section 8.4.1 for details), advise the RWE on design and treatment facilities for new schemes, advise villages, towns, and the RWE on source protection methods. When so assigned the ZWHE can carry out effluent and receiving water tests. The special training of the ZWHEs in engineering and water quality should permit them to make effective recommendations which are feasible to implement.

The staffing of the Zonal Water Hygiene Centres is presented in Table 9.10 and the estimated salary costs are given. The Table shows the start up staffing and the increments required as more mobile units are added.

Support Requirements

In this section we cover some of the support problems of the WHD.

Transport

Transportation is one of the most essential aspects of the programme. Land rovers (station wagon or hard top) or equivalent four wheel driving vehicle are needed for each mobile team. In addition, we recommend a land rover for the central laboratory; and also a vehicle for the central administration.

MAJI headquarters calculates the cost for transport with a land rover to be TSh 2/- per km. (This includes deprecialtion, repair, fuel and oil, salary and night-outs for the driver). Depreciation is calculated to be 13 000 TShs. After deduction of depreciation, salary and night-out the cost is calculated at TSh 1/25 per km. Although

TABLE 9.8
SCHEDULE FOR EXPANSION OF ZONAL HYGIENE CENTRES

Alternative A

Regions covered	Sites	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Sites	Regions covered
Morogoro												Morogoro	2	2	2	3	Morogoro	Morogoro
Coast Dar es Salaam	Dar es Salaam	1	1	1	1	1	2	2	2	2	3	3	2	3	3	3	Dar es Salaam	Coast Dar es Salaam
Mbeya Rukuwa	Mbeya	1	1	1	2	2	2	3	3	2	2	2	2	3	3	3	Mbeya	Mbeya Rukuwa
Iringa Ruvuma									Iringa	2	2	2	3	3	3	3	Iringa	Iringa Ruvuma
Arusha Kilimanjaro	Moshi	1	1	1	1	2	2	2	3	3	3	2	2	3	3	3	Moshi	Arusha Kilimanjaro
Tanga											Tanga	2	2	3	3	3	Tanga	Tanga
Mtwara Lindi	Mtwara	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	Mtwara	Mtwara Lindi
Mara Mwanza	Mwanza	1	2	2	2	2	3	3	2	2	3	3	3	3	3	3	Mwanza	Mara Mwanza
West Lake Kigoma								Bukoba	2	2	2	2	2	2	3	3	Bukoba	West Lake Kigoma
Dodoma Singida							Dodoma	1	1	1	2	2	2	2	3	3	Dodoma	Dodoma Singida
Tabora Shinyanga	Shinyanga	1		2	2	2	2	1	1	2	2	2	2	2	3	3	Shinyanga	Tabora Shinyanga

TABLE 9.9

ALTERNATIVE SCHEDULE FOR EXPANSION OF ZONAL HYGIENE CENTRES

Alternative B

Regions covered	Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Sites	Regions covered
Morogoro													Morogoro			1	1	1	2	2	2	Morogoro	Morogoro
Coast																							Coast
Dar es Salaam	DSM	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Dar es Salaam	Dar es Salaam
Arusha																							Arusha
Kilimanjaro									Moshi		1	1	1	1	2	2	2	2	3	3	3	Moshi	Kilimanjaro
Tanga															Tanga		1	1	1	2	2	Tanga	Tanga
Mtwara		Mtwara	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	Mtwara	Mtwara
Lindi																							Lindi
Mbeya	Mbeya	1	1	1	1	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	Mbeya	Mbeya
Rukwa																							Rukwa
Iringa												Iringa		1	1	2	2	3	3	3	3	Iringa	Iringa
Ruvuma																							Ruvuma
Mara																							Mara
Mwanza	Mwanza	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	Mwanza	Mwanza
West Lake								Bukoba	1	1	2	2	2	2	2	2	2	3	3	3	3	Bukoba	West Lake
Kigoma																							Kigoma
Dodoma							Dodoma	1	1	1	1	2	2	2	2	2	2	3	3	3	3	Dodoma	Dodoma
Singida																							Singida
Tabora																							Tabora
Shinyanga	Shinyanga	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	Shinyanga	Shinyanga
Total ZWHC		4	5	5	5	5	5	6	7	7	8	8	8	9	9	10	11	11	11	11	11		
Total Mobile Units		4	5	6	7	8	9	10	11	12	14	15	16	17	19	21	23	26	28	30	30		

TABLE 9.10

ZONAL WATER HYGIENE CENTRE

Proposed Staff

1. Laboratory and one Mobile Unit

Title		Salary Scale	Est. Salary	
Water Hygiene Engineer	1	MS 5	2 675/- - 3 110/-	
Sr. Water Technician I (chief technician)	1	MS 4	1 865/- - 2 605/-	
Water Technician I	1	MS 1	600/- - 795/-	
Typist	1		450/-	
Cleaner	1		450/-	
Driver	1		450/-	
			6 490 x 12 =	77 880/-

2. Additional Staff for Centre with two Mobile Units (Total staff 1 + 2)

Title		Salary Scale	Est. Salary	
Senior Water Hygiene Engineer (head of the zonal centre)	1	MS 6	3 155/- - 3 370/-	
Water Technician I	1		600/- 795/-	
Driver	1		450/-	
			4 205 x 12 =	50 460/-
			TOTAL	128 340/-

3. Additional Staff for Centre with three Mobile Units (Total staff 1 + 2 + 3)

Title		Salary Scale	Est. Salary	
Water Hygiene Engineer	1	MS 5	2 675/- - 3 110/-	
Water Technician I	2	MS 1	600/- 795/-	
Typist	1		450/-	
Cleaner	1		450/-	
Driver	1		450/-	
			4 625 x 12 =	55 500/-
			TOTAL	183 840/-

we have used these estimates in the report, fuel prices are increasing and transportation costs will be much higher.

Based on the Consultant's experience, it is possible to travel about 250 km per day while sampling. Provided the mobile unit can travel 100 days a year will the total mileage be 25,000 km/year. Allowing for an additional travel of 10,000 km for the rest of the year will the total mileage per year become 35,000 km. This is close to the 40,000 km used by MAJI in cost calculations as an average for one year.

The cost for transport is thus estimated to 56,750 shillings per mobile unit and year (including depreciation).

Buildings

Building and office equipment requirements are given in Annex 9.3. Annex 9.4 contains a construction schedule based on alternative A.

Equipment

The laboratory equipment required, given in Annex 9.5, is listed in three groups: general laboratory equipment, bacteriological equipment and physical-chemical equipment. The costs for equipment and consumables are given together with estimates of annual costs for bacteriological and physical-chemical testing.

Sampling and Testing Procedures

Good sampling and testing procedurew are important for obtaining reliable results. Standard procedures, as outlined in handbooks should be chosen whenever possible. A few comments are made in the following paragraphs. The cost of the surveillance organisation depends entirely on the directives for the sampling frequency. In order to reduce the costs a proposal for a sampling programme is given. It is discussed in detail in Annex 9.6 and in short in the following.

Bacteriological Sampling and Testing

It is proposed to test for both faecal coliforms and streptococci with the membrane filter technique. The use of this technique is discussed in Section 2.2. The Consultant proposes the use of dehydrated media as being substantially cheaper than media in ampoules.

Millipore equipment is the only alternative for field testing; it has been used with good experience by three WMP laboratories and also by the Consultant during the field survey. The incubators can be connected to the 12V socket in any land rover. The mobile team is thus able to use any vehicle for the surveying.

Sampling programmes for bacteriology are discussed in detail in Annex 9.5. One programme, based on the quality of the source and the population served and applicable to alternative A organisation schedule, is proposed in Table 9.11.

TABLE 9.11

PROPOSED MAXIMUM INTERVALS BETWEEN SUCCESSIVE SAMPINGS

Population Served	- 2000	2001-5000	5001-10000	10000-20000	20001-50000
Borehole, protected spring	1 year	6 months	3 months	1 month WHO Standard	2 weeks WHO Standard
Large lakes, protected shallow well	6 months	3 months	1 month		
Other surface waters, unprotected shallow well	3 months	2 months	1 month		

It is proposed that three samples are collected at each scheme. Minor errors in sampling and testing should not then result in a misleading interpretation. With the proposed programme and the 1975 situation on water schemes, 4,798 visits will be made and 13,290 samples taken.

With the reduced resources available with alternative B the samplings for schemes serving a population less then 10 000 has to be reduced furthermore. This alternative is given in Table 9.12.

