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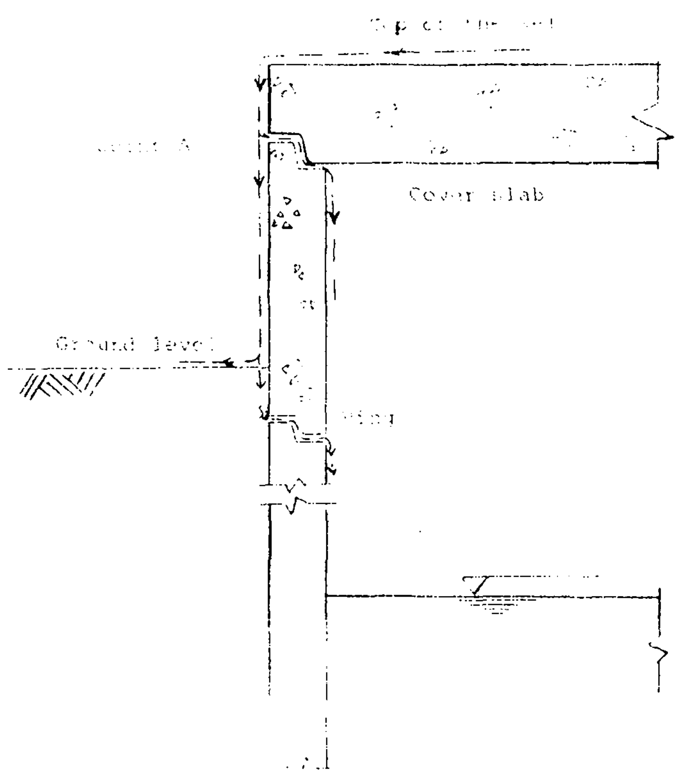
Drinking Water Quality Control in Mtwara and Lindi Regions, Tanzania



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DRINKING WATER QUALITY CONTROL IN MTWARA AND LINDI REGIONS, TANZANIA

By

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Thesis to be submitted to the Department of Civil Engineering, Tampere University of Technology, Finland in partial fulfilment of the requirements for the degree of Master of Science in Engineering

March 1986

Dar es Salaam, Tanzania

Dedicated to:
My fiancee
Agnes D. Mikina
Dar es Salaam

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ABSTRACT

By 1976, when the United Nations gave recommendations on the initiation of rural water supply programmes, Tanzania was already implementing her own, launched in 1971. In March 1973, Temporary Standards of Quality of Domestic water in Tanzania were launched.

Standards and regulations achieve nothing unless they can be implemented and enforced. If the funds are limited, and a water source of acceptable bacteriological quality is not available, it may be necessary to use the available source without treatment purely to improve access to the water.

Fluoride concentrations for Mtwara and Lindi regions are very low, with a mean value of 0,55 mg/l. They are normally below 1,5 mg/l which is the limit allowed for drinking water according to WHO standards.

Any water quality control programme for Mtwara and Lindi regions should be essentially simple and matched with the economic situation of this area. Emphasis should be given to preparing programmes which require very little running costs. Sanitary inspections assisted by occasional sampling for laboratory analysis are one alternative.

Use of existing laboratories of the Ministry of Health for water quality monitoring may lead to saving in terms of transport and time.

1. INTRODUCTION

Tanzania covers an area of 937 062 km^2 including 53 483 km^2 of water (Figure 1.1). The present population, projected from 1978 census, is slightly above 20 million people. Agriculture is the backbone of the country's economy engaging more than 90 % of the population.

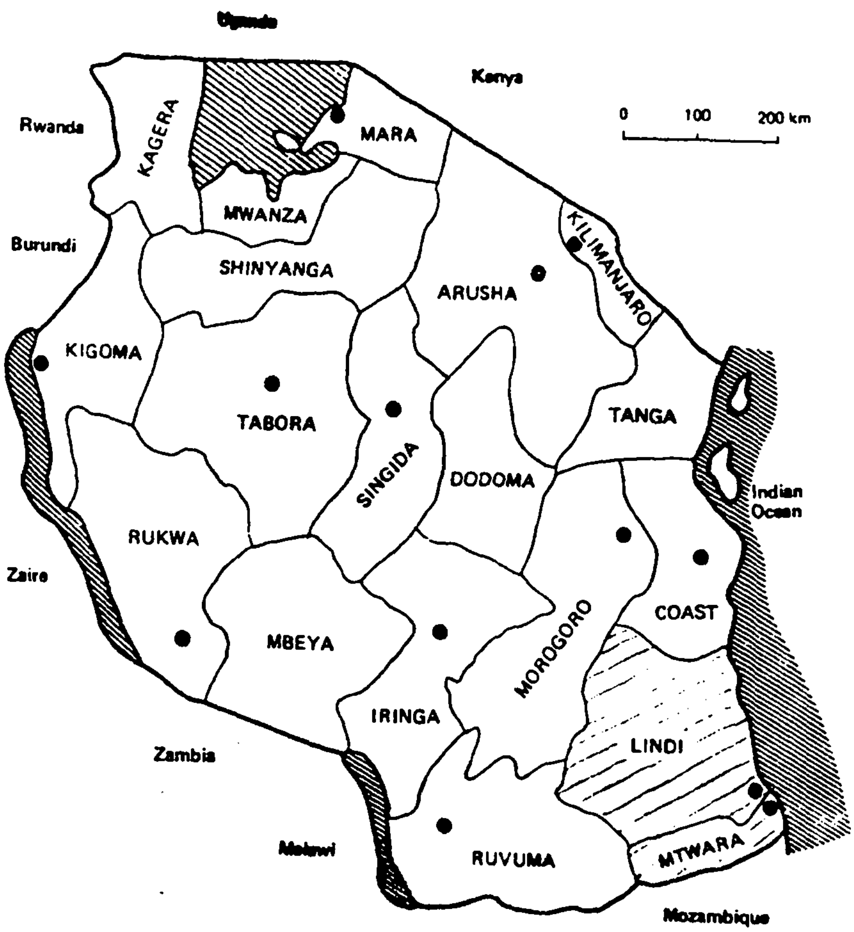


Figure 1.1. Administrative boundaries of Tanzania.

Mtwara and Lindi regions cover an area of 84 700 km^2, Mtwara covering 17 750 km^2 and Lindi 66 950 km^2. The area covered by water represents less than 1 % of the total area, most of it being in Ruvuma river.

Quantity and quality of water available is an essential factor of development. With this in mind, Tanzania launched a 20 year water supply programme in 1971. The aim was to provide clean potable water to the rural areas by the year 1991, at an average distance of 400 m to a domestic water point.

When the programme was introduced, it was realized that there would be difficulties in making sure that the water provided was safe and remained safe. At the time, there were not enough facilities and personnel for water quality monitoring. To ease these problems, very encouraging steps have been taken, including:

1. Establishment of Temporary Standards of Quality of Domestic Water in Tanzania in 1973.

2. Establishment of a course for water laboratory technicians at the Water Resources Institute in Dar es Salaam.

3. Plans to establish zonal water quality laboratories in Mtwara, Mbeya, Moshi, Mwanza, Shinyanga and expansion of the Soils and Water Laboratory in Ubungo. The Mbeya zonal laboratory is already operational, as from June 1984. At present, there are small laboratories in Mwanza, Mtwara, Shinyanga, Tabora, Kigoma, Rukwa, Iringa and Ruvuma.

The aim of these steps is to establish a water quality control and surveillance programme for the whole country.

Tanzania is one of the poorest nations in the third world. The resources available for water quality control are very limited. It is the responsibility of the very few experts available to serve the whole nation, to device means of utilizing these meagre resources economically and effectively.

Regional variations in water quality in Tanzania have been established in other studies. The aim of this paper is to re-examine the water quality in Mtwara and Lindi regions and possibly establish water quality control model or models for the regions.

2. WATER QUALITY MONITORING

2.1 Consumer understanding of drinking water quality

In assessing the quality of drinking water, the consumer relies completely upon his senses. Water constituents may affect the appearance, smell or the taste of the water and the consumer will evaluate the quality and the acceptability essentially by these criteria. Water that is highly turbid, highly coloured or has an objectionable taste will be regarded as dangerous and will be rejected for drinking purposes. However, we can no longer rely entirely upon our senses in the matter of quality judgement. The absence of any adverse sensory effects does not guarantee the safety of water for drinking.

The primary aim of water quality monitoring is to protect public health and eliminate or reduce to minimum the constituents of water that are known to be hazardours to health and wellbeing of the community.

2.2 Priorities as regards water quality

In most cases, the priorities assigned to physical and chemical parameters depend on local circumstances. Parameters like pH and colour are not related directly to health, but have been applied widely and successfully over many years to ensure wholesomeness of water. Microbiological quality of drinking water is of greatest importance. It is also important to note that the adoption of drinking water standards implies the need to provide suitably qualified and experienced staff to undertake surveillance activities, including monitoring the microbiological quality.

2.3 Water quality aspects

2.3.1 Bacteriological aspects

Natural and treated waters vary in microbiological quality. Ideally drinking water should not contain any micro-organisms known to be pathogenic. It should also be free from bacteria indicative of pollution with excreta.

The coliform group of bacteria is normally the principal indicator of the suitability of water for domestic use.

The methods used to detect and confirm the presence of coliform organisms are designed to demonstrate one or more of the properties in the following working definition which is practical rather than taxomanic (WHO 1985):

- The term "coliform organisms" (total coliforms) refers to any rod-shaped, non-spore-forming, Gram-negative bacteria capable of growth in the presence of bile salts or other surface active agents with similar growth inhibiting properties, which are cytochrome oxidase negative and able to ferment lactose at either 35 or 37 °C with the production of acid, gas and aldehyde within 24 - 48 hours.

  Those which have similar properties at a temperature of 44 or 45 °C are described as faecal (thermotolerant) coliform organisms. Faecal coliform organisms which ferment both lactose and other suitable substrates such as mannitol at 44 or 44,5 °C with the production of acid and gas, and which also form indole from tryptophan, are regarded as presumptive E. Coli. Confirmation as E. Coli may be made by demonstration of a positive result in the methyl red test, by failure to produce acetyl methyl carbinor, and by failure to utilize citrate as the source of carbon.

These steps in the detection and confirmation of coliform organisms should be regarded as parts of a progressive sequence, those needed for any particular sample depending on type of water, objective of the examination, and the capability of the laboratory. Supplementary indicator organisms, such as faecal streptococci and sulfite reducing clostridia, may sometimes be useful in determining the origin of faecal pollution as well as in assessing the efficiency of water treatment processes.

In Tanzania as in most developing countries, bacteriological quality of water assumes much greater importance than chemical quality due to limited industrial and commercial development and low sanitation standard.

2.3.2 Chemical and physical aspects

The changes in the chemical quality of water take place much more slowly than in the bacteriological quality, and therefore the chemical examination is not required so often.

The health risk due to toxic chemicals in drinking water differs from that caused by bacteriological contaminants. It is very unlikely that any substance could result in acute health problem except under exceptional circumstances, such as massive contamination of the supply. Water usually becomes undrinkable after such incidents for obvious reasons such as its taste, odour and appearance.

The problems associated with chemical constituents arise primarily from their ability to cause adverse effects after prolonged periods of exposure, of particular concern are cumulative poisons and carcinogenic.

The short routine chemical and physical examination of water should include appearance, colour, odour, taste, temperature, alkalinity, oxidizability, ammonia, nitrate, nitrite, chloride, iron and in disinfected supplies also residual chlorine.

2.4 Planning for water quality control and surveillance

Most developing countries lack adequate community water supplies. In many of these countries water supply schemes are being planned, some on large scale. In the rural areas and urban squatter settlements of these countries, water quality control and surveillance programmes should be realistic and attuned to the levels of economic and manpower development (Simpson 1978).

While it is good to monitor the water quality of existing schemes serving small villages, it is also important to realize that the quality of the water must be related to the general consumer understanding of the subject. It may not be necessary to maintain high water quality by treatment while the water is easily contaminated on its way to the consumer after collection, mainly due to ignorance on the part of basic health education.

On the other hand, it might be better to start by improving the traditional water sources of the villagers in terms of accessibility to the sources and means of fetching the water, and impart at the same time to the villagers the necessary basic health education. After this the villagers will get the idea of good water quality. They will know the importance of protecting their water sources against pollution. It would then be easier to look for better water sources for development because the villagers, knowing why they have to abandon their old water source, can give moral and some financial support to the new schemes.

2.4.1 Level of surveillance

The programme and level of surveillance should be suited to local situations and the economic resources of the country,by taking into account the following:

- type of supply system (size, source type, water quality and others);

- technology used and available;

- employment practices and level of the community served by the water supply system;

- community participation;

- geographical and climatological conditions and

- communication and transportation infrastructure.

Having the above mentioned points in mind, the following experiences can be cited:

a) NORAD - supported laboratories

Following positive recommendations from a NORAD mission, 3 water quality experts were recruited in 1975 for the Ministry of Water Development Laboratory in Kenya. NORAD - recruited staff continued for a period of 4 years during which purchasing, training, laboratory expansion and routine operation were carried out. The laboratory operation was then continued without NORAD support (Haldorsen 1983).