TABLE 9.12
ALTERNATIVE MAXIMUM INTERVALS BETWEEN
SUCCESSIVE SAMPLINGS

Population Served	-3000	3001-5000	5001-10000	
Borehole, protected spring	1 year	6 months	6 months	WHO Standard
Large lakes, protected shallow well	1 year	6 months	3 months	
Other surface water, unprotected shallow well	6 months	3 months	1 month	

This must be considered as the absolute minimum and is not recommended. Further reductions would result in a sampling programme of virtually no value. This alternative would reduce the surveillance programme to initially 4,159 visits and 11,325 samples to be taken.

The Consultant proposes that all samples are collected during the day and processed in the afternoon, at the office or hotel room. This speeds up the processing and also reduces the risk for contamination. Collection procedures are given as a checklist in Annex 9.7. The volumes 50 and 5 ml are proposed for filtration whenever information on the quality of the source is lacking. Alternatively, based on the information two other volumes, differing 10 times can be chosen. Plastic filter funnels, sterilisable in boiling water, are proposed to be used as being substantially cheaper than Millipore stainless steel funnel XX 63 001 20. The latter is, however, very useful when testing a single sample.

Physical-Chemical Sampling and Testing

Sampling for physical-chemical testing is straightforward. Preferably samples of 2 x 500 ml are taken together with bacteriological sample. The sampling frequency, as proposed in Temporary Standards, of twice per year is recommended. This frequency is not always followed for boreholes and protected springs, in such cases one sample per year will be sufficient.

No testing, except for residual chlorine, is proposed to be be made in the field, HACH field photometer equipment (HACH DR/EL 2 and equivalent) has been used in the field by Ubungo laboratory staff and the Consultant. The unit was found too delicate for Tanzanian roads. Furthermore, most chemical constituents can, without serious disadvantage, be tested for on stored samples. The Consultant does not propose sample preservation since it is expected that most samples will be handled within one week from sampling.

The use of a laboratory spectrophotometer will make any change in methods simple and also makes an expansion of the analysis to include testing of receiving waters and effluents possible.

Constituents to be tested have been grouped in three priority groups: compulsory, supplementary, and additional analyses as shown in Table 9.13 and discussed in Annex 9.8. Only compulsory and whenever possible supplementary analyses are proposed to be made at the Zonal Laboratory.

TABLE 9.13
PROPOSED PRIORITY LIST FOR PHYSICAL-CHEMICAL ANALYSIS OF RAW WATER AND DOMESTIC WATER

Priority		
I Compulsary Analyses	II Supplementary Analyses	III Additional Analyses
Conductivity	Iron	Sodium
pH	Manganese	Potassium
Fluoride	Total Hardness	Zinc
Nitrate	Alkalinity	Copper
Colour (Turbidity)	Sulphate	Other heavy metals
Chlorine 1)	Nitrite 2)	Calcium
	Chloride	Magnesium
	Permanganate Value	Organic Pollutants

1) Comparators should be used for testing in the field of residual chlorine.

2) Has to be tested soon after sampling (24 hours).

3) All these constituents can be determined on preserved samples within six months. Provision for analysis of these is available at Ubungo laboratory and at the laboratory of Government Chemist.

The compulsary analyses include nitrate and fluoride as being severe hazards to health. The other tests give background information on the water quality. With these of all analyses or a selected number of supplementary should be performed whenever possible. The Zonal Water Hygiene Centre is fully equipped for these tests. The equipment (atomic absorption spectrophotometer and gas chromatograph) required for testing of constituents in the additional group is complicated and expensive.

Whenever the Zonal Water Hygiene Engineer suspects the presence of any other contaminating constituent he should take a sample for additional testing. This sample is sent to the Central Laboratory for additional testing with a description of the background and specification of tests to be performed.

The object is to bring down costs for testing without losing means to detect or indicate the most important physical-chemical quality problems. Possibilities for complete test are available at the Central Laboratory, Ubungo.

Also the laboratory of Government Chemist is proposed to be utilised whenever advanced analyses are required. It is the most advanced laboratory in this field in Tanzania.

Record-Keeping and Dissemination of Results

With large decentralised organisation proper record-keeping and dissemination of results is essential.

Two, partly separate, sets of data are collected; one is the information collected during the survey at the water scheme (actual or proposed) see Annex 9.2), the other is the bacteriological and physical-chemical data. The survey form when completed (or when bacteriological test results are above non-compliance levels) is sent to the RWE, Regional Water Hygiene Committee and one copy filed on the scheme. The form for test results should be arranged in such a way as to permit coding for computer. Special care should be taken in the identification of the site for the sample. Preferably the UTM grid could be used, this is, however, difficult in many areas as topographic maps may not be available. The test results are sent to the Water Hygiene Division and one copy is filed on the scheme.

Cost Estimates

The total annual costs for one Zonal Water Hygiene Centre is estimated in Table 9.14. The capital costs are annualised at zero interest rate with appropriate lifetimes for depreciation. These costs are presented as for one, two or three mobile units.

TABLE 9.14

TOTAL ANNUAL COST FOR ONE ZONAL WATER HYGIENE CENTRE

(Tsh. Depreciation included)

	Number of Mobile Units		
	One	Two	Three
Building depreciation 30 years (99 100)	3 300	3 300	3 300
Electricity and water	3 000	5 000	7 000
Office consumables	2 000	4 000	6 000
Personal emoluments	77 880	128 340	183 840
Night outs	36 000	72 000	108 000
Transport	56 750	113 500	170 250
	178 930	326 140	478 390
Annual cost for testing			
General laboratory equipm.	1 520	1 520	1 520
Bacteriological	26 840	53 680	80 520
Physical-Chemical	12 247	16 446	20 680
	41 520	72 120	102 720
Total cost	220 450	398 260	581 110

The operating costs of the components of the WHD are given in Table 9.15. (These differ from the previous table in that the depreciation of equipment is excluded.)

Comprehensive 15 year budgets are given in Table 9.16 and 9.17 for A and B. In these tables we have listed the activities or numbers for the Zonal Centres and cost estimates for the Central Laboratory and Central Administration. The totals are broken down into foreign and local components. During the first five years the alternative A surveillance programme requires approximately 3 million shillings per year of which approximately 40% is foreign cost and 60% local while the annual cost with alternative B is approximately 2 million shillings.

Finally, we estimate the costs and requirements for testing for residual chlorine at existing treatment plants using chlorination equipment. This is given in Annex 9.8. (Note these are not included in the surveillance cost estimates.)

9.5 Legislative Recommendations

The full programme of legislative and regulatory recommendations is given in Chapter 8. In brief the recommendations are:

(a) To pass Domestic Water Quality Legislation which would establish a framework for issuing regulations on standards and on compliance procedures.

(b) To issue the Temporary Tanzanian Domestic Water Standards with some recommended adjustments.

TABLE 9.15

WATER HYGIENE DIVISION

OPERATING COSTS

(TSH)

(Depreciation Excluded)

Items	Number of Mobile Units			Local %
	1	2	3	
Zonal Laboratories				
Electricity & water	3,000	5,000	7,000	100
Office consumables	2,000	4,000	6,000	100
Personal emoluments	77,880	128,340	183,840	100
Night-outs	36,000	72,000	108,000	100
Transport cost	43,750	87,500	131,250	20
Consumables-bacteriol.	20,244	40,488	60,732	0
Consumables-chemicals	7,201	11,795	16,389	0
Foreign	62,445	122,283	182,121	
Local	127,630	226,840	331,090	
Total	190,075	349,123	513,211	
Central Laboratory				
Electricity & Water	50,000			100
Office consumables	10,000			100
Personal emoluments 1/	221,160			100
Transport cost	43,750			20
Night-outs	40,000			100
Consumables total	158,000			0
Foreign	193,000			
Local	419,910			
Total	612,910			
WHD-Central Administration				
Electricity & water	20,000			100
Office consumables	30,000			100
Personal emoluments	131,460			100
Transport cost	47,750			20
Night-outs	30,000			100
Foreign	68,200			
Local	191,010			
Total	259,210			

1/ Present staff assigned to central laboratory minus one SWT III and one WT I (assigned to Dar es Salaam zonal hygiene centre) + one research officer III.

TABLE 9.16: WATER HYGIENE DIVISION - 15 YEARS BUDGET ALTERNATIVE A

(Thousand TSh)

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15
I. ZONAL LAB. Structures Building, new	Mbeya Moshi 198200					Dodoma 99100		Iringa 99100			Morogoro 99100				
Building improvement and expansion	Shinyanga 5000 Mtwara 500	Mwanza 3000			Mtwara 3000 Mwanza 30000					Tanga 20000	Mwanza 3000		Shinyanga 30000		
Office equipment [1] Furniture [2]	Mtwara 7000[1] Mwanza 7000[1] Shinyanga 7000 [1]	Mwanza 3000[2]			Mwanza 10000 [2]			Bukoba 7000	DSM 7000		Bukoba 7000 [1]				
Lab. equip. units	4	0	0	0	0	0	1	1	1	1	5	1	0	0	0
bacteriolog.	4	1	1	1	1	6	3	3	3	3	10	5	7	6	5
physic-chem.	5						1	1	1	-	6	1	-	-	-
							Dodoma	Bukoba	Iringa		Tanga	Morogoro			
Vehicles	6	1	1	1	1	8	3	3	3	3	10	5	7	6	5
Operations 1 mobile unit	6	5	4	3	2	1	2	2	1	0	0	0	0	0	0
2 " "	0	1	2	3	4	4	3	4	7	7	8	9	5	2	1
3 " "	0	0	0	0	0	1	2	2	1	2	2	2	6	9	10
II. CENTRAL LAB. Building										30000					
Lab equipment	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000
Vehicles	80000					80000					80000				
Operations	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910
III. CENTRAL ADM. Building	100000									50000					
Office equip.	50000		5000		5000		5000	5000			5000		5000		5000
Vehicles	80000					80000		5000			80000				
Operations	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210
TOTAL COSTS (Thousand TSH) Foreign exch.	1,330	777	837	896	956	1,580	3,790	1,530	1,650	1,740	2,810	2,180	2,530	2,630	2,610
Local	1,650	1,600	1,680	2,570	1,920	2,560	2,710	2,710	2,830	3,130	3,620	3,540	4,060	4,310	4,390
Total	2,980	2,520	2,670	2,670	2,880	4,140	3,790	4,240	4,480	4,870	6,430	5,720	6,590	6,940	7,000

Explanatory notes for Table 9.16 - Schedule of Expenditures for Water Quality Program Surveillance System: This table divides expenditures with those for Zonal Laboratory, Central Laboratory and Central Administration of the Water Hygiene Revision. No allowance is made for inflation or for price contingencies in this table.

I. ZONAL LAB: This should be read in conjunction with Table 9.9 giving the schedule of build up of the general lab. and mobile teams. Structures covers new construction, expansion of buildings, and procurement of office equipment and furniture. Equipment covers: a) Common lab. equipment; b) Bacteriological lab. equipment; c) Physical-chemical lab. equipment; d) Vehicles (landrovers). Operations: in this row are given the number of general laboratories with one, two, or three mobile teams. (See Table 9.8).

II. CENTRAL LABORATORY: Items include laboratory equipment procurement, vehicles, and operations. The breakdowns are given in separate tables. Equipment procurement is estimated at replacements 158,000/- per year. There is a large amount of equipment already at Ubungo and this requires replacement on a regular basis. The lifetimes and ages of this equipment are sufficiently variable and uncertain that a constant annual figure is the best approximation that we can make to annual requirements. No major procurement is needed for this laboratory.

III. CENTRAL ADMINISTRATION: This covers buildings, office equipment, vehicles and operations costs for this central administration of the proposal Water Hygiene Division (See Table 9.8).

TABLE 9. 17 WATER HYGIENE DIVISION - 15 YEARS BUDGET ALTERNATIVE B

(Thousand TSh)

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15
I. ZONAL LAB. Structures Building, new	Mbeya 99100					*Dodoma* 99100			Moshi 99100			Iringa 99100		Morogoro 99100	
Building improvement and expansion		Mtwara 5000	Mwanza 3000								Mwanza 3000 Mtwara 3000		Shinyanga 30000 Mwanza 30000		Tanga 20000
Office equipment, [1] Furniture [2]	Mwanza 7000[1] Shinyanga 7000[1]	Mtwara 7000	Mwanza 3000	DSM 7000[1]				Bukoba 7000[1]			Bukoba 7000[1]		Mwanza 10000[2]		
Lab.equipment units Bacteriolog. Physic-chem.	Mbeya 1 2 3 Mtwara	1 1 1	0 1 0	0 1 0	0 1 0	0 3 0	1 2 1 Dodoma	1 2 1 Bukoba	0 2 0	1 3 1 Moshi	4 4 4	1 3 1	1 3 1 Iringa	0 4 0	1 5 1 Morogoro
Vehicles	4	1	1	1	1	5	2	2	2	4	6	3	3	4	6
Operations 1 mobile unit 2 mobile unit 3 mobile unit	4 0 0	5 0 0	4 1 0	3 2 0	2 3 0	1 4 0	2 4 0	3 4 0	3 3 1	3 4 1	2 5 1	1 6 1	2 6 1	1 6 2	1 7 2
II. CENTRAL LAB Building										30000					
Lab. equipment	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000	158000
Vehicles	80000					80000					80000				
Operations	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910	364910
III. CENTRAL ADM Building	100000									50000					
Office equip.	50000		5000		5000		5000				5000		5000		5000
Vehicles	80000					80000		5000			80000				
Operations	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210	259210
TOTAL COSTS (Thousd TSH) Foreign exch.	1,010	718	730	790	850	1,850	1,080	1,150	1,160	1,460	1,920	1,530	1,590	1,750	2,040
Local	1,360	1,190	1,290	1,370	1,480	1,850	1,520	1,620	2,080	2,320	2,480	2,540	2,610	2,890	3,120
Total	2,370	1,910	2,020	2,160	2,330	3,130	2,600	2,770	3,240	3,780	4,400	4,070	4,200	4,640	5,160

Explanatory notes for Table 9. 17 - Schedule of Expenditures for Water Quality Program Surveillance Systems: Same as Table 9. 16.

We recommend issuing compliance procedures along the lines specified in Section 8.4.1. These compliance procedures set out what actions should be taken in the event according to the extent of violation of a standard. The emphasis is on the bacteriological contamination and the procedures for establishing compliance are linked to the financial situation and to a flexible interpretation of the water quality standards.

(c) To amend the Water Utilization Act to organise control of extractions and water discharges by drainage basin (in Section 8.4.3 called Water Basins) rather than by region; to introduce a more flexible narrative standard for water quality; and to provide a legislative framework for the issuing of effluent and receiving water standards and compliance regulations.

(d) To issue the drafted Effluent and Receiving Water Standards under the framework of the amended Water Utilization Act.

These legislative recommendations have quite far reaching effects on the planning and management of the quality and quantity water resources in Tanzania. The water quality programme in the short run is focussed on the domestic water supply problem where the most severe problems occur. But in time it will be impossible to separate the effluent problems from the domestic water problems.

We also suggest that there should be a review of the regulatory and legislative situation during the third and fourth year of the programme. This review would determine how well the regulatory systems were working, drawing on case experience and recommending adjustments or changes that seem needed based on what has been achieved.

9.6 Emergency Water Quality Fund

We also propose the creation of an Emergency Water Quality Fund. This Fund would be appropriate to the control of Principal Secretary MAJI for use to solve water quality problems for water schemes that are near closure or are closed under the proposed compliance regulations.

Water quality surveillance must deal severely with dangerous situations - but it is equally futile to expect action when there is no ready financing. Normally there is little room in regional budgets for emergency actions when water schemes are dangerous to the health of the population. The objective of the Emergency Water Quality Fund is to provide possibility in financing corrective actions.

The method of operation of the Fund is as follows:

RDDs could request funds from the Emergency Fund whenever a ZWHE was required to close or could close a water scheme due to the water quality. The ZWHE's recommendation may well include equipment procurement or treatment plant construction. The cost of which was beyond the immediate resources of the region. The RDD could in such circumstances ask to borrow from the Emergency Fund being agreed that this would be repaid out of the region's development budget over the following two years. This could only be used for schemes which were closed or threatened with closure due to poor water quality.

Approval for the use of the Fund would rest with the Principal Secretary, MAJI on the advice of the Director of the Water Hygiene Division.

We estimate that approximately 50 schemes would be closed under our proposed initial compliance rules. These schemes are now dangerous to the public health. Estimating that an average of 100,000/- is necessary for each scheme and that these schemes must be improved within three years, we would propose an initial appropriation of 3,000,000/-. This would serve as a revolving fund and be drawn on by the RDDs to solve emergency water quality programmes but be repaid. As the ZWHEs gain experience and the compliance rules become more rigorous more money could be added to the fund. The objective of the Fund is to be sure that there are sufficient resources to permit prompt action by RDDs without having to wait for the next fiscal year or budget cycle.

9.7 Manpower and Training

Manpower

Manpower requirements for alternatives A and B are set out in Tables 9.17 and 9.18 for the entire Water Hygiene Division. The development of the WHD is based on expansion of both the size and the number of zonal laboratories. The central laboratory and administration are held at a constant size during the period covered by the plan. The Consultant recommends that maximum resources be directed at the provision of services in the regions rather than building up of an elaborate central organisation.