No professional evaluation of the laboratory has taken place after the last NORAD -expert left in 1979. It has been reported by other NORAD staff in the Ministry that planners and designers have little confidence in analytical results presented by this laboratory. Although the need for water quality control is just as important as before, the Ministry has not given priority to recruitment of water quality experts from the pool of 14 experts per year provided by NORAD (Haldorsen 1983).

In 1980 Norconsult A.S. established laboratories in Kigoma and Rukwa regions, Tanzania, in connection with the NORAD supported water master plans. Under the supervision of an expatriate chemist, the laboratories provided the consultant's water master plan team with water quality data. When this study was completed in 1981 the administration and the professional supervisions were handed over to the Ubungo Water Quality Laboratory in Dar es Salaam (Haldorsen 1983).

It seems that the difficulties in the laboratories started shortly after operation was handed over and that the main reason for the problems lies in the shortage of qualified staff and limited access to chemicals, maintenance and spare parts for the equipment. The actual need for laboratory service has repeatedly been stressed also by the water engineers working in Rukwa and Kigoma (Haldorsen 1983).

b) Funds allocated to water schemes

In Tanzania, the annual allocations of funds to the Ministry of Water, Energy and Minerals has been fluctuating, but it is important to note that this water sector gets one of the biggest allocations compared to other Ministries. Since water quality surveillance and control is under the Ministry and therefore gets its funds from the same, it is important to look into the actual figures as presented in table 2.1 (Balaile 1983).

Table 2.1. Yearly planned allocation per capita against actual allocation (Balaile 1983).

Year	Population to be served		Finances allocated as per 1971 (Million TAS)	
	Planned	Actual	Planned	Actual
1971/72	1 500 000	200 000	260	24
1972/73	1 500 000	210 000	260	43
1973/74	1 500 000	360 000	260	64
1974/75	1 500 000	488 000	260	112
1975/76	1 500 000	480 000	260	159
1976/77	1 500 000	715 000	260	157
1977/78	1 500 000	730 000	260	161
1978/79	1 500 000	940 000	260	207
1979/80	1 500 000	1 100 000	260	242
1980/81	1 500 000	1 060 000	260	233

2.4.2 Assessment of existing situation

Water supply systems vary greatly in size, ranging from small schemes serving individual families with wells or rainwater cisterns to systems serving large communities like cities with piped supply. In the case of small community water supplies, adequate and safe water may not be available in a large number of villages. In the rural areas, and also in many squatter settlements in urban areas, control, operation and maintenance of water systems are often inadequate.

The small communities of rural areas can be at great risk from waterborne diseases and their water supplies need safeguards which can be brought about only through effective surveillance. It is also good to know that standards and regulations achieve nothing unless they can be implemented and enforced (WHO 1985). If the funds are limited, and a water source of acceptable bacteriological quality is not available, it may be necessary to use the available source without treatment purely to improve access to the water. However, in such a case the size of the scheme should be carefully considered. Any faecal pollution in a large rural scheme supplying several villages carries the threat of a large epidemic. In small village systems the size of any resulting epidemic is much smaller. Cooperation between villages to provide their inhabitants with water from a large scheme should in such cases be postponed untill the funds are available for introducing disinfection. In the meantime, smaller schemes should be arranged (Myhrstad 1983).

2.4.3 Special considerations for small water supplies

There are particular problems associated with ensuring that small rural water supply systems comply with drinking water standards. These can arise, for example, because of distance and the lack of good transportation to the nearest laboratory; bacteriological monitoring is an especial problem. In such cases, especially in the developing countries, emphasis should be placed on (WHO 1985):

- selection of adequate, safe sources, preferably those which do not need treatment

- regular and frequent sanitary surveys; local operators should be adequately trained to undertake sanitary surveys

- testing to ensure bacteriological quality; if the supply can only be tested once, the most effective samples are those that assist in selecting the source

- testing chlorine residuals (in chlorinated systems); this is a quick and easy test to perform and is a good indicator of the bacteriological integrity of water works operations

- reliability of operation and convenient access to consumers.

2.5 Sanitary inspection

A sanitary inspection is an extensive field inspection and evaluation of local environmental and health conditions. It assesses current and potential hazards to the water supply source or the existing water system, or both. It requires technical knowledge and good judgement.

Sanitary inspections are important as backup information when interpreting the results of a laboratory of field analysis of a water sample. A sanitary inspection may also indicate that a supply used regularly without incidence of disease should not be condemned when analysis of a single sample shows contamination.

Sanitary inspections should be undertaken to new water sources and also to existing water supply schemes, especially in the rural areas. Simple observation is the first part of all sanitary inspections. Closer inspection of existing water supply systems involves checking facilities and operational practices for signs of contamination. For example, water from a well should not be considered safe if the well is not covered or unprotected, or the collection vessel is not kept clean. Water stored in uncovered tanks or other containers may be contaminated by birds, animals and human beings. Water stored in leaking, broken or loose covered tanks may also be contaminated especially during rainy seasons.

Leaky pipes may draw in sewage or other contamination from the soil. If pipes have been packed or repaired with jute, hemp, cotton or leather, they may provide a wet breading material for bacteria (Water... 1982).

2.6 Handling of water analysis results

As a guide for those carrying out remedial measures, the surveillance group should provide information on the following:

- a report on the situation

- date, time and place of contamination or other problem

- suggested remedial measures for the water supply

In addition to any remedial measures that may need to be applied to the water supply, certain other measures could be taken as far as the local community is concerned sometimes for instance advice on boiling all drinking water.

The following points are also important and should be undertaken whenever possible:

- resample the water supply as soon as possible

- check residual chlorine for chlorinated water supplies at appropriate points

- make a full sanitary inspection

- identify the source of pollution and rectify it

2.7 Handling of sanitary inspection results

The action is similar to that of handling the results of water analysis. However, the level of training needs to be more specialized, and experience in giving relevant judgement and writing proper reports is essential.

3. HISTORY AND SITUATION OF WATER QUALITY MONITORING IN TANZANIA

3.1 Development of water quality control and surveillance in Tanzania

By 1976, when the United Nations gave recommendations on the initiation of rural water supply programmes, Tanzania was already implementing her own. Since 1971, quantity and quality of water available as an essential factor of rural development was clearly emphasized in Tanzania when the 20 year water supply programme was started. The aim of the programme was to provide clean potable water within an average distance of 400 m for the people of the rural areas.

When the programme was started, it was realized that there would be difficulties in making sure that the water provided was safe and remained safe. At the time there were no facilities and personnel to carry out water quality monitoring. There were also not laid down Tanzanian water quality standards which were to be followed (Kassum 1982).

To remedy these deficiencies, two steps were taken. First, it was decided in late 1970 that the then Ministry of Water Development and Power as well as the Ministry of Health should constitute an Inter-Ministerial committee which would investigate and recommend Rural Water Health Standards. The committee started its work in March 1971 and produced the Temporary Standards of Quality of Domestic Water in Tanzania, in March 1973. These standards are now under review (Kassum 1982).

The second step was to move towards establishing a water quality surveillance programme. A report by Brokonsult (1979) recommended the following:

- establishment of a course for water laboratory technicians

- establishment of a training programme for chemists, sanitary engineers and bacteriologists

- formation of a Water Hygiene Division within the Ministry of Water Development and Power

- establishment of zonal water hygiene centres at Mtwara, Mwanza, Moshi, Mbeya and Shinyanga

- purchase of mobile laboratiories in each of the zonal water laboratories

- formation of a water quality legislation and

- expansion of the Ministry's Soils and Water Laboratory at Ubungo in Dar es Salaam.

According to Kassum (1982), some of the recommendations have been implemented as follows:

- a three year course for water laboratory technicians is being conducted at the Water Resources Institute in Dar es Salaam

- plans to establish the zonal water quality laboratories in Mtwara, Mwanza, Moshi, Mbeya and Shinyanga, of which the Mbeya laboratory is already operational since June 1984

- to safeguard the water quality of boreholes, rivers, springs, lakes, reservoirs, charcos and shallow wells the Ministry, in May 1981, prepared a bill to amend the Water Utilization Act, 1974. This bill was subsequently approved by the National Assembly

- the Ministry is also considering the recommendation to establish a Water Hygiene Division

3.2 Tanzanian water quality standards

Temporary Standards of Quality of Domestic Water in Tanzania applicable to rural water supplies have been in use since 1973.

According to the Health Committee which prepared the standards, they will be in use until the circumstances permit the full application of the International standards laid down by the World Health Organization (Ministry... 1974).

The committee defined three categories of water supply schemes as follows:

- urban water supplies serving cities, municipalities and townships

- large scale rural water supplies serving rural populations of more than 5 000 people

- small scale rural water supplies serving less than 5 000 people

International Standards of Quality of Domestic Water will be applied to urban water supplies and large scale rural water supplies serving more than 5 000 people.

The temporary drinking water quality standards are divided into three categories:

- Bacteriological standards
- Physical and chemical standards
- Standards of sanitary protection of water intake and surrounding land

3.2.1 Bacteriological standards

According to the Tanzanian Temporary Standards, water supplies serving less than 5 000 people should be examined as in table 3.1. This frequency of sampling refers to those water supplies which on previous examination showed total absence of faecal coliform.

Table 3.1. Sampling and examination frequency of water sources serving up to 5 000 people (Ministry... 1974).

Type of source	Population served		
	≤ 1 000	≤ 2 000	≤ 5 000
Borehole deeper than 8 m	6 months	4 months	3 months
Well less than 8 m deep	2 months	1 month	1 month
Surface water, lakes, rivers, springs and dams	1 month	2 weeks	2 weeks

The standards state that if the result of bacteriological examination indicates faecal pollution, the supply should be re-examined within two weeks, at the latest, irrespective of the type of source or population served.

In urban and large-scale rural water supply systems, to which the International standards are applied, samples should be taken from where water enters the distribution system, and also from the actual distribution system. Slightly different bacteriological requirements are applied to the place where water enters the system depending on the possible disinfection of the supply. In the distribution system the water quality requirement is the same irrespective of disinfection. Following standards are given in the International Standards (WHO 1985):

a) Treated water entering the distribution
   - No coliforms in any sample of 100 ml.

b) Untreated water entering the distribution
   - Not more than 3 coliforms in 100 ml occasionally. If coliforms are frequently present, the bacteriological quality is unsatisfactory.

c) Throughout any year, 95 % of samples should not contain any coliform organisms in 100 ml.
   - No sample should contain faecal coliforms in 100 ml.
   - Coliforms should not be detectable in 100 ml of consecutive samples collected from the same sampling point.

The repeated demonstration of coliform organisms, or their appearance in large numbers, suggests that contamination of the water is occurring and remedial action, especially in relation to the chlorine residual, should be taken at once. The actual measures will vary with circumstances but, as a minimum, the water must be resampled. The problem can be considered to be resolved only if a cause is found and eliminated or if a series of samples shows that the pollution was temporary (WHO 1985).

Sampling for bacteriological examination , as recommended by the International Standards for piped water supplies, should be carried out as in table 3.2.

Table 3.2. Minimum sampling frequencies for piped water supplies (WHO 1985).

Population served	Minimum number of samples
less than 5 000	1 sample per month
5 000 - 100 000	1 sample per 5 000 population per month
more than 100 000	1 sample per 10 000 population per month

Although it is desirable to take samples at least weekly, this may not be possible with small systems. If possible, decisions on sampling frequencies should be taken by national authorities.

3.2.2 Chemical and physical standards

The Tanzanian Temporary Standards prescribe that irrespective of the size of population served by the water supply, the water should be tested at least two times per year, once under dry conditions and once under rainy conditions. Some of important parameters defined in the Tanzanian Temporary Standards of Physical and Chemical Quality of Drinking Water are compared to the then International Standards for Drinking Water set way back in 1971, in table 3.3.

Table 3.3. Chemical and physical Standards, International and Tanzanian Temporary Standards (Ministry... 1974).

Parameter	Unit	International		Tanzania
		Accepted	Allowable	
Water causing toxic effects				
1. Lead, Pb	mg/l	n.m.	0,05	0,10
2. Arsenic, As	mg/l	n.m.	0,05	0,05
3. Chromium (b+), Cr	mg/l	n.m.	0,05	0,05
4. Cyanide CN	mg/l	n.m.	0,20	0,20
5. Cadmium Cd	mg/l	n.m.	0,10	0,05
6. Mercury, Hg	mg/l	n.m.	n.m.	n.m.
Water affecting human health				
1. Fluoride, F	mg/l	n.m.	1,5	8,0
2. Nitrate, NO_3	mg/l	n.m.	30,0	(100)
Water being organo-septic				
1. Colour	mgpt/l	5	50	50*
2. Turbidity, SiO_2	mg/l	5	25	30*
3. Taste	-	n.o.	n.o.	n.o.
4. Odour	-	n.o.	n.o.	n.o.
Water of salinity and hardness				
1. pH	-	7,0-8,5	6,5-9,2	6,5-9,2*
2. Total hardness, $CaCO_3$	mg/l	n.m.	n.m.	600*
3. Sulphate, SO_4	mg/l	200	400	600*
4. Chloride, Cl^4	mg/l	200	600	800*
Water with non toxic metals				
1. Iron Fe	mg/l	0,3	1,0	1,0*
2. Manganese Mn	mg/l	0,01	0,5	0,5*
3. Copper Cu	mg/l	1,0	1,5	3,0*
4. Zinc, Zn	mg/l	5,0	15,0	15,0*

Notes:

n.m. = not mentioned

n.o. = unobjectionable

* = tentative figures

The International Standards (WHO 1971), have been revised and superseded by the Guidelines for Drinking Water Quality (WHO 1985). These guidelines are intended for use by countries as a basis for the development of standards which, if porperly implemented, will ensure the safety of drinking water supplies. Some of the important parameters which have been given guideline values are presented in table 3.4.

Table 3.4. Guideline values (WHO 1985) compared to International Standards (WHO 1971).

Parameter	Units	International Standards (WHO 1971)		Guideline Value (WHO 1984)
		Accepted	Allowable	
Lead, Pb	mg/l	n.m.	0,05	0,05
Arsenic, As	mg/l	n.m.	0,05	0,05
Chromium, Cr	mg/l	n.m.	0,05	0,05
Cyanide, CN	mg/l	n.m.	0,20	0,10
Cadmium, Cd	mg/l	n.m.	0,01	0,005
Mercury, Hg	mg/l	n.m.	n.m.	0,001
Nitrate, NO_3	mg/l	n.m.	30,0	10,0
pH	-	7,0 - 8,5	6,5 - 9,2	6,5 - 8,5
Total Hardness, $CaCO_3$	mg/l	n.m.	n.m.	500
Sulphate, SO_4	mg/l	200	400	400
Chloride, Cl	mg/l	200	600	250

3.2.3 Standards of sanitary protection

Protection of the water sources from pollution is an important factor of the Tanzanian Temporary Standards. The Committee which prepared the standards urged the then Ministry of Water Development and Power as well as the Ministry of Health to expedite the formation of an advisory board which should define and set up sanitary zones for the protection of water sources. They also recommend that the sanitary zones are an integral part of every rural water supply system.

The standards suggest the following distances from sources of pollution:

a) 50 metres from:	- pit privies
	- septic tanks
	- sewers
b) 100 metres from:	- borehole latrines
	- seeping pits and trenches
	- sub-surface sewage disposal fields
c) 150 metres from:	- cesspools
	- sanitary land fill areas
	- graves

According to the standards, the following precautions must also be observed:

a) animals should be kept away from the intake by fencing the area at a minimum radius of 50 m from the installation

b) defecation and urination around the intake should be completely prohibited by law

c) drainage and run off waters should be led away from the intakes

d) the water source should be guarded against inundation by flooding of nearby rivers

e) soil erosion should be prevented by reforestation and other methods

f) algal growth should be prevented by draining swamps and pools around the intake or reservoir

When water is drawn from rivers, streams, lakes and reservoirs, intakes should be placed and designed so that the water abstracted is as clean and palatable as the source can provide:

- river intakes should be constructed upstream from villages and industries, and the intake should be in deep water close to a stable bottom

- small stream intakes should comprise an intake pool which can also act as a settling basin

- lake intake should as much as possible avoid shore water, avoid stirring up of sediments, and seek the clean bottom water

The standards also recommend disinfection by chlorination of newly built water supplies before handing over to the public.

3.2.4 Remarks on the WHO sampling guidelines

The WHO (1985) guidelines for sampling of bacteriological examination, table 3.2 shows that for population of 5 000 - 100 000 one sample per 5 000 population per month should be taken, while for populations of more than 100 000 one sample per 10 000 population should be applied. This means that for 80 000 people altogether 16 samples per month, and for 120 000 people altogether 12 samples per month should be taken.

It is clear that the risk of water contamination in the distribution system increases with the length of network and the number of plumbing systems attached (WHO 1985). The number of population served is also a factor.

Table 3.2 might be better if it were modified as in table 3.5, suggested by the author.

Table 3.5. Minimum sampling requencies for piped water supplies, modified from table 3.2.

Population served	Minimum number of samples
less than 5 000	1 sample per month
5 000 - 100 000	1 samplen per 5 000 population per month
more than 100 000	20 samples + 1 sample per 10 000 population exceeding 100 000 per month

Based on table 3.5 for a population of 120 000 people altogether 22 samples should be taken.

3.3 Role of the Ministry of Health

The Ministry of Health in Tanzania is responsible for the health of the general public. It operates facilities like dispensaries, rural health centres, district and regional hospitals. These health facilities are among other things, active in health education campaigns to improve the hygiene and nutrition among the rural population.

When there is an outbreak of diseases like cholera, the Ministry becomes very active in water quality monitoring and advising the general public on boiling of drinking water and disinfection of water supplies by the supplier.

4. WATER QUALITY IN MTWARA AND LINDI REGIONS

4.1 General description

The total area of the two regions is 84 700 km^2, Mtwara region covering 17 750 km^2 and Lindi region 66 950 km^2. The area covered by water represents less than one percent of the total area, most of it being in Ruvuma river. The annual long term precipitation average varies from 800 to 1 100 mm. The annual precipitation in the area may rise once in twenty years on the average up to 2 000 mm and on the other hand, once in twenty years on the average a minimum annual precipitation of 500 mm may occur (Finnwater... 1977a).

The rainy season begins rather regularly at the end of November or in December, and ends in May or June. The period from May to November is practically rainless. There are droughts during the dry period and heavy rains causing severe floods during the rainy season. Evaporation is rather even in different parts of the area, though somewhat less in the interior parts (Finnwater... 1977a).

There are five rivers which run to the Indian Ocean and where hydrological observations have been made. They are Matandu, Mbwemkuru, Lukuledi, Mavunji and Ruvuma. The catchment areas of the first four rivers vary from 3 000 to 15 000 km^2. In spite of the large catchment areas these rivers dry up regularly for most parts every year. Ruvuma river is perennial and constitutes the largest surface water in the area. There are five small lakes with a total area of 18 km^2 (Finnwater... 1977a).

A basement zone, covering approximately 40 % of the total area lies in the middle of the area. The dominant rock types are different gneisses, granites and schists (Figure 4.1). The topography of the basement area is generally very slightly undulating, apart from at places protruding residual mountains, inselbergs. A thin, mainly lateritic soil covers the major part of the bedrock surface. Closest to the coast, where the sedimentary formations are thickest, limerich rock types occur relatively most frequently. Moving towards the interior, the proportion of sandstone dominated sediments increases.

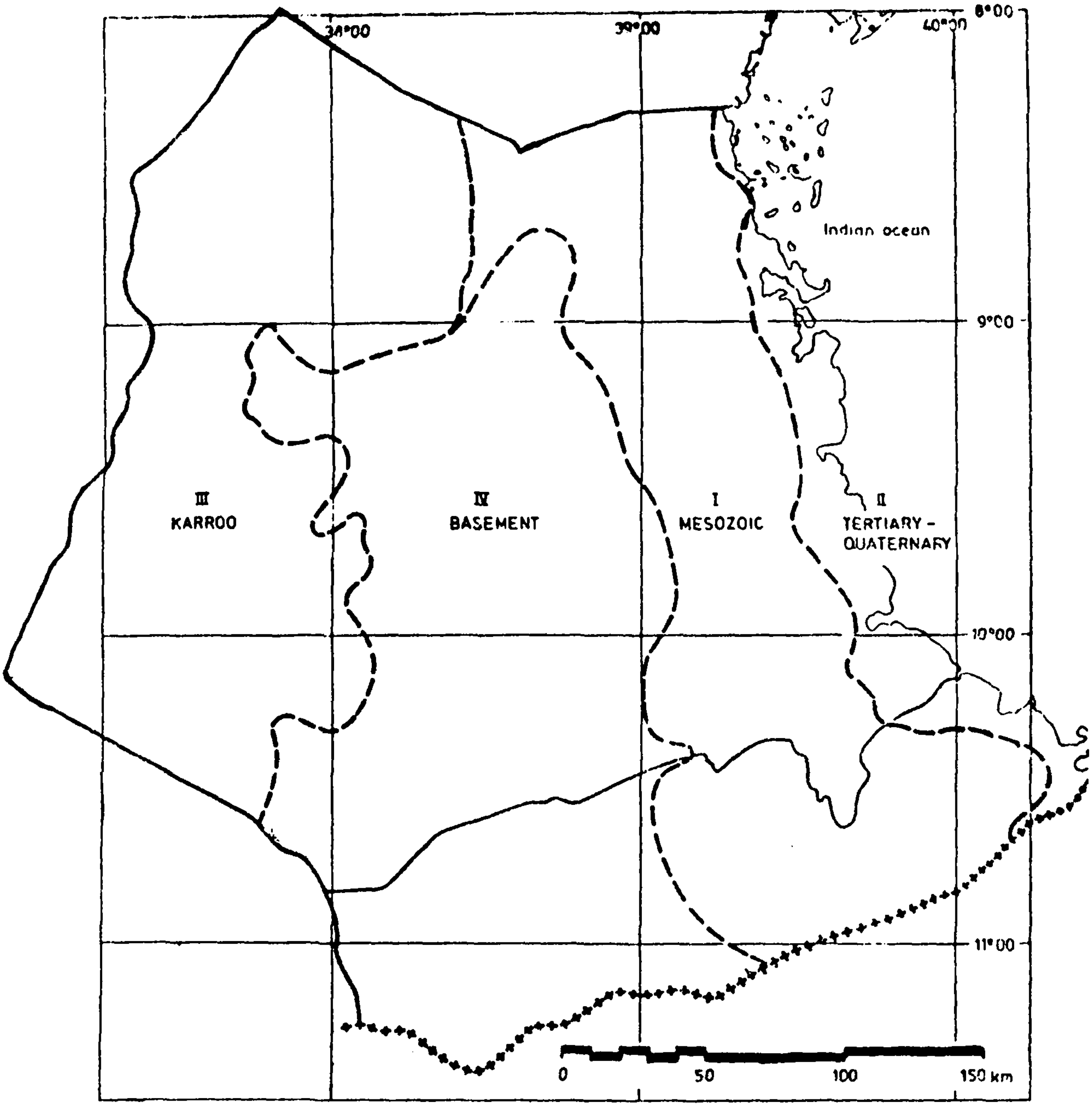


Figure 4.1. Geological formations in Mtwara and Lindi regions (Finnwater... 1977c).

Another sedimentary rock formation occurs on the western side of the regions. It is mostly composed of rocks of the Karroo group the most frequent type being sandstone.

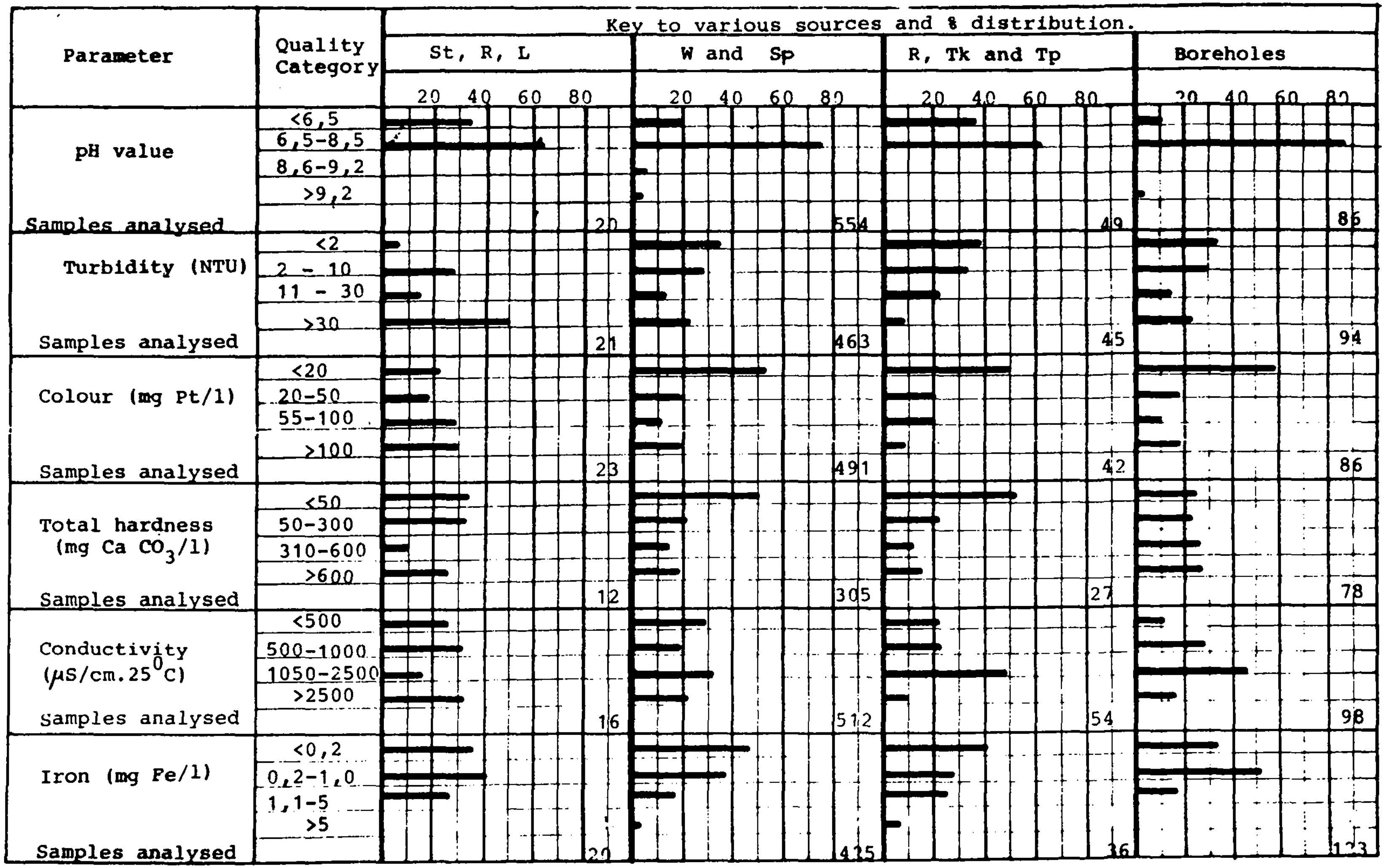
The sedimentary areas are for the most part covered by a thin top soil consisting partly of sand and silt dominated soil and partly of laterite. The thickness of the soil layers in the areas of the big river valleys is assumed to be high, even over 100 m. Mostly alluvial sandy and silty soil occurs as top soil (Finnwater... 1977c).