Alternative A (Table 9.18)

For engineers or equivalent university graduates, a total of 18 are required by the beginning of the fifth year of operation of the programme. There are three required for the central administration, four for the central laboratory and eleven for the zonal laboratories; this increases to 26 after ten years and 38 after fifteen years. The increases in engineers are all needed for the zonal laboratories and the mobile teams. These heavy requirements are a result of the assumption that there will be provision of water through improved supplies to the entire rural population by the end of twenty years and that these water supplies will require regular surveillance. This 20 year assumption, should be noted, is fairly arbitrary; if rural water supplies are provided more quickly, the surveillance system will have to increase at a somewhat faster rate; but the general magnitude of the engineer requirements holds.

Water technician requirements total 24 at the start increasing to 29 at the end of five years. Subsequent increases are to 43 after 10 years and 65 after 15 years. We have indicated in Table 9.17 how many are needed as senior water technicians but of course it is recognised that the exact mix depends upon the availability of experienced staff. Of the 29 water technicians needed five year after programme starts, 12 are needed in the central laboratory and 17 in the zonal laboratories.

Alternative B (Table 9.19)

For engineers or equivalent university graduates, a total of 14 are required by the beginning of the fifth year of operation of the programme. The central administration and central laboratory remain the same as for Alternative A.

TABLE 9.18

MANPOWER REQUIREMENTS FOR TECHNICAL STAFF OF PROPOSED WATER HYGIENE DIVISION, ALTERNATIVE A

Position Title / Organization Level	Years 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Qualifications
Central Administration																
Division Head	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Administrator; engineering background desirable
Planning Officer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Graduate Engineer
Special Programme Officer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Graduate Engineer
National Laboratory																
Laboratory Head	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Graduate Chemist or Engineer
Chief Technician	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Senior Water Technician I
Research Officers	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Graduate Engineers, micro biologists or chemists
Laboratory Technicians	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	Senior Water Technician
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	Water Technician
Zonal Laboratories																
Water Hygiene Eng.	6	7	8	9	11	12	14	16	18	20	22	24	28	31	32	Graduate Engineer
Chief Technicians	6	6	6	6	6	6	7	8	9	9	10	11	11	11	11	Senior Water Technicians
Laboratory Technicians	6	7	8	9	11	13	16	18	19	22	24	26	34	40	42	Water Technician
TOTAL	36	38	40	42	46	49	55	60	64	69	74	79	91	100	103	
Total by Level																
Senior	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Engineer	10	11	12	13	15	16	18	20	22	24	26	28	32	35	36	
SWT	15	15	15	15	15	15	16	17	18	18	12	20	20	20	20	
WT	9	10	11	12	14	14	19	19	27	25	27	29	37	43	45	

TABLE 9.1[illegible]

MANPOWER REQUIREMENTS FOR TECHNICAL STAFF OF PROPOSED WATER HYGIENE DIVISION, ALTERNATIVE

Years

Position Title / Organization Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Qualifications
Central Administration																					
Division Head	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Same as ALTERNATIVE A
Planning Officer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Special Programme Officer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
National Laboratory																					
Laboratory Head	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Chief Technician	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Reseach Officers	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Laboratory Technicians	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Zonal Laboratories																					
Water Hygiene Eng.	4	5	6	7	8	9	10	11	12	14	15	16	17	19	21	23	26	29	30	30	
SWT 1	4	5	5	5	5	5	6	7	7	8	8	8	9	9	10	11	11	11	11	11	
WT 1	4	5	6	7	8	9	10	11	13	15	16	17	18	21	23	26	32	35	38	38	
Total	30	33	35	37	39	41	44	47	50	55	57	59	62	67	72	78	87	93	97	97	
Total by Level																					
Senior	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Engineer	8	9	10	11	12	13	14	15	16	18	19	20	21	23	25	27	30	32	34	34	
SW[illegible]	13	14	14	14	14	14	15	16	16	17	17	17	18	18	19	20	20	20	20	20	
[illegible]	7	8	9	10	11	[illegible]	[illegible]	14	16	18	[illegible]	20	21	24	26	29	35	39	40	41	

A total of eight are required for the zonal laboratories, this increases to 14 after ten years and 21 after fifteen years. For Alternative B the programme only reaches full development in year 20.

Water technician requirements total 20 at the start increasing to 25 at the end of five years. Subsequent increases are to 35 after 10 years, 45 after 15 years, and 61 after 20 years. The mix of senior and ordinary water technicians is given in the Table 9.19. Of the 25 water technicians needed five years after the programme starts, 12 are for the central laboratory and 13 for the zonal laboratories.

Reviewing the technical manpower requirements in detail we turn first to the WHD Central Administration. For the headquarters of the WHD we recommend to be basically a development administrator preferably with an engineering or scientific background. The requirements of this position are that the Division Director be able to direct a scientific technical programme, using the results of the surveillance system to improve water quality through practical projects. The position of Director of Division is critical in achieving this goal and a careful selection of this officer is necessary to ensure he combines the technical ability with awareness of the national resource limitations and a desire to reach practical solutions.

We recommend that the Division Director have a Deputy who would serve as Chief of the Planning Section. This officer should also have an engineering - administration background. The main responsibilities that the Deputy has are to assist the Division Director and act for him during his absence as well as direct the work of the planning section. Thus there should be two senior staff and one engineer on the technical professional staff. We have deliberately kept the administration of WHD small.

The central laboratory staff is recommended to remain at the same level as it is now. The head of the laboratory should be an experienced graduate water chemist or bacteriologist. The analysis of the current laboratory situation (Chapter 4) indicated that there was sufficient capacity to handle a major increase in the number of samples handled.

Finally, the zonal laboratories require trained staff for the mobile teams; we have prepared a schedule of expansion which is aimed at reasonable coverage of the water schemes and treatment methods with a target cover the entire country within 20 years.

Each mobile team will require a water hygiene engineer as leader. The training of these engineers is discussed later in this section. The position of water hygiene engineer is quite critical in our approach to the surveillance system. This individual will not only be concerned with the proper testing of the source but also with the action recommendations on source protection, source selection for new schemes, design problems bearing on water quality and ultimately testing of effluent and receiving water standards. Furthermore, he must work with the RWE in solving problems of poor quality water by practical means. With this broad approach aimed at finding solutions to water quality problems we recommend an engineer for this position.

Next we turn to the development of the staff; the recruitment and training requirements are set out in Tables 9.20 and 9.21 for Alternatives A and B respectively. For each principle occupational category (engineer and water technician) we indicate the number that must be recruited to provide for increases and losses from people leaving. For engineers the number of expatriates is also suggested (Tables 9.22 and 9.23); expatriates are recommended in the early years to fill staff positions pending the completion of training programmes. This table indicates the training levels that must be achieved. For engineers, the training levels indicate the number undergoing university training and the number undergoing the water hygiene training to be organised by MAJI (see the following section on training). For water technicians we give the number in training for the three year programme required for the Water Quality Programme.

The manpower shortage in Tanzania will affect the Water Quality Programme as it does to all of the development activities of the country. The problems in realistic planning are to match as closely as possible the high ambitious of the nation with the manpower resources available, using expatriates to go faster in the near term and training to permit going faster eventually. This programme has been designed to balance between these alternatives. The functions of the expatriates are summarised in the following:

Planning Officer

The planning officer would be responsible for assisting the Division Director in planning the start up of the programme and the initial work programme. He should help to establish the planning systems, the data recording and management systems for laboratory testing and follow up, and the planning for the various special programmes. A job description is given in Annex 9.1.

TABLE 9.20

RECRUITMENT OR TRAINING REQUIREMENTS

WATER HYGIENE DIVISION

Alternative A

Occupational Group	Year																
	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineer																	
1. Start of year			10	11	12	13	15	16	18	20	22	24	26	28	32	35	36
Expatriate	2	3	6	6	6	4	4	2	2	0	0	0	0	0	0	0	0
Tanzanian	0	1	4	5	6	9	11	14	16	20	22	24	26	28	32	35	36
Counterpart	1	1	4	4	4	2	2	1	1								
2. Increase																	
Expatriate	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzanian	1	6	1	1	1	2	2	2	3	2	2	2	2	4	3	1	0
3. Loss																	
Expatriate	0	0	0	0	2	0	2	0	2	0	0	0	0	0	0	0	0
Tanzanian	0	0	0	1	1	1	1	1	1	2	2	2	2	3	3	3	3
4. Recruitment																	
Expatriate	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzanian	1	6	1	2	2	3	3	3	4	4	4	4	4	7	6	4	3
5. Training	8/6	10/1	11/2	13/2	14/3	15/3	16/3	16/4	19/4	21/4	21/4	20/4	16/7	13/6	12/4	12/3	12/3
SWT																	
1. Start of year	0	9	15	15	15	15	15	15	16	17	18	18	19	20	20	20	20
2. Increase	0	6	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0
3. Loss	0	0	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3
4. Recruitment	0	6	2	2	2	2	2	3	3	3	3	4	4	3	3	3	3
5. Training	8	10	6	6	6	7	8	9	9	10	11	11	10	9	9	9	9
WT																	
1. Start of year	4	4	9	10	11	12	14	16	19	21	22	25	27	29	37	43	45
2. Increase	0	5	1	1	1	2	2	3	2	1	3	2	2	8	6	2	0
3. Loss	0	0	1	1	1	1	1	1	2	2	2	2	2	3	3	4	4
4. Recruitment (=Training)	0	5	2	2	2	3	3	4	4	3	5	4	4	11	9	6	4