4.2 Chemical and physical water quality

The general water quality data for the two regions had been quantitatively compiled by Finnwater (1977 c + d) in the Mtwara - Lindi Water Master Plan. In this study attempt has been made to compile the water quality data filed in the laboratory at Mtwara, with the aim of finding any chemical and physical changes that might have occured during the period from 1977, and comparing the bacteriological quality of different water sources. The analyses done and filed from January 1981 up to September 1985 were taken.

Since it is easier to work and channel resources through the districts' administrative centres, the author attempted to break down the water quality data according to districts to see possible qualitative variations. This is to simplify the existing data on water quality variation according to geological formations. However, owing to the small number of samples, this was not really possible. The results are shown without further discussion in appendix A.

During the period from January 1981 to September 1985, altogether 710 samples from different sources in the two regions were analysed and filed in the laboratory at Mtwara. Most of these samples, about 75 % represented shallow ground water, either shallow wells or springs (Figure 4.2). According to the project staff and authors' observations during the compiling process, sampling was mostly carried out during the dry season. During the Water Master Plan Study a total of 1 500 water samples, taken from 400 sampling points in Mtwara and Lindi regions, were analysed (Finnwater... 1977e).



Key: St, R, L = Streams, Rivers and Lakes
W and Sp = Wells and Springs
R, Tk and Tp = Reservoirs, Tanks and Taps

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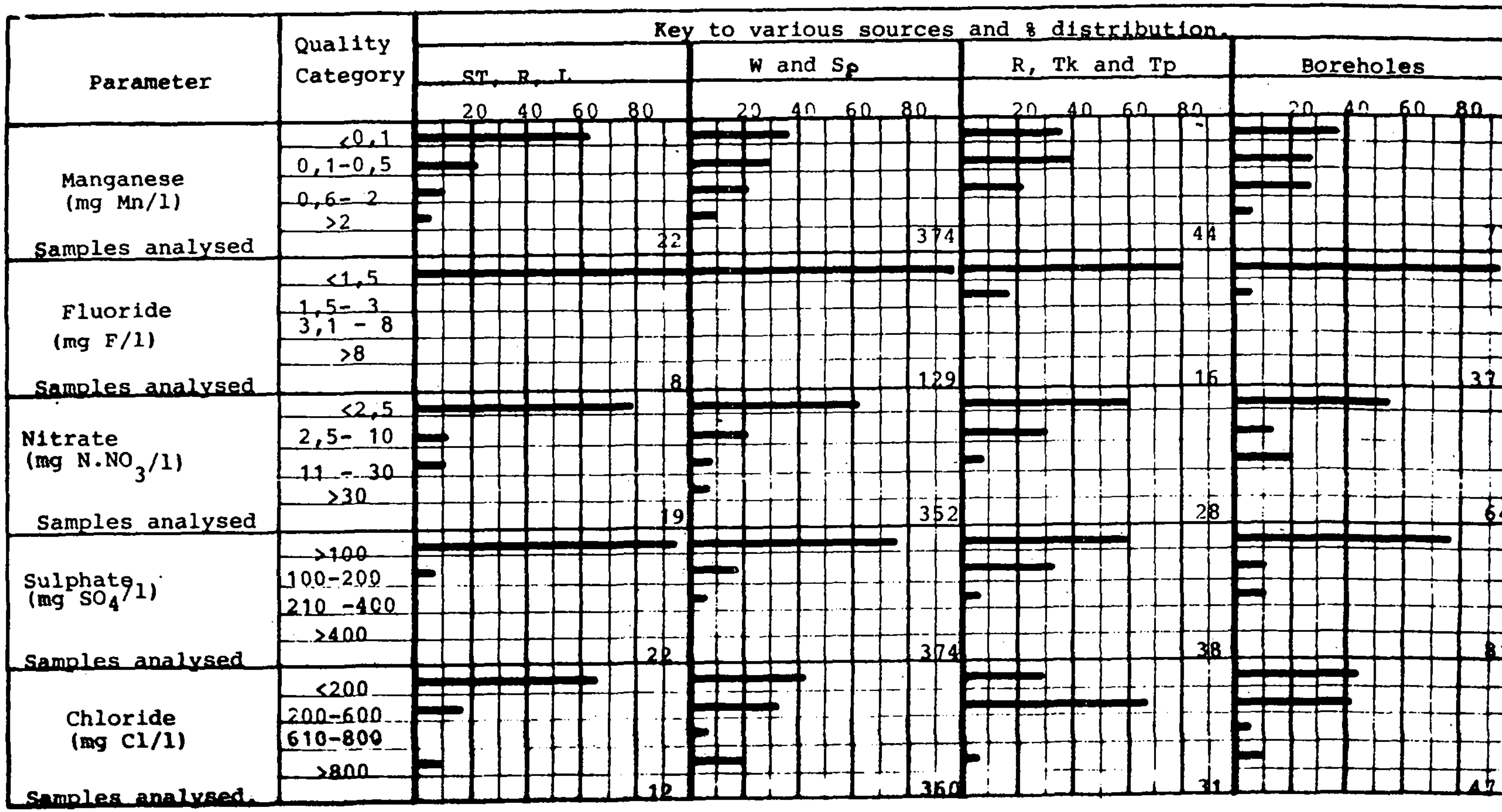


Key: St, R, L = Streams, Rivers and Lakes
W and Sp = Wells and Springs
R, Tk and Tp = Reservoirs, Tanks and Taps

Figure 4.2. Occurrence of different physical and chemical parameters. Various sources with different quality categories. Mtwara and Lindi regions. Data from January 1981 to September 1985.

The following characteristics of different surface and ground water sources can be pointed out, based on the two data banks mentioned above.

4.2.1 Streams

Salinity is low, EC varying from 250 to 1 000 μS/cm, with the average below 700 μS/cm. The content of organic matter is higher than in ground water sources, especially during the rains, when the permanganate value varies from 30 to 120 mg/l.

4.2.2 Rivers

During the dry season river waters are slightly acidic, but neutral or even alkaline in wet seasons. Salinity is low, with EC varying from 200 to 2 000 μS/cm, the average being below 500 μS/cm. The content of organic matter is high, especially during the rains, when the permanganate value is about 80 mg/l.

4.2.3 Lakes and dams

The pH values of these water bodies vary from 6,5 to 8,4. The two remarkable lakes in Mtwara region, Kitere and Chidy are alkaline, while the two remarkable impounding reservoirs, Nanyamba and Masasi are acidic. Salinity varies from low to medium, and EC varies from 300 to 1 700 μS/cm. The content of organic matter in lakes is high, permanganate value is over 100 mg/l. In dams this value is somewhat lower, with an average of 50 mg/l.

4.2.4 Pits

Pits are comparable to shallow wells, although some differences in water quality do exist. The first ores are acidic during dry seasons, and saline at same levels as shallow wells. EC is below 700 μS/cm on the average. Content of oxidizable organic matter is high,with a permanganate value of 40...80 mg/l, varying from 30 to 140 mg/l.

4.2.5 Shallow wells

Water is mostly neutral. Salinity is lower than in boreholes. EC is about 700 μS/cm on the average, but varies from 150 to 3 500 μS/cm. High salinity exists in low lying areas near the coast. The content of oxidizable organic matter is low, but higher than in boreholes, permanganate value being 20...40 mg/l on average, varying between 10 to 100 mg/l. The permanganate value is often higher than the allowable value for drinking water.

4.2.6 Springs

Salinity of spring water is higher than in shallow wells, EC being below 1 000 μS/cm on the average, varying from 200 to 3 500 μS/cm. The pH value varies from acid to alkaline. The content of organic matter is lower than in shallow wells, permanganate value varying from 10 to 80 mg/l.

4.2.7 Boreholes

Water is slightly more alkaline than in other sources of ground water. Salinity is also higher, EC about 700 to 5 000 μS/cm. Content of organic matter is low. Permanganate value is also low, at 5..70 mg/l.

4.2.8 Occurrence of different constituents

Fluoride concentration in Mtwara-Lindi waters is within the international drinking water standards of 1,5 mgF/l. Occurrence of fluoride in Tanzanian water sources (Table 4.1) shows that Mtwara, Ruvuma and Lindi have very good waters without fluoride problem.

Table 4.1. Average concentrations of fluorides in Tanzanian water sources (Ministry... 1974).

NO.	REGION	NUMBER OF SAMPLES	MEAN VALUE	MIN. VALUE	MAX. VALUE	50% PROBABILITY
1	ARUSHA	124	7.11	0.10	78.00	1.80
2	COAST	204	0.56	NIL	20.40	0.32
3	DODOMA	391	1.45	NIL	92.00	0.90
4	IRINGA	68	0.61	NIL	6.10	0.36
5	KIGOMA	30	0.52	NIL	3.21	0.34
6	KILIMANJARO	98	1.91	NIL	25.00	0.56
7	MARA	58	2.02	0.20	9.60	1.45
8	MBEYA	79	0.74	NIL	10.00	0.42
9	MOROGORO	93	0.60	NIL	4.00	0.48
10	MTWARA-RUVUMA-LINDI	90	0.55	NIL	7.00	0.39
11	MWANZA	52	3.43	0.20	18.00	1.90
12	SHINYANGA	38	3.22	0.28	14.80	2.00
13	SINGIDA	78	5.85	NIL	67.00	3.20
14	TABORA	44	1.20	NIL	7.60	0.74
15	TANGA	116	0.94	NIL	20.00	0.47
16	WEST LAKE	27	0.93	NIL	4.40	0.48
	TANZANIA	1590	1.91	NIL	92.00	0.68

From author's findings and those of Finnwater...1977b), the occurence of different constituents can be summarized as follows:

a) Fluoride

Normally the fluoride content is below 1,5 mg/l, which is the limit allowed for drinking water according to the WHO standards. High fluoride content occurs in boreholes in the basement zone, where it varies from 0,8 to 1,2 mg/l. High fluoride content often occurs in the connection with high salinity, when water is not suitable for domestic use due to high salinity and not due to high fluoride content. Some remarkable water sources with a high fluoride content are the Lindi town water supply (1,1 mg/l), the Nachingwea town water supply (1,0 mg/l), the Chikwiwi shallow well (1,9 mg/l) and Mambi river (1,3 mg/l).

b) pH

The pH value varies from acid to alkaline. Acid water occurs especially in pits during rainy seasons.

c) Total dissolved salts

Total dissolved salts are expressed in terms of electrical conductivity (EC), at 25°C, where EC_{25} of 1 μS/cm is equivalent to 0,64 mg/l of salts. High EC values occur in boreholes, especially in the basement area. The EC value often exceeds 5 000 μS/cm, and it is always above 700 μS/cm. Low salinity occurs in rivers and streams.

From author's findings, it is seen that the EC value from shallow wells and springs is less than 2 500 μS/cm (25°C) in 80 % of 512 samples (Figure 4.2).

d) Hardness

Boreholes have harder water than other sources. In the basement area, it varies from hard to very hard, hardness over 5 mEq/l and sometimes more than 15 mEq/l. Soft water occurs in shallow wells, pits, springs and streams, also in the basement zone.

e) Chloride

High chloride content occurs in boreholes in the basement area, over 800 mg/l on the average. Low chloride content occurs in shallow wells, springs, rivers and streams.

f) Nitrate

Nitrate in shallow wells and springs is relatively low, with only 4 % of 352 samples exceeding 30 mg $N.NO_3$/l. In boreholes, out of 64 samples all had concentrations of less than 30 mg $N.NO_3$/l.

g) Iron

Iron occurs normally with manganese, but the iron content is not generally very high. About 75 % of the samples had iron content of less than 1 mg/l, which is allowable according to the International and Tanzanian standards. High iron contents occur especially in pits. Also boreholes often have a high iron content.