TABLE 9.21
RECRUITMENT OR TRAINING REQUIREMENTS
WATER HYGIENE DIVISION

Alternative B

Occupational Group	Year																				
	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Engineer																						
1. Start of year			8	9	10	11	12	13	14	15	16	18	19	20	21	23	25	27	30	32	34	34
Expatriate	2	3	4	4	4	3	3	1	1													
Tanzanian	0	1	4	5	6	8	9	12	13	15	16	18	19	20	21	23	25	27	30	32	34	34
Counterparts	1	1	3	3	3	2	2	1	1													
2. Increase																						
Expatriate	1	1																				
Tanzanian	1	5	1	1	1	1	2	1	1	1	2	1	1	1	2	2	2	3	2	2	0	0
3. Loss																						
Expatriate					1	0	2	0	9													
Tanzanian	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3
4. Recruitment																						
Expatriate		1																				
Tanzanian	1	5	1	2	2	2	3	2	2	2	3	3	3	3	4	4	4	5	5	5	3	3
5. Training	7/5	9/1	9/2	9/2	9/2	9/3	10/2	11/2	12/2	13/3	14/3	15/3	17/3	18/4	19/4	18/4	16/5	14/5	12/5	12/3	12/3	12/3
SWT																						
1. Start of year	9	9	13	14	14	14	14	14	15	16	16	17	17	17	18	18	19	20	20	20	20	20
2. Increase	0	4	1	0	0	0	0	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0
3. Loss	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3
4. Recruitment	0	4	1	1	1	1	1	2	2	2	3	2	2	3	2	3	3	3	3	3	3	3
5. Training	5	6	3	3	3	4	5	6	7	7	7	7	7	8	8	9	9	9	9	9	9	9
WT																						
1. Start of year	4	4	7	8	9	10	11	12	13	14	16	18	19	20	21	24	26	29	35	39	41	41
2. Increase	0	4	1	1	1	1	1	1	1	2	2	1	1	1	3	2	3	6	4	2	0	0
3. Loss	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3
4. Recruitment (=Training)	0	4	2	2	2	2	2	2	2	3	3	2	2	3	5	4	5	8	7	5	3	3

TABLE 9.22

EXPATRIATE STAFF REQUIRED

COMPARE TABLE 9.23

Alternative A

Position	Year							
	0	1	2	3	4	5	6	7
Planning Officer (Central Admin.)	✓	✓	✓	✓	✓	✓	✓	✓
Research Officer (Central Laboratory)	✓	✓	✓	✓	✓	✓	✓	✓
Research Officer (Central Laboratory)	✓	✓	✓	✓	✓	✓		
Water Engineer (Central Admin.)		✓	✓	✓	✓	✓		
Zonal WHE		✓	✓	✓				
Zonal WHE		✓	✓	✓				
Training Officer	✓	✓						
TOTAL	4	7	6	6	4	4	2	2
Cost (thousand TSh)	1440	2520	2160	2160	1440	1440	720	720
Foreign exchange	1248	2184	1872	1872	1248	1248	624	624
Local	192	336	288	288	192	192	96	96

NOTES:

1. This covers eight years including the start-up year. At this time there are two expatriate research officers with the central laboratory.

2. A training officer is included here; this is a temporary position and would be abolished after the first two years. It is included in order to have a satisfactory training program at the start when the intake of engineers for Water Hygiene training is at a maximum.

3. Costs: 1978 prices - person month 30,000/-
Foreign 26,000/-
Local 4,000/-

(There are expatriates supplied by direct technical assistance.)

TABLE 9.23

EXPATRIATE STAFF REQUIRED

Alternative B

Position	Year							
	0	1	2	3	4	5	6	7
Planning Officer (Central Admin.)	√	√	√	√	√	√		
Research Officer (Central Laboratory)	√	√	√	√	√	√	√	√
Research Officer (Central Laboratory)	√	√	√	√	√	√		
Zonal Water Hygiene Engineer		√	√	√				
Training Officer	√	√						
TOTAL	4	5	4	4	3	3	1	1
Cost (thousand Tsh)	1 440	1 800	1 440	1 440	1 080	1 080	360	360
Foreign exchange	1 248	1 560	1 248	1 248	936	936	312	312
Local	192	240	192	192	144	144	48	48

Water Engineer (Alternative A only)

The Water Engineer would work with the Construction and Maintenance Division in preparing standard materials, design criteria, maintenance manuals dealing with:

a. Water quality relevant design criteria;
b. Guidelines for source protection;
c. Designs for water treatment systems;
d. Maintenance manuals for water treatment systems.

He would provide back up technical support to the zonal water hygiene engineers.

Research Officers (2)

These officers would be assigned to the central laboratory. The responsibilities would be to assist in the work of the laboratory; to support the zonal laboratories; to provide on-the-job training to the laboratory technicians; and to carry out quality control checks. One of these officers should specialise in bacteriology and the other specialise in water chemistry.

Training Officer

His work is discussed in the Training Section.

Zonal Water Hygiene Engineers (one or two)

These two officers are assigned for three years and it is considered that they will rotate among the initial zonal laboratories working with the water hygiene engineers providing on-the-job training. In addition during this work a great deal of information on water quality problems and practices would be developed and provide the basis of detailed recommendations to RWEs and village authorities on how to maintain and protect water sources.

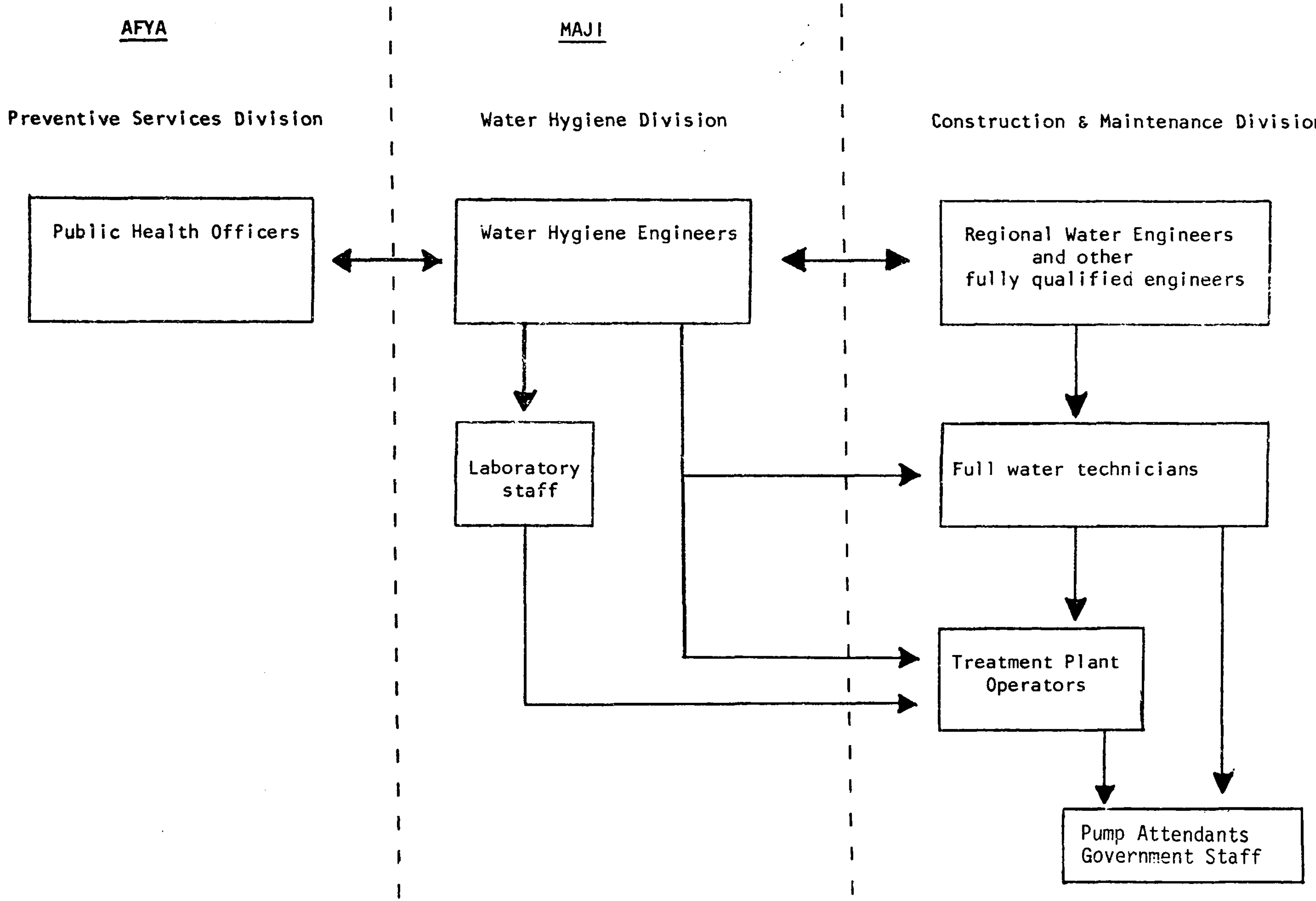
Training

In discussing the training programme we cover the different levels and functions that must be provided by training staff.

Figure 9.5 gives the broad categories of staff and their interrelationships. We will discuss the training appropriate for different staff related to Water Quality. This discussion covers most of the Government officers or employees whose work concerns water quality.

FIGURE 9.5

RELATIONSHIP BETWEEN STAFF CATEGORIES



MAJI Staff

Zonal Water Hygiene Engineers (job description is given in Annex 9.1)

This occupation group is proposed as appropriate to the position of chief of the zonal water surveillance centres. It will require a high degree of training. Although the main tool of the surveillance service will be a laboratory, its main function will be to advise the RWEs on methods to reach and to maintain improvements in water quality. We recommend that this person should not be a laboratory scientist but an engineer by basic training. In addition to the basic university engineering education, three areas of specialised knowledge will be required. These are:

(a) Water-related disease and its control; basic epidemiology and statistics; vector entomology.

(b) Rural water treatment and supply engineering.

(c) Laboratory procedures for bacteriological and chemical water analysis; laboratory management and quality control.

The total number of persons required with this broad range of knowledge is limited, so it is not now feasible to set up a special course for them. Instead, we must find suitable courses which are already available. The health training can probably be obtained at the School of Hygiene, Muhimbili Medical Centre. The course is presently being reconstructed and will then organised in a "block" form. This will greatly facilitate the possibility of water hygiene engineers attending the relevant part of the course.

Specialised training in rural water supply is hard to come by. Some specific education in this field is given in the School of Hygiene course, and again, in the new course it is hoped that there will be more material, particularly with a practical orientation on these subjects, and more "guest" teaching by experienced MAJI engineers. The University of Dar es Salaam and the Chuo cha Maji might also be able to offer a short, specialised course specifically for the water hygiene engineers. An additional possibility would be the organisation of three month study tour in addition to the above, to institutes of public health engineering such as in Nagpur (India), Bangkok (Thailand), Bandung (Indonesia) and possibly also in China and Brazil, both developing countries with a well-developed public health engineering service.

Such a tour would also be of assistance in teaching the principles of laboratory management and quality control. Visits to more sophisticated laboratories in some of the countries mentioned would be very edifying. It would however be essential for these visits to be carefully planned. The aim would be specifically to learn good quality control practices to be applied in the Tanzanian laboratories, and not to encourage the use of a wider range of more sophisiticated tests. Further training of 1-2 months at the Government chemist would be useful to ensure knowledge of the laboratory techniques being used.

This sequence of training would require about 1 year and produce a group of engineers highly qualified in rural water hygiene. It is important they should be trained as a group, so that the new water hygiene division has an identity and good internal relations. Initially, under Alternative A we propose to train 8 such candidates. Under Alternative B this number would be 7.

The recommended programme is to assign eight of the group of graduate engineers returning from India; the training would take place during the period 1979-80 and then they would take up their posts in 1980. To carry this out successfully the training programmes must be organised as soon as possible. This requires that agreement with candidates AFYA to accept the water hygiene engineers and that the timing of the course is made known to MAJI to permit planning of other parts of the programme. The study tour arrangements also must be made as soon as possible.

We review briefly the problem of trained engineers at MAJI. The Regional Water Engineer is one of the critical positions in the rural water supply programme. Many officers in regional water engineers positions have been trained only to technician level, and even of the few presently employed engineers most are only general civil engineering graduates with some emphasis towards the water aspects. MAJI is desperately short of engineers and sanitary engineers with advanced training and experience of water engineering. As a result there is an acute shortage of well trained engineers with an understanding of water quality problems.

For engineers, the situation is improving. Each year about 3 graduates from the water resources option of the Dar es Salaam civil engineering course are assigned to MAJI. Their training is, however, largely in general civil engineering and the instructors of water engineering have difficulty in fitting as much material as they would like into the course The syllabus of the Civil Engineering Department at the University of Dar es Salaam has recently been revised to provide more courses relevant to rural water supplies. In addition, 128 graduates from Indian universities, specially sponsored by MAJI to take a similar course to that taught at University of Dar es Salaam, are due to return in 1979 and a further 30 are scheduled for 1980. This should ease the shortage of engineers considerably. However, this type of training does not include much specific information on rural water supply, which will be the main concern for most these graduates. It will thus be important to assess the extent of their knowledge when they return, to allow the rational planning of necessary in-service training. We are proposing now to take some of this group and by additional training upgrade them to water hygiene engineers.

There are some MSc. courses of one year's duration which specialise in sanitary engineering. These do allow more specialisation in water supply but still place emphasis on western-type systems. In Africa they exist at Nairobi (Kenya) and Ahmadu Bello (Nigeria). The International Institute for Hydraulic and Environmental Engineering at Delft in Holland and the University of North Carolina in the United States also give courses oriented towards tropical countries. Nevertheless, the expenditure involved in sending large groups of students abroad for protracted periods might be better employed elsewhere, save for a few selected students of exception promise. If forign assistance funds are available for this type of training, then these courses might be considered for more students. However, we recommend the course of training set out previously.

In training the first group of water hygiene engineers we believe consideration should be given to appointment of training officer whose functions would be:

(1) To maintain continuity of training;

(2) To prepare from available literature, field visits with the trainees, and experience a manual of rural water quality problems, solutions, testing methods, construction methods, type drawings, cost estimates, etc. This material is to provide the basis for training future water hygiene engineers and also be a handbook for use by the Zonal Water Hygiene Engineers.

Laboratory Technicians

The nation's requirements for laboratory technicians, the training facilities and curricula needed to provide the necessary trained manpower require study. To the best of our knowledge no such detailed assessment has been carried out. The laboratory technicians required for the Water Quality Programme are a small percentage of the total national requirements and consequently this study did not take up the problem of providing laboratory technicians to the nation.

However, assessment of laboratory technician manpower requirements and organisation of the training should be carried out with resulting recommendations on facilities, equipment, administrative support, funding and curricula.

At present about 15 are being accepted each year on a 3 year course. A study guide for Water Laboratory Technicians gives the details for the water part. This is shared between Chuo Cha Maji which is the parent organisation and the Government Chemist Laboratory, Central Pathology Laboratory and the Ubungo laboratory. The system appears to be operating satisfactorily. The first group will complete their course in July 1980. As previously noted the WHD requires a few per year after the next two years so that the annual intake should be reduced significantly.

The level of training required for most of the water laboratory technicians required for the Water Quality Programme is less than provided under the existing laboratory technician course. Staff receiving training to senior water technician level receive significantly more compensation than ordinary technicians. Thus training staff to these higher level will result in major increases in personnel costs of the Water Hygiene Division. The Consultant therefore recommends that most of the Water Technicians required in the ZWHCs be trained through courses and on-the-job training.

The chief laboratory technician (Senior Water Technician I) in each zone must have experience. As this experience cannot be gained within Tanzania, the chief technicians may also have to go abroad for 2-3 months to gain insight into quality control and laboratory management.

Full Water Technicians

The water technicians play an important role in the rural water supply programme and their training in water quality aspects is relevant to this report. The Chuo cha Maji is at present running 3 year courses in water resources engineering leading to full water technician qualifications. The course accepts just over 100 students each year who are divided approximately equally between three options in water resources engineering, hydrology and hydrogeology. After 4 or 5 years the output will be reduced to replacement levels.