From author's findings 38 % of 425 samples from shallow wells and springs had iron content above 1,1 mgFe/l.

h) Manganese

The content of manganese is often higher than allowed for good drinking water. Half of the water samples had concentrations of more than 0,5 mg/l, which is the limit according to the Tanzanian Standards. High concentrations, over 1,0 mg/l, occur both in ground water and in surface water. Highest concentrations occur in pits, mostly above 1,0 mg/l.

From author's findings only 32 % of 374 samples from shallow wells and springs had manganese concentrations of more than 0,5 mg Mn/l and 43 % of 77 samples from boreholes had concentrations above 0,5 mg Mn/l.

i) Organic matter

The content of oxidizable matter is expressed in mg/l of potassium permanganate required for oxidizing the organic compounds in the water sample. High permanganate values occur in surface waters and pits, low values in springs and boreholes (Finnwater... 1977b).

4.3 Bacteriological water quality

Bacteriological quality of a water source is very much affected by the method of fetching the water. The method of fetching water from open wells in Mtwara and Lindi regions is mainly by a small tin (about 4 l) or a bucket, fitted to a long rope made of sisal fibre or other material. This container and the rope are manually handled by the person who is fetching the water from the well. This practice makes the well at risk to contamination, and according to field observations it would hardly be possible to find an open well which is not contaminated. However, from the compiled data (Table 4.2), 25 % of 16 samples analysed showed total absence of faecal contamination. Even then, this should not be relied upon, owing to the small number of samples.

Table 4.2. Frequency (%) of samples of specified quality. Bacteriological data, Mtwara and Lindi regions. Data from January 1981 to September 1985.

Source	Number of samples analysed	Frequency of samples (%) of quality categories (faecal coliforms per 100 ml)			
		0	1 - 10	11 - 50	> 50
Streams, Rivers, Lakes	5	20	0	40	40
Springs	2	0	100	0	0
Open wells	16	25	25	6	44
Ring wells	105	47	27	8	18
Hand auger wells	126	73	25	2	0
Boreholes	16	56	44	0	0
Tanks, Reservoirs, Taps	27	30	44	26	0

From 105 samples taken from ring wells, 47 % showed total absence of faecal coliforms. Ring wells are either machine excavated or hand dug, and lined with precast concrete rings. They are covered by concrete slab and fitted with hand pump. Theoretically, they are safe from contamination by people fetching water.

A construction detail of the cover slab on a ring well is shown in Figure 4.3 (Putaala 1986). Ideally, joint A should be water-tight. The author feels that it is not easy to make it water-tight, and in most cases wastewater from washing and spilling finds its way back into the well through the joint, as shown by dotted line, and contaminates the well water. According to author's knowledge most if not all of the donor-supported water projects are using the same type of well design. It should be further studied, whether it is in practice feasible to install the rings on upside down position and change the structure.

Other factors like loose pump body and vandalism may also contribute to pollution of the well water. 18 % of the samples showing severe faecal contamination of above 50 counts per 100 ml may be attributed to these factors. Wrong sampling and infiltration of dirty water into the aquifer especially when the water table is high may also contribute to pollution.

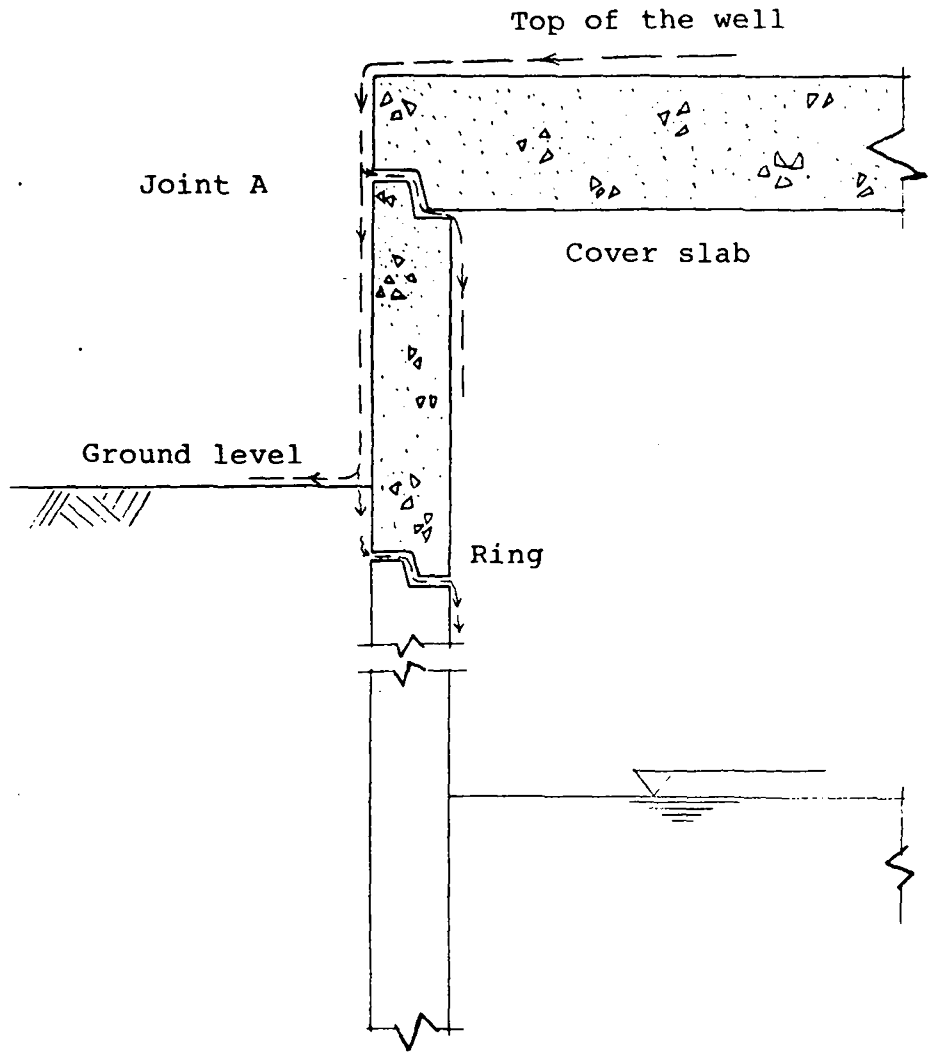


Figure 4.3. Detail of ring well cover slab join to the rings.

Hand auger wells are bacteriologically better than ring wells because 73 % of 126 samples showed total absence of faecal coliforms, and 25 % within 1 - 10 numbers per 100 ml.

Boreholes are deeper than hand auger wells, and it could be expected that the water in boreholes should be safer than in hand auger wells. However, only 56 % out of 16 samples showed total absence of faecal coliforms and 44 % showed 1 - 10 faecal coliforms per 100 ml. This is not reliable due to the small number of samples.

Tanks, reservoirs and taps are expected to give good water quality because it is mainly treated water in a distribution system. However, only 30 % out of 27 samples showed total absence of faecal coliforms. Contamination can take place at the treatment plant when treating the water for chemical and physical parameters and along the distribution line.

Contamination in the distribution line

Mtwara and Lindi regions use thermal power dependent on imported oil. Shortage of oil in the country, coupled with inadequate transportation network makes the two regions' power supply somehow unreliable. Leaking water pipes are also common sites where there are old pipe networks, which results in sucking dirty water into the pipes when there is interruption in pumping due to power cuts or mechanical breakdown of pumps. This results in contaminated water reaching the consumer when pumping resumes.

5. WATER QUALITY MONITORING IN MTWARA AND LINDI REGIONS

5.1 Water quality laboratory in Mtwara town

The water quality laboratory presently serving Mtwara and Lindi regions is situated in the Regional Water Engineers' premises at Mtwara town. It is manned by two technicians who are under the direct supervision of an engineer working with Mtwara - Lindi Rural Water Project. The Project is practically running all the activities of the laboratory, except for the salaries of the two technicians, including the provision of transport for sampling and sample transport.

Theoretically, the laboratory is under Ubungo Soils and Water Quality Laboratory from which it should get the running costs including transport for sampling and sample transport. It is also supposed to work under the Regional Water Engineer.

5.1.1 Installed capacity

Considering the installed capacity of the laboratory, in ideal conditions, it is possible to make about 350 faecal coliform tests per week, working with one incubator which can hold 70 petri-dishes at one time, and not incubate on Saturdays. This is about 18 000 faecal coliform tests per year.

After discussions with the laboratory technicians, it is also possible to carry out 560 physical and chemical analyses per week with the apparatus in the laboratory. This is about 40 water samples per week, carrying out 14 physical and chemical tests on each sample. This makes about 2 000 samples per year.

5.1.2 Actual working situation

Taking other factors like manpower, transport, water shortage, power failures, shortage of consumables like chemicals and filter membranes, the operating level of the laboratory is very low. It performs about 200 faecal coliform tests and 300 samples for chemical and physical analysis per year. This is about 1 % of the theoretical capacity of faecal coliform tests and 15 % of the chemical and physical tests capacity.

5.2 Factors affecting water quality monitoring in Mtwara and Lindi regions

5.2.1 Economic growth

When the Tanzanian Temporary Standards were made in 1973, the economic situation of Tanzania and the world was very sound compared to the present one. Also, since that time, a very big step has been taken towards reaching the people of the rural areas. Much has been done to improve the water schemes in the rural areas through shallow wells, some of them just open wells and many of them covered, fitted with hand pumps.

In Mtwara and Lindi regions, there are about 2 000 shallow wells (end of 1985) scattered in seven districts. Road networks and transportation in the regions are not good, making sampling very difficult.

5.2.2 Priorities and interest

The people who are constructing and running the water schemes are also responsible for the quality monitoring activities. More accusations from the public will be heard when there is no water than when there is water of poor quality. This means that with the meagre resources, more emphasis is placed on putting more schemes in operation rather than quality monitoring of the running schemes. This is especially true for Mtwara and Lindi regions where most people do not have adequate supplies of water, and walking a few kilometres (up to 5 km) for a bucket of water is common in the rural areas.

6. ALTERNATIVE MODELS FOR WATER QUALITY CONTROL IN MTWARA AND LINDI REGIONS

6.1 General

Rural water supplies

These are mainly open wells, unprotected and protected springs, ring and tube wells with hand pumps normally serving less than 5 000 people per source. They are scattered and accessibility from urban centres may be impossible during rainy seasons.

Urban water supplies

These can be boreholes, small dams, springs and piped schemes serving more than 5 000 people.

Before construction, chemical and physical analyses should be carried out irrespective of the size of the scheme.

The alternative models have been worked out in advancing order. This means that model one is the cheapest and model four is the most expensive one.

6.2 Model one, based on sanitary inspections

During operation of water schemes, routine sanitary inspections should be carried out. During these inspections, the operators of the schemes may be given some guidelines for maintaining the schemes with regard to sanitary protection.

During the period of operation and sanitary follow-up, effort should be made to make the villagers especially the village leadership take more involvement in water source protection. By laws, regulations and policies for water source protection should be encouraged at village level.

Important things to be checked during the sanitary inspections for wells and springs are:

- distances from potential polluting sources. These are latrines, septic tanks, sewage discharges, agricultural drainage water discharge and surface runoff from homes

- cracks in well covers and any possible points through which water can go back into the well

- improper use of the well, like washing or bathing on well cover

- surroundings of the wells and springs

Important things to be checked during sanitary inspections for piped schemes and those with treatment works are the following:

- sanitary zones for water sources as defined in the Tanzanian Temporary Standards

- the treatment works, contact tanks, reservoirs, aeration chambers and chemical feeding points

- tanks in the distribution system and break-pressure tanks

- leaking pipes, valves and new connections

- areas and pipes which experience occasional negative pressures

- broken or leaking sewers that are close to water pipes

Tables 6.1 and 6.2 may be used for guidance with regard to frequency of visits.

Table 6.1. Suggested sanitary inspections for different sizes of schemes serving more than 5 000 people.

Population served	Sanitary inspections per year	Remarks
5 000 - 20 000	6 - 12	At least one sanitary inspection every two months
20 000 - 50 000	12 - 24	At least once every month
More than 50 000	24 - 48	Twice every month, and whenever there are environmental changes like heavy storms

Table 6.2. Suggested sanitary inspections for schemes serving less than 5 000 people.

Source	Sanitary inspections per year	Remarks
Open wells and unprotected springs	2 - 4	Pollution expected to occur. Sanitary education to the users, especially on better ways of using the source
Protected spring, ring and tube wells with hand pumps	1 - 2	At least one visit per year and if possible during the wet season
Boreholes with piped supplies	1 - 3	At least one visit per year and if possible during the rainy season

6.2.1 Implementation

Operations will be carried out from regional and district water engineers offices, where one person will be responsible for water quality monitoring as a sanitary inspector. A regional sanitary inspector will supervise the activities by making regular visits to the districts.

6.2.2 Facilities

The district sanitary inspector will be provided with a bicycle, so that he or she is able to visit very remote water sources. A water proof bag for carrying the reports and stationary will also be provided. Rain boots, rain coat and working clothes will be an incentive to the inspector.

6.2.3 Recruiting and training

Recruiting of the sanitary inspectors will be done by the respective district and regional water engineers. Training can be done in Mtwara in form of short courses conducted by an experienced sanitary engineer, assisted by laboratory technicians.

6.2.4 Costs

The major cost component is in salaries and night allowances. A bicycle and a water proof bag working in the rural roads will need replacement every three years. Rain boots, rain coat and two pairs of working clothes may also be taken for three years. Table 6.3 gives estimated costs of running the model, valued at 1986.

Table 6.3. Estimated annual costs of running model one, based on sanitary inspections.

Item	Total number	Unit cost (TAS)	Total cost (TAS)	Remarks
Bicycle	7	1 500	10 500	3 years use. Yearly costs including maintenance.
Water proof bag	7	600	4 200	1 unit costs 1 800 for 3 years.
Rain boots	7 pairs	600	4 200	1 unit costs 1 200 for 3 years.
Working clothes	14 pairs	400	2 800	
Salaries	7 people	22 000	154 000	
Night	7 people	7 000	49 000	
Total annual costs			230 000	

6.2.5 Discussion

For this model, it might be boring for the sanitary inspector to be full time engaged in sanitary inspections. It might be better to use him in other activities in the district or regional water engineers office. In the districts he could be one of the members of the follow-up teams for maintenance and rehabilitation. In the regions, he could be one of the engineers. In that case the monitoring costs could be reduced by say 50 % to about TAS 115 000 per annum.

Advantages:

- More people can participate in water quality control. This is especially true for village water supplies where remedial measures are done by the villagers, sanitary education will be given at the same time.

- Does not demand foreign exchange since all facilities will be locally available.

Disadvantages:

- Not possible to quantify levels of pollution ; at least not scientifically.

- Not possible to keep a record of water quality variation.

6.3 Model two, based on sampling

Sampling will be carried out and analyses will be done both in the field with field equipment and in the laboratory in Mtwara as in tables 6.4 and 6.5.

Sampling will be limited to protected sources for bacteriological analyses.

Table 6.4. Suggested sampling for water schemes serving less than 5 000 people.

Source	Activities per year		Remarks
	Bacterio-logical	Chemical/ Physical	
Open wells, unprotected springs and pits	0	Once initially if it is a community water source	If it is a community water source, pollution usually expected to occur
Protected springs, ring and tube wells with hand pumps	0 - 1	0 - 1	As the situation may demand, like outbreak of waterborne diseases
Boreholes and piped supplies	0 - 1	1	As the situation may demand, like outbreak of waterborne diseases

Table 6.5. Suggested sampling for water schemes serving more than 5 000 people.

Population served	Activities per year		Remarks
	Bacterio-logical	Chemical/ Physical	
5 000 - 20 000	2 - 4	1	As situation may demand
20 000 - 50 000	4 - 8	1	As situation may demand
More than 50 000	8 - 12	1 - 2	As situation may demand

6.3.1 Implementation

Operations will be carried out from Mtwara water quality laboratory, where two technicians will be employed. Sampling, especially for chemical and physical analyses will be done during follow-up activities for rehabilitation or maintenance. Somebody in the follow-up trips will be requested to take samples to the laboratory. Regional water engineers will be approached to take more action towards water quality control. Someone from the offices of the regional water engineer (preferably an engineer) is to be given the responsibilities of water quality control as one of his duties. He will monitor the sampling in the region and the activities in the laboratory in Mtwara and the use of office vehicles.

6.3.2 Facilities

The laboratory in Mtwara will be equipped to conduct bacteriological, chemical and physical tests. A field kit and an incubator will also be provided to conduct tests in the field. List of the equipment and chemicals to perform the tests are shown in appendices B and C.

6.3.3. Recruiting and training

Two laboratory technicians from recognized institutions will conduct sampling and analyses. Short instructions on sampling will be given to a member (preferably the leader) of follow-up groups to collect and bring samples to the laboratory. An assistant, preferably a form four leaver, will help with cleaning, filling and other duties in the laboratory.

6.3.4 Costs

The main cost components of this model will be laboratory equipment, transport, sample analyses costs and salaries. Laboratory equipment is expected to last three to five years. For cost calculations, replacements have been put at every five years. Equipment, sample analysis, energy and transport cost calculations are shown in appendices B, D, E and G.

The salaries are covering two technicians plus one assistant, while the allowances are for the technicians when they go to the field. It is estimated that at the minimum level of operation, the technicians will take two night allowances each per month, and at the other extreme they will take the maximum allowable number of seven night allowances each per month.

Table 6.6 gives a summary of estimated costs of model two.

Table 6.6. Estimated annual costs of running model two.

Item	Annual cost (TAS)
Salaries	78 000
Allowances	10 000 to 20 000
Laboratory equipment	106 000
Bacteriological analysis	14 000 to 95 000
Chemical/Physical	16 000 to 125 000
Transport	25 000 to 150 000
Energy	10 000
Total	259 000 to 584 000

Total cost of about TAS 260 000 at minimum level of operation and, up to 585 000 at the higher level can be expected per annum.

6.3.5 Discussion

If the regional water engineers will participate actively as suggested in this model, the transport cost allocated to water quality monitoring may be reduced to minimum. At the same time the activities in the laboratory will be increased. This will reduce the overall cost of analysis per sample, considering the expensive fixed equipment of the laboratory.

Advantages:

- Possible to monitor variation in the quality of water sources.

- Evidence can be written and filled if water quality has really improved.

Disadvantages:

- Cannot be easily decentralized owing to expensive equipment and trained personnel.

- Demands foreign exchange for equipment and chemicals.

6.4 Model three, based on sanitary inspections and sampling

This is a combination of the models one and two. Sanitary inspection is to be carried out as in model one, together with sampling as in model two, tables 6.7 and 6.8.

Table 6.7. Sanitary inspection and sampling activities for water schemes serving more than 5 000 people.

Population served	Activities per year			Remarks
	Sanitary inspect.	Bacteriol. analysis	Chemical Physical	
5 000 - 20 000	6 - 12	2 - 4	1	If situation allows, do up to 12 sanitary inspections and 4 bacteriological analyses
20 000 - 50 000	12 - 18	4 - 8	1	
More than 50 000	18 - 24	8 - 12	1 - 2	If situation allows, make 2 chemical/physical analyses per year per source

Table 6.8. Sanitary inspection and sampling activities for water schemes serving less than 5 000 people from different sources.

Source	Activities per year			Remarks
	Sanitary inspect.	Bacteriol. analysis	Chemical Physical	
Open wells and unprotected springs	2 - 4	0	0	Pollution usually expected to occur. Sanitary education to the users, especially on better ways of using the source
Protected springs, ring and tube wells with hand pumps	1 - 2	0 - 1	0 - 1	At least one visit per year. More visits as situation allows, bacteriological analysis whenever possible
Boreholes and piped supplies	1 - 3	0 - 1	1	

6.4.1 Implementation

Operations to be carried out from district water engineers offices and the water quality laboratory in Mtwara. Supervision of the sanitary inspectors to be done by the laboratory staff during sampling trips to the districts.

Due to high field analysis costs, bacteriological tests will be done in the laboratory whenever it is possible to transport the sample within six hours to the laboratory.

6.4.2 Facilities

Facilities as for model one will be provided for the seven districts for sanitary inspections. The laboratory in Mtwara will be equipped as in model two.

6.4.3 Recruiting and training

This will be as in models one and two.

6.4.4 Costs

The costs will be as in models one and two, as summarized below:

- For sanitary inspections	TAS 230 000
- For sampling	TAS 260 000 to 585 000
Total costs for model three	TAS 490 000 to 815 000

To run this model, it will therefore cost about TAS 490 000 to 815 000 per annum.

6.4.5 Discussion

The possibilities of reducing the running costs of this model will be as in models one and two.

Advantages:

- Can be partly decentralized.

- Levels of pollution can be quantified.

- Proper records of water quality variations can be filled.

Disadvantages:

- Demands foreign currency.

6.5 Model four, based on sampling according to the Tanzanian Temporary Standards

The standards do not give guidelines for sanitary inspections during operation of water supply schemes. The standards give recommendations of sanitary protection of water sources and intakes.

Irrespective of the size of the water supply scheme, chemical and physical examination should be done at least twice a year, once during rainy season and once during dry season.

Tables 6.9 and 6.10 have been worked out from tables 3.1 and 3.2.

Table 6.9. Sampling per year for water sources serving up to 5 000 people, based on the Tanzanian Temporary Standards.

Type of source	Population served		
	≤ 1 000	≤ 2 000	≤ 5 000
Surface waters, lakes, rivers, springs and dams	12	24	24
Wells less than 8 m deep	6	12	12
Wells deeper than 8 m	2	3	4

Table 6.10. Sampling per year for water supplies serving more than 5 000 people, based on the Tanzanian Temporary Standards.

Population served	Minimum number of samples per year
less than 5 000	12
5 000 - 100 000	12 samples per 5 000 people
more than 100 000	12 samples per 10 000 people

If sampling is to be carried out according to the Tanzanian Temporary Standards of Quality of Domestic Water, the number of samples for the two regions would be as shown in Tables 6.11 and 6.12.

Table 6.11. Sampling activities per year based on the Tanzanian Temporary Standards for water supply schemes serving more than 5.000 people in Mtwara and Lindi regions.

Name of scheme	Population served	Number of activities		Remarks
		Bacterio-logical	Chemical/ Physical	
Mtwara	61 000	144	2	one sample per 5 000 population per month for schemes serving 5 000 - 100 000 for bacteriological analyses
Mikindani	11 000	24	2	
Lindi	37 000	84	2	
Mwiti w/s	8 900	12	2	
Mwema w/s	20 700	48	2	
Liputu-Mkungu w/s	11 600	24	2	
Lulindi w/s	25 000	48	2	one sample per 10 000 population per month for schemes serving more than 100 000 people for bacteriological analyses
Makongonda w/s	11 000	24	2	
Mikangaula	5 600	12	2	
Makulani	8 100	12	2	
Masasi	19 700	36	2	
Kitays w/s	7 300	12	2	
Mbawala Chini	5 200	12	2	
Nanyamba	17 900	36	2	
Chiwambo juu	11 400	24	2	at least 2 samples per year for each water source, for chemical and physical analyses
Mahuta w/s	15 800	36	2	
Kitangari	120 000	144	2	
Mkunya-makote	30 000	72	2	
Kilwa Kivinje	6 200	12	2	
Mandawa	6 500	12	2	
Mnacho	7 000	12	2	
Rutamba	6 700	12	2	
Kilwa Masoko	9 500	12	2	
Ruangwa	7 000	12	2	
Mnazimmoja	14 000	24	2	
Liwale	11 000	24	2	
Nachingwea	12 000	24	2	
Total		948	56	

Table 6.12. Sampling activities per year based on the Tanzanian Temporary Standards for water supplies serving less than 5 000 people.

Type of source	No of sources	No of activities		Remarks
		Bacterio-logical	Chemical/ Physical	
Boreholes deeper than 8 m	140	420	280	These sources are serving 250 - 5 000 people. They are handpumped and some have machine powered pumps. Average of 1 sample per source per 4 months have been taken for bacteriological analysis.
Well less than 8 m deep	1 950	11 700	3 900	Serving ≤ 1 000 people, 1 sample per source every two months.
Surface waters, lakes, rivers, springs and dams	90	1 080	180	Serving ≤ 1 000 people, 1 sample per source every month.
Total number of samples		13 200	4 360	

6.5.1 Implementation

Operations to be conducted and arranged from Mtwara water quality laboratory, as for the case of model two.

6.5.2 Facilities

The number of samples and tests shown in tables 6.11 and 6.12 can be taken to be indicative of the magnitude of sampling and testing necessary for the ideal case of monitoring as per model four.

Since bacteriological tests carried out by the filter membrane technique have to be incubated within six hours of sampling, it will be necessary for most bacteriological tests to be done in the field with portable incubators. The limiting factors of sampling and testing will be then the capacity of sample incubation and the time constraint of sampling each site together with travelling between sites.

A maximum rate of 3 to 4 villages per day on average could reasonably be covered by a continuous monitoring programme and this would represent some 8 to 12 samples depending on village size and scheme character. An average of some 250 samples per month per mobile unit would therefore result.

The present situation of the existing laboratory is such that it conducts an average of 200 bacteriological tests per year. If an average of 250 samples per month can be delivered for bacteriological tests in the laboratory, the remaining 11 200 samples must be done in the field by the mobile units. These will need about 4 mobile units.

From the above mentioned facts, the laboratory in Mtwara will be equipped as in model two, plus four portable incubators, three pH meters and three conductivity meters.

The mobile units will carry out pH, conductivity and bacteriological tests.

6.5.3 Recruiting and training

Two laboratory technicians with one assistant will man the water quality laboratory in Mtwara.

One laboratory technician for each mobile unit will be necessary.

6.5.4 Costs

Laboratory equipment, sample analysis costs, salaries and transport are the major cost components, as summarized in table 6.13. Detailed information of the cost calculations are given in appendices B to G.

6.5.5 Discussion

This model is mostly dependent on highly trained manpower, imported equipment which will need spare parts and chemicals from abroad. Its operational reliability can be compared to that of other projects which rely on imported raw materials and spare parts. In that case it will not be surprising to find a programme based on this model operating at say 20 % of its planned capacity.