The water resources engineering (works) option is not very well balanced for the problems facing rural Tanzania's water supplies. The syllabus is an old one, inherited when the course was moved in 1974 to the newly opened Chuo cha Maji from the technical college. As such, it contains a large amount of general civil engineering with only a small section of the course devoted to specifically water engineering subjects, such as water treatment, water distribution and pump mechanics. The course has been much improved as some of the present teachers have rewritten their parts of the course. It certainly will improve further when the new workshops now being prepared have come into operation. With the course revision already underway, it is a matter of urgency for people within MAJI to identify clearly what skills are required of these technicians and to have training in such skills written into the course. In addition to present problems facing MAJI, particularly those with pumping machinery, the operation of treatment plants and low cost methods of improving water quality must be taken into consideration during the revision process. It is a matter of urgency for MAJI's training advisor to devote his time to this matter.

Lower-grade Technicians

Although the Chuo cha Maji hopes to have completed its expansion plans by 1980, the Institute will still be too small to train all the pump attendants, mechanics, construction personnel and carpenters that will be needed. The present central training programme for these personnel is the one-month course given up to four times a year at Ubungo for 20 pump attendants. Attempts are now being made to establish training programmes in the regions for these skills, and funds are available for training 20 per year in every region. This year eight regions participated in the examinations, in an attempt to standardise what is basically on-the-job training.

The drawback with the system at present is that the training is left very much to the discretion of the local personnel, and can thus vary very widely in quality. A regional training scheme which the British agreed to sponsor in 1975, with full-time instructors and money for workshop training, has not yet begun because of difficulties in staff recruitment. This will start as soon as suitable instructor can be found, and it should considerably alleviate the problems.

The resources of the central Chuo cha Maji (and the University, which has expressed strong interest) could better be used in training the more skilled workers such as treatment plant operators, and, indeed plans are being made for this at both places. In addition, these more skilled workers should be encouraged to and shown how to train more junior staff. There should be some formal cooperation between the Chuo cha Maji and Chuo Kikuu on this matter, to make the best use of workshops and teaching staff. In this connection we would propose a restructuring of the training and career structure for these people. The pump attendants are at present a vastly under-used resource, present at all water supply schemes but doing very little apart from switching the pump on in the morning and off in the evening. Preventive maintenance of the pump, distribution system and stand pipes and simple repairs often have to wait several weeks or months until the central maintenance team can reach the site. Regional MAJI personnel have identified two causes for this. The first is inadequate training and the lack of even simple tools, and the second is the problem of low calibre recruits and lack of motivation. As implied above, it is a false economy to recruit standard VII leavers, and we suggest that with the increased number of available form IV leavers it should be possible to recruit from this level instead. A new career structure should also be implemented, enabling retraining and promotion, to supply the motivation which is at present sorely lacking. Two options have been identified. The first is the establishment of water treatment plant operators as a special category, with the training already discussed. The second is the possibility of retraining to water technician level on the regional survey, design, construction and maintenance teams.

Teaching and Reference Materials

A cheap and simple way of increasing staff effectiveness and the quality of on-the-job training would be the preparation of a series of manuals and checklists for staff at all levels working in the field.

The need for standardisation is increased by the great decentralisation within MAJI which makes direct intervention from head office, even on technical matters, very difficult, and hence greatly hinders the flow of information within MAJI.

A summary of these materials is presented in Annex 9.12. It should be noted here that they could be prepared by consultation between senior MAJI technical staff, the university and the training adviser. Efforts should be made to keep the manuals up to date, and include successful innovations. It is notable that at present, experience gathered by one regional office may easily not be shared, thus hindering progress. This updating could be supervised and coordinated (along with the distribution of te manuals) by the training officer.

AFYA Staff

The public health officers (Bwana Afya and the rural health assistants) form the backbone of AFYA's public health department. In many cases their position seemed ambiguous, and they appeared to have limited resources and hence very limited functions. This is very unfortunate as they have great potential to contribute to the improvement of public health, particularly in coordination with the programmes of MAJI (such as the water quality programme). The proposal to train the zonal water hygiene engineers at the School of Hygiene for some time is thus expected to be a two-way process. If good relationships are established between MAJI and the public health service at the training stage, they may become more aware of each other's capabilities and more ready to cooperate. With MAJI training some of its people at the School of Hygiene it is also hoped that more lecturers from MAJI personnel, and field visits to water supplies of different types, can be arranged.

The public health officer course is at present being revised. Apart from efforts to include more field work, in which MAJI can help (especially by organising visits to unsophisticated supplies instead of the present ones to Lower Ruvu (Dar es Salaam Water Supply and Mtoni Works), several other important changes need to be made. Foremost amongst these, which will help both the public health officers and zonal water hygiene engineers, is the inclusion of more on the understanding of disease transmission and epidemiology as affected by environmental conditions. This should touch not only on water supply but also housing and excreta disposal, all of which are important to an understanding of the role of water in disease transmission. As stated above, the water hygiene engineers participating in the course could usefully attend the parts covering:

(i) Water-related disease and its control.
(ii) Epidemiology and statistics.
(iii) Vector entomology
(iv) Rural water treatment engineering.
(v) Rural water supply engineering.

A second important change being made in the course is its conversion to a block system. If MAJI personnel are to make the best use of the course, the content and timing of the blocks must be discussed between MAJI and the School of Hygiene.

RWE Seminars

It is recommended that seminars be held by the Water Hygiene Division to explain to the Regional Water Engineers and the Regional Health Officers the purposes of the programme, the objectives, the methods of cooperation among the RWE, RHO, and Zonal WHE. The seminar should also include subjects such as sanitation and health programmes. We suggest this seminar should cover half of the regions every year. As experience develops the exchange of views and ideas will contribute to a much more effective water quality programme.

Training Cost Estimates

In Table 9.24 we give the training cost programmes based on the following assumptions.

a. Water Hygiene Engineers training programme will include:

   4 months general training and orientation within MAJI.

   4 months training at AFYA's School of Hygiene.

   3 months study tour.

   Incremental staff will include one training officer for the first two years. We anticipate that this will be filled by an expatriate.

b. Seminar for RWEs on Water Quality: 3 days and 50 attendies per year plus 2 days for travel.

TABLE 9.24

TRAINING COSTS FOR WATER HYGIENE ENGINEER

1.	Salary: 12 months	à Tsh.	32,100/-
	Night-out allowances: 60 days	à Tsh. 80/-	4,800/-
2.	Study tour		
	Transport		20,000/-
	Allowances: 90 days	à Tsh.400/-	36,000/-
	Total per person		92,900/-
	Foreign exchange		56,000

SEMINAR COSTS

1.	Night-outs:	250 nights	à Tsh.150/-	37,500/-
2.	Transport:	50 persons	à Tsh 1000/-	50,000/-
3.	Organisation of seminar			10,000/-
	Total per year			97,500/-

9.8 Research Programme

To establish and maintain water quality requires not only resources and organisation but also a constant effort at improving the technology of water quality and of deeping the understanding of the health consequences of water quality. We have included in the water quality programme four research proposals which we believe are important enough that they should be initiated within the near future. In this section we set out these four proposals and make an approximate cost estimate in Table 9.25. Two of the proposals are set out in more detail in Annexes 9.10 and 9.11.

(1) Indicator Bacteria

The problem of accurate and sensitive tests of the bacteriological contamination in water is not really solved for tropical conditions. We believe it is possible to significantly improve the reliability of the tests but that more work is needed as set out in the Annex 9.10.

(2) Fluorosis

The impact of concentrations of fluorides of the order of 5-10 mg/l on rural population in Tanzania (fluorosis) is not fully understood. In our view a careful investigation is necessary of several communities that have been exposed to high fluoride levels in water. The methodology would be medical interviews and x-ray examination.

(3) Treatment of Water with High Fluoride Concentrations

Fluoride concentrations can be lowered with several different methods of treatment. These are relatively difficult to operate and generally unsuitable for rural Tanzanian conditions.

From a review of methods, the NALGONDA method seems worth pilot testing for possible use in Tanzania. A "Proposal for Defluoridation Project" has recently (1979) been prepared at the Water Laboratory, Ubungo.

The Consultant proposes as a research project field testing and development of cost estimates under Tanzanian conditions.

(4) Optimal Storage Tank Design

The key conclusion in the analysis of the treatment level that is economically justified is to increase storage so that the retention time of water is two days in storage. The evidence that this will work is convincing and reviewed in Annex 9.11; the expected expenditure during the next

TABLE 9.25

RESEARCH COST ESTIMATES

(Thousand Shillings)

Type	Year			
	1	2	3	4
1. Indicator bacteria		400	500	200
2. Fluorosis		500[1)]		
3. Storage design	500	1000	500	
4. Fluoride treatment			200	200
TOTAL	500	1900	1200	400
Foreign exchange	250	1000	700	200
Local	250	900	500	200

1) KCMC Staff considered as local expenditures

15 years is TSh. 150 million. It is essential that the design of the storage be optimised to make them as efficient as possible and keep the construction and maintenance costs to a minimum. For this purpose we propose an investigation as outlined in the Annex 9.11.

In summary the estimated cost of the four research proposals is 4,000,000/- over a four year period. The returns hoped for are:

(a) A more effective method of measuring bacteriological contamination; this would improve the effectiveness of the water quality checks. Present testing methods may be leading to excessive investments in water treatment.

(b) Establishment of an improved estimate for the acceptable fluoride level in domestic water supplies; the present proposed Temporary Standards is satisfactory so long as it can be demonstrated that this is not medically damaging. It is urgent to resolve this issue in the next few years. One cost is possible injury to citizen from excessive fluoride intake; the other cost is excessively expensive water sources developed to avoid fluoride levels which may be acceptable.

(c) Optimising storage tank design to serve as a treatment plant; this is recommended to obtain the most effective storage tanks.

(d) Fluoride reduction: wherever the fluoride level is set in the water standards there are areas of Tanzania where the groundwater contains excessive fluorides. We propose that one of the more promising ones should be investigated in Tanzanian conditions.

Each of these four projects promises a large pay-off in cheaper or better rural water supplies and will help to reduce the cost of achieving the national rural water supply targets.

9.9 Schistosomiasis

In Chapter 5 we reviewed the basic relationship between schistosomiasis and water problems. The legislative recommendation were specified and set out in Chapter 8. The prevalence of schistosomiasis is widespread in certain parts of Tanzania although available evidence is rather dated and probably understates the extent of the disease. Knowledge of the biological transmission mechanism is well understood, partly as a result of the considerable research work carried out through the years by the Tanzania Medical Research Institute in Mwanza. The degree of seriousness of schistosomiasis in Tanzania as a public health problem is open to debate; there are a consideraale number of serious health problems and the resources directed at schistosomiasis must be evaluated against the alternative uses. In our judgement schistosomiasis is an important health problem, but certainly not one of the most important facing Tanzania.

The pattern by which schistosomiasis is transmitted from man to man implies that the exposure to cercariae is mainly through any water in which people bathe, launder, wash, play, etc. Provision of improved water sources will reduce schistosomiasis; pumping and storage (for 48 hours) are quite effective at killing the cercariae, so that most improved water sources, even without elaborate treatment, will reduce the chance of cercariae penetrating the skin. Furthermore, bringing improved water closer to the users' homes will result in reduced use of natural unimproved water sources (ponds etc.) and reduce the chance of exposure to schistosomiasis.

In judging the importance of schistosomiasis we must take account of the fact that development of irrigation will be one of the critical tasks facing Tanzania in the future; increased food production, rationalisation of the livestock situation, and reduction of the large rural insecurities from uncertain rainfall can all be achieved through greater use of water for irrigation. But one of the unfortunate consequence is the strong possibility that schistosomiasis will increase if a significant part of the population is engaged in irrigated agriculture since the irrigated fields are excellent breeding grounds for snails. The Government has a clear responsibility to ensure that the development programmes which it supports do not lead to a marked increase and intensification of a serious disease.

The Consultant's recommended action programme on schistosomiasis is limited in its scope, concentrating largely on domestic water supply programmes in rural areas. There are five other areas where we believe action is appropriate:

(1) Legislation to establish a general Government policy, to require a systematic approach to reduction in prevalence, and to establish a policy for irrigation. This has been dealt with in Section 8.4 in detail and below we only list the recommendations briefly.

(2) Carry out a survey of the present extent and intensity of schistosomiasis disease in Tanzania. This would provide an up-to-date baseline survey of the prevalence. At the moment it is only possible to have a very general idea of how widespread this disease is and the age and sex distribution of prevalence within the population.

(3) Any protracted attack on schistosomiasis requires satisfactory medical research support, an institution able to provide training to the medical staff engaged, and an objective assessor of progress and problems. The TMRC is ideally suited for this role with experienced staff, laboratory, library, and years of knowledge of the area around Lake Victoria where the schistosomiasis problems are particularly acute. Although we do not recommend any further specialisation in schistosomiasis for TMRC we do believe that the resources available should be increased to permit more work on schistosomiasis but within the context of a larger medical research programme to be carried out by the Institute. It is not the intention here to draw up a detailed programme suggestion, but instead to propose that the expansion of TMRC be one of the projects taken up for consideration in the five year schistosomiasis control plan. Within that framework the needs and possibilities for institutional support are drawn up.

(4) The next area where we recommend action is the immediate implementation of several village level pilot projects aimed at: (a) assessing prevalence levels; (b) investigation of transmission modes in the village (i.e. people's behavior which either promotes spreading or actions which have a beneficial, limiting effect); (c) affecting reduction in the prevalence of the disease. Again the specifics of these projects should be prepared under the five year action programme that we recommend the Ministry of Health should formulate.

(5) Although direct testing for cercaria is not feasible, the zonal engineer and his staff should be able to search for snails with a scoop and also use simple

snail traps. They should be able to separate out those snail genera which are completely irrelevant to transmission and forward suspicious specimens to the TMRC at Mwanza for detailed examination. They should also be able to put up snails for testing of cercarial emergence. These skills could be taught to zonal laboratory staff in a one week course at Mwanza. These investigations will only be undertaken where they effect the planning of a new supply.

Taking these five up in more detail, first the legislative issues we have previously discussed (Section 8.4) and we refer to that discussion. It is the intention that the five year action plan should be prepared at once, that it provide specific cost and manpower estimates of the components. We have suggested some. These components are: A survey of prevalence; an institutional development programme for TMRC and several pilot projects in villages. This should be an action plan which will bring some resources to bear upon schistosomiasis problems at once; it should be realistic in terms of resources that are available; it should recognise the complex economic, social, medical and biological problems; and it should place initial stress on public education and village self help which require the lowest financial inputs from Government. It is important that the Treasury provides guidelines on the resource levels that should be feasible for the Action Programme.

As for the prevalence survey we outline very briefly what is necessary: First areas which are known to have schistosomiasis are identified as well as contiginous districts to which the disease may have spread. In determining the survey areas available medical evidence should be reviewed on the presence of schistosomiasis. Then a sample of villages is selected and a population sample drawn from the village. Appropriate stool and urine analysis should be done to obtain a picture of the health conditions facing the person including particularly schistosomiasis but also other parasites. The resulting data should be analysed to determine prevalence rates for schistosomiasis by region and by age group; other disease data should be profiled in the same way for general interest.

The particular village projects to be carried out should be the responsibility of the RHO with the guidance of TMRC. Various approaches to the reduction problem such as cleaning of snail habitats, filling in of wet season ponds and better sanitation practices should be designed and implemented.

The village energies should be directed towards schistosomiasis reduction. Each village should initially be assessed for prevalence of schistosomiasis and again reassessed after reasonable periods say two and four years so that the impact of different methods can be evaluated. An attempt should be made to trace the history of new cases and cures so as to identify the social and economic processes in the village which can be associated with the changes.

Time Schedule

Assuming the recommendations made here are more or less accepted, then assignment of the Action Programme preparation could take place through the legislation or directly. The preparation should take AFYA approximately one year. The survey should start as soon as possible; this could be initiated as one of the early actions of the planning group. The Action Programme would take several months for discussion and approval after it is completed. The target should be to start the Action Programme in approximately two years from the time that work on its preparation commences.

9.10 Public Education Programmes

Public education campaigns on various water quality issues can be of considerable importance in teaching people about water quality. There are various target audiences at which such programmes can be aimed. Among the more important groups are the village leaderships (chairman, managers), the RWEs, the RHOs, as well as the rural masses. In practical terms, this might not be achieved by joining the technical knowledge of the WHD with the organisational ability of the CCM. It may be necessary at first also to draft some people with specialised knowledge of adult education. Such knowledge certainly exists within the country, particularly in ELIMU and AFYA. There are a number of points that need to be stressed in these campaigns and we note in this same section. What is recommended is that the special programme's section of the WHD work with appropriate media experts in preparing materials for campaigns. The audiences require rather different treatment but the basic themes are largely the same.

Water Source Protection

Emphasis should be on practical steps that can be taken by the village; the points developed in Section 9.3 covering source protection provide the basic concepts. Also the recommendations of the Rural Water Supply Committee (see Annex 8.3) should be utilised . Most source protection measures are common sense but there is a widespread "blindness" to these problems. What is needed is a material to help people "see" the problems of water source pollution that they are causing by their actions.

Excreta Disposal

We have emphasised in this report the importance of sanitary excreta disposal in rural areas. We believe that continued information is necessary at all levels combined with practical pamphlets or ways and means of constructing pit latrines, etc.

The basic two themes that we suggest are straightforward. What is difficult is preparing appropriate material in the form of "how to do it" booklets which will be usable by the village leadership. In the course of preparing such material the connection between water, health, and sanitation should be explained so that the reason for the source protection and excreta disposal is better understood.

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