Table 6.13. Cost estimates of running model four.

Item	Cost per annum (TAS)
Salaries	198 000
Allowances	30 000 to 40 000
Laboratory equipment	150 000
Bacteriological tests	580 000
Chemical/Physical tests	240 000
Transport	620 000
Energy	15 000
Total	1 833 000 to 1 843 000

To operate this model it will cost about TAS 1 850 000 per annum.

6.6 Comparison of the alternative models

It is widely recognized that the influence of a domestic water supply on health of the populations served is as much dependent on the quantity of water provided as on the quality. It is furthermore recognized that water supply is only one factor in the improvement of the health situation, medical facilities, health and hygiene education are equally important.

It can be said that even the best water quality control system would result in a reduction of not more than 50 percent of faecal/oral disease without other influencing factors also being dealt with. A more realistic figure in terms of practical water quality control has been put at 20 percent (CCKK 1984).

The significance of these facts, together with the cost and practical considerations involved in maintaining water quality surveillance programmes, may result in step-wise improvement in water quality monitoring.

The idea of having water quality monitoring activities cooperated in other activities in district and regional water engineers' offices with the aim of reducing costs may appear good, but it might be difficult to implement. In the present set up, very little attention is given to water quality control. If, for example, a construction engineer is to be given the task of co-ordinating water quality monitoring activities in a region he might end up doing his most pressing jobs and forget about water quality monitoring. This will be especially true for the case of understaffed offices, with meagre facilities.

On the other hand it might be unrealistic to adopt an expensive water quality monitoring programme while the operation and maintenance of the water schemes cannot be implemented according to plans due to the lack of funds. It will also be unrealistic to adapt a separately financed monitoring programme when remedial action which is dependent on operation and maintenance cannot be implemented due to lack of funds. In that case even if monitoring is frequent, same results will be observed without action being taken.

In the water quality monitoring models discussed in this chapter, model one with its option of combining with other activities constitutes the lower level of monitoring, while model four is the highest level. An intermediate solution of monitoring so that an acceptable input level of say sanitary inspections with some sampling could be adapted. Model three could be taken, but still some modification to reduce the sampling frequency might be left for discussion. Sampling could for example be restricted to urban and large rural water schemes, and to those areas where outbreak of waterborne diseases are reported.

Table 6.14 compares the alternative models with regard to costs, man-power, vehicles needed, decentralization, water quality record keeping, village participation, operational reliability and flexibility.

Table 6.14. Comparison between the four alternative monitoring models.

Parameter	Models			
	One	Two	Three	Four
Costs TAS (x 1 000)	230	580	810	1.850
Portion of foreign currency	0 %	83 %	70 %	87 %
Level of personnel training	Regional	National	Regional to National	National
Amount of vehicles	0	1	1	5
Decentralization	Possible	Not possible	Partly possible	Not possible
Water quality record keeping	Non-existent	Good	Good	Very good
Village participation	Good	Poor	Poor to good	Poor
Operational reliability	Good	Poor	Poor to good	Poor
Combining with other activities	Good	Poor	Poor to good	Very poor
Flexibility	Very good	Good	Excellent	Poor

6.7 Suggestions for reporting procedures

6.7.1 Reporting on sanitary inspection

Rural water schemes

Rural water schemes, which are mainly open wells, pits, unprotected springs, hand pump wells, protected springs and boreholes, will be inspected from district water engineers' offices.

Reporting of the sanitary inspection will be necessary when defects are discovered and remedial action is to be taken. Figure 6.1 gives a suggestion of reporting the case.

When there is a well caretaker in the village, he will assist the sanitary inspector in conducting the inspection.

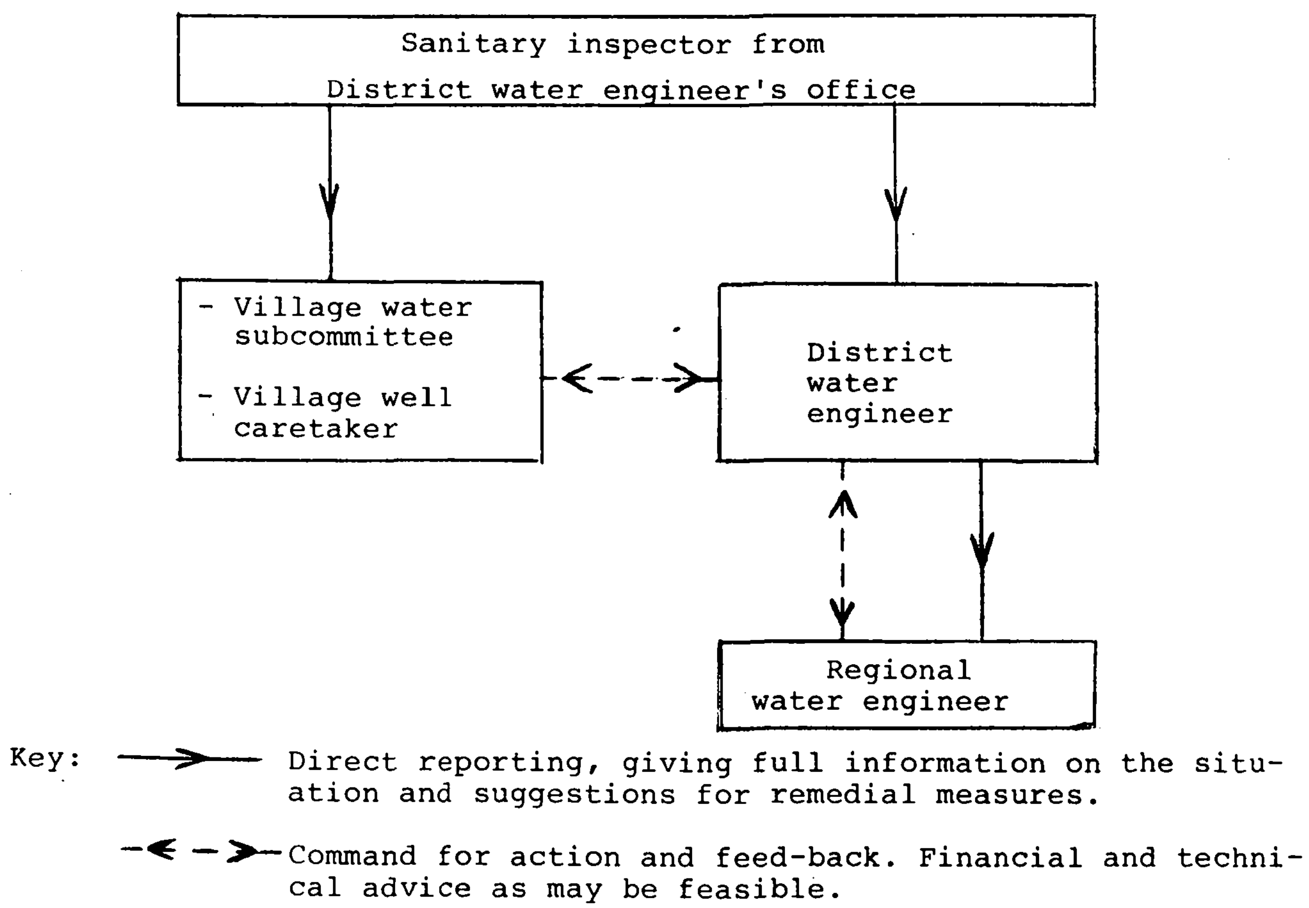
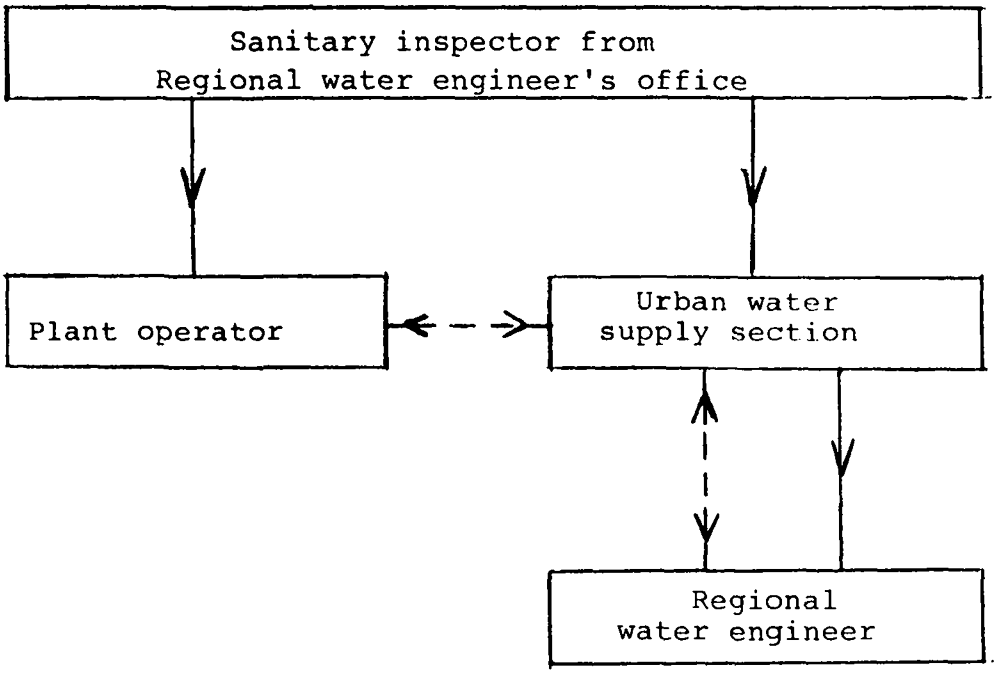


Figure 6.1. Suggested information flow after a sanitary inspection in a village water supply.

Piped water schemes in Mtwara and Lindi towns

Piped water schemes in the two urban centres will be inspected from regional water engineer's office. Reporting and information flows may be as suggested in Figure 6.2.



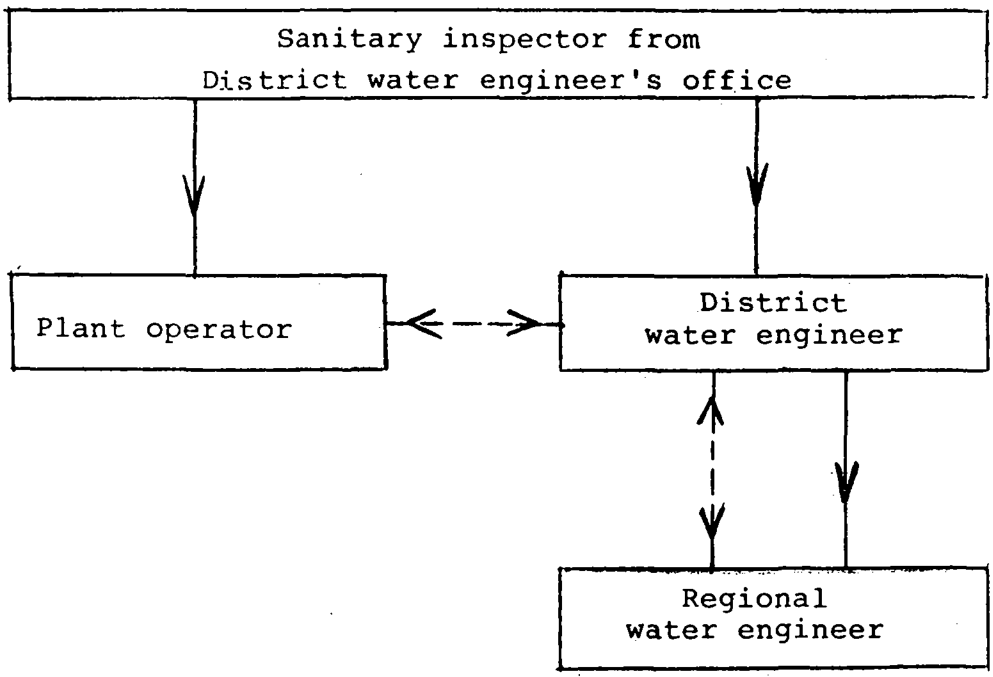
Key: Direct reporting, giving full information on the situation and suggestions for remedial measures.

Command for action and feed-back. Financial and technical advice as may be feasible.

Figure 6.2. Suggested information flow after a sanitary inspection for piped schemes in Mtwara and Lindi towns.

Other piped water schemes for rural and districts urban centres

These schemes, in rural and urban centres, have plant operators working under the district water engineer's offices. Sanitary inspections for these schemes can be conducted from the district water engineer's offices. Flow of information after the sanitary inspection may be conducted as in Figure 6.3.



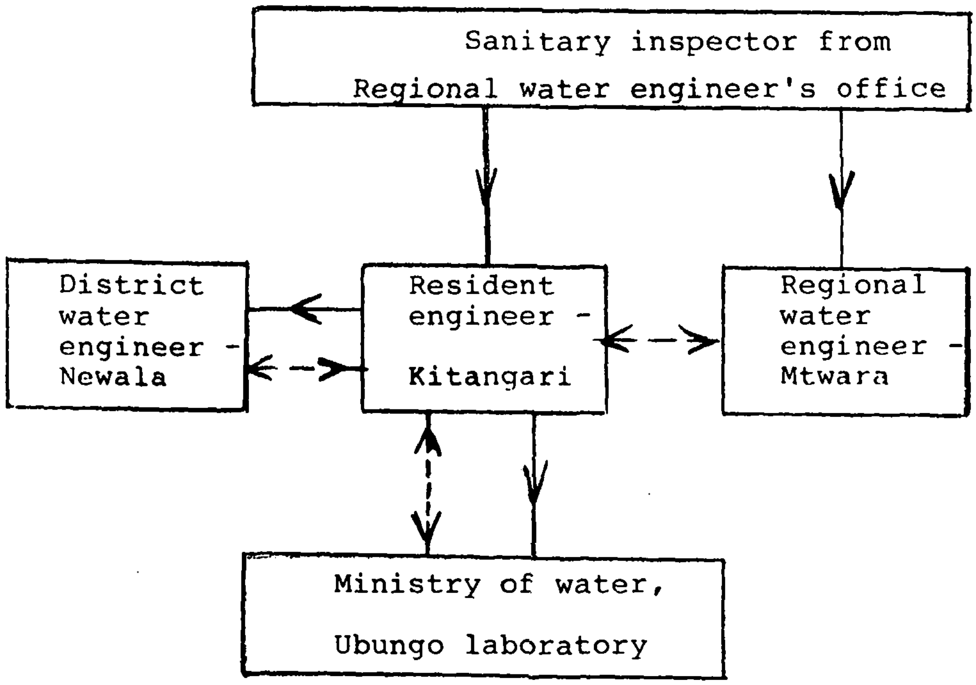
Key: ——> Direct reporting, giving full information on the situation and suggestions for remedial measures.

<- -> Command for action and feed-back. Financial and technical advice as may be feasible.

Figure 6.3. Suggested information flow after a sanitary inspection of a piped water scheme in rural and the districts urban centres.

Kitangari water scheme

Kitangari water scheme will be monitored from Mtwara regional water engineer's office. Reporting and information flow may be as suggested in Figure 6.4.



Key: Direct reporting, giving full information on the situation and suggestions for remedial measures.

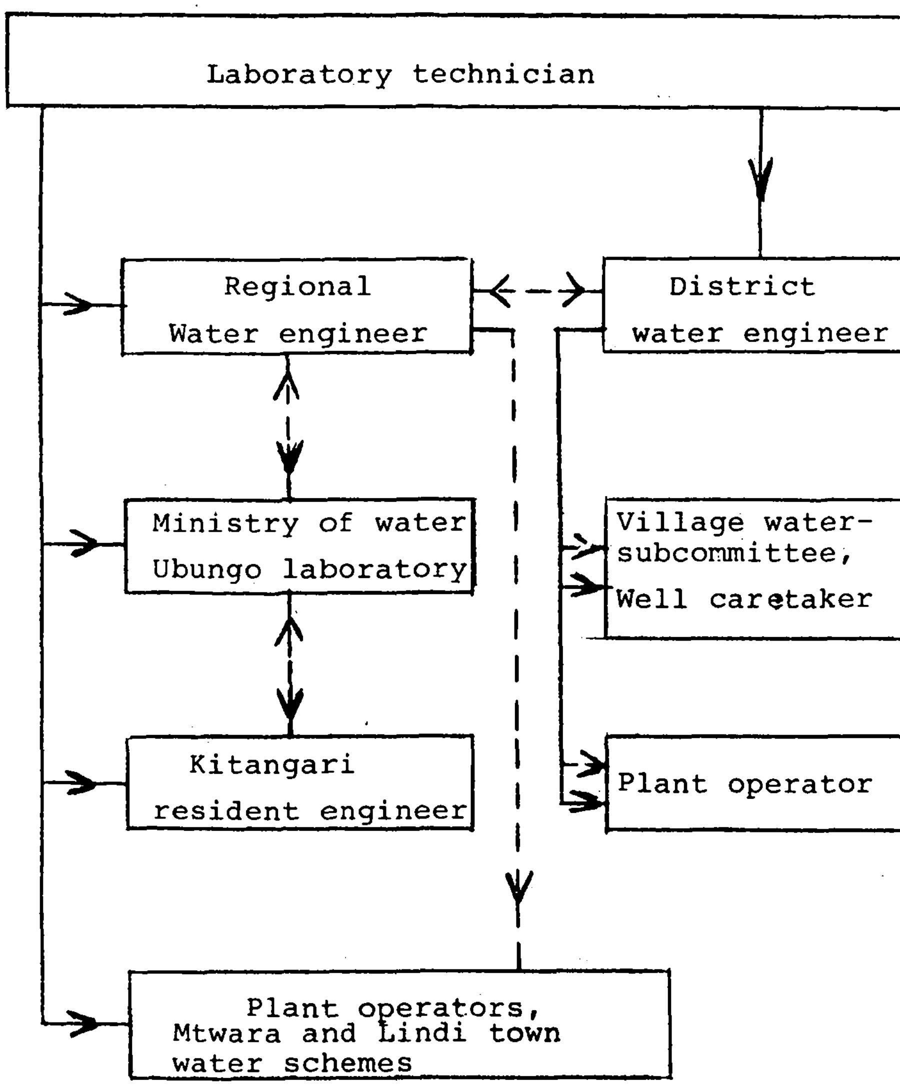
Technical cooperation and financial assistance as may be feasible.

Figure 6.4. Suggested information flow after a sanitary inspection at Kitangari water scheme.

6.7.2 Reporting on water analyses results

All water analyses will be conducted by laboratory technicians based in Mtwara town. Most of the tests will be done at the laboratory in Mtwara, while some bacteriological tests will also be carried out in the field.

Reporting of the results of water analysis may go through the lines shown in Figure 6.5. The information, together with remedial instructions may be conveyed by telephone, radio or by any other means which may be available at that moment.



Key: ⟶ Direct reporting of the case, with proposals for remedial action.

← – → Action and feed-back. Financial and technical assistance as may be feasible.

Figure 6.5. Suggested information flow for water analysis results.

6.8 Reporting format

It is most important that the instructions given in water quality surveillance operations both written and verbal, are clearly understood. This will not only help to avoid misunderstanding but should also help to avoid conflicts between different activities of various people.

Use of specially designed forms on which to fill the findings will save time and avoid lengthy and unnecessary information. It will also help the unexperienced personnel to insure that all format for reporting of sanitary inspections on a hand pump well is shown in appendix H.

7. CONCLUDING REMARKS

There are particular problems associated with ensuring that small rural water systems comply with drinking water standards. These can arise for example, because of the distance and lack of good transportation to the nearest laboratory; bacteriological monitoring is an especial problem. In such cases, especially in developing countries emphasis should be placed on:

1. Selection of adequate, safe sources, preferably those which do not require treatment.

2. Regular and frequent sanitary surveys; local operators should be adequately trained to undertake sanitary surveys.

3. Testing to ensure bacteriological quality; if the supply can only be tested once, the most effective samples are those that assist in selecting the source.

4. Reliability of operation and convenient access to consumers.

Standards and regulations achieve nothing unless they can be implemented and enforced, and this requires relatively expensive facilities and expertise. Furhermore, water is essential to sustain life and must be available even if the quality is not satisfactory. Adoption of stringent drinking water standards could limit the availability of water supplies that meet those standards, which is a significant consideration in regions of water shortage.

Evidence of faecal pollution of drinking water supplies should be acted upon immediately. However, a decision to close the supply carries an obligation to provide an alternative safe supply. The immediate objective must be to ensure that remedial action is instituted with as little delay as possible.

A sanitary inspection carried out on most water supplies will detect possible sources of faecal contamination. When there is slight indication that a water supply is being contaminated, immediate action will be to eliminate the contaminating source. Sampling should be done whenever possible, to confirm that the remedial action taken in the form of maintenance was effective.

Setting moderate water quality standards which can be implemented for different regions could be better than having universal ones which cannot be implemented in other parts of the country. It is not necessary to lower the standards of other regions for the sake of having universal values for the whole country. Each region, or group of regions could have its own standards of water quality with regard to bacteriological and even chemical or physical parameters. For example, there is no need to put fluoride concentration of 8 mg/l as acceptable for Mtwara and Lindi regions where it is very exceptional to find a source with fluoride concentration of more than 3 mg/l. Such sources should be abandoned in these two regions.

The guidelines for Drinking Water Quality (WHO 1984), do not give recommendations on the amount of funds to be allocated for water quality monitoring. There should be some tentative figures for planners of water projects. These can be in percentage of total project cost or related to the population to be served. The amount should cover salaries, equipment, laboratories, training and transport.

Any water quality monitoring programme for Mtwara and Lindi regions should be essentially simple, flexible and easy to match with other development activities within the prevailing economic situation of this area.

In Mtwara and Lindi regions there are institutions which could help with water quality monitoring. Institutions like Health Education Unit and Rural Sanitation Unit, both under the Ministry of Health and Institute of Adult Education should be approached for their experiences with regard to matters concerning community participation and sanitation. It might also be possible to utilize existing manpower and laboratories of the regional and district hospitals with the aim of saving in terms of manpower and transport by combining water quality monitoring with other activities.

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Appendix A. Frequencies in percentage of samples of specified quality: Mtwara, Masasi, Newala, Lindi, Nachingwea, Liwale and Kilwa districts.

Frequency (%) of samples of specified quality. District: MTWARA

Parameter	Number of samples analysed	Quality categories			
Bacteriological (Col/100ml) Faecal coliforms	203	0 39	1 - 10 34	11 - 10 9	>50 18
pH Value	265	<6,5 15	6,5 - 8,5 84	8,6 - 9,2 1	>9,2 0
Turbidity (N T U)	182	<2 35	2 - 20 27	11 - 30 18	>30 20
Colour (mg pt/l)	209	<20 43	20 - 50 25	55 - 100 11	>100 21
Total Hardness (mg Ca CO_3/l)	176	<50 28	50 - 300 27	310 - 600 17	>600 28
Conductivity (µS/cm, 25°C)	282	<500 18	500 - 1000 20	1050-2500 39	>2500 23
Iron (mg Fe/l)	181	<0,2 58	0,2 - 1,0 26	1,1 - 5 15	>5 1
Manganese (mg Mn/l)	169	<0,1 37	0,1 - 0,5 36	0,51 - 2 27	>2 0
Fluoride (mg F/l)	57	<1,5 91	1,5 - 3,0 7	3,1 - 8 2	>8 0
Nitrate (mg N. NO_3/l)	142	<2,5 60	2,5 - 10 27	10,1 - 30 9	>30 4
Sulphate (mg SO_4/l)	177	<100 57	100 - 200 27	210 - 400 14	>400 2
Chloride (mg Cl/l)	188	<200 37	200 - 600 48	610 - 800 2	>800 13

Frequency (%) of samples of specified quality. District: MASASI

Parameter	Number of samples analysed	Quality categories			
Bacteriological (Col/100ml) Faecal coliforms	19	0 89	1 - 10 0	11 - 10 6	>50 5
pH Value	150	<6,5 31	6,5 - 8,5 68	8,6 - 9,2 1	>9,2 0
Turbidity (N T U)	139	<2 29	2 - 20 20	11 - 30 18	>30 33
Colour (mg pt/l)	143	<20 42	20 - 50 22	55 - 100 10	>100 26
Total Hardness (mg Ca CO_3/l)	72	<50 46	50 - 300 26	310 - 600 14	>600 14
Conductivity (µS/cm,25°C)	133	<500 38	500 - 1000 15	1050-2500 31	>2500 16
Iron (mg Fe/l)	125	<0,2 32	0,2 - 1,0 41	1,1 - 5 27	>5 0
Manganese (mg Mn/l)	122	<0,1 51	0,1 - 0,5 29	0,51 - 2 13	>2 7
Fluoride (mg F/l)	36	<1,5 92	1,5 - 3,0 6	3,1 - 8 2	>8 0
Nitrate (mg N. NO_3/l)	93	<2,5 45	2,5 - 10 35	10,1 - 30 14	>30 6
Sulphate (mg SO_4/l)	127	<100 95	100 - 200 2	210 - 400 3	>400 0
Chloride (mg Cl/l)	116	<200 65	200 - 600 29	610 - 800 2	>800 4

Frequency (%) of samples of specified quality. District: NEWALA

Parameter	Number of samples analysed	Quality categories			
Bacteriological (Col/100ml) Faecal coliforms	7	0 0	1 - 10 100	11 - 10 0	>50 0
pH Value	39	<6,5 64	6,5 - 8,5 36	8,6 - 9,2 0	>9,2 0
Turbidity (N T U)	53	<2 26	2 - 10 32	11 - 30 2	>30 40
Colour (mg pt/l)	47	<20 40	20 - 50 15	55 - 100 9	>100 36
Total Hardness (mg Ca CO_3/l)	25	<50 24	50 - 300 32	310 - 600 0	>600 44
Conductivity (μS/cm, 25°C)	26	<500 69	500 - 1000 23	1050-2500 4	>2500 4
Iron (mg Fe/l)	22	<0,2 68	0,2 - 1,0 18	1,1 - 5 9	>5 5
Manganese (mg Mn/l)	22	<0,1 9	0,1 - 0,5 59	0,51 - 2 23	>2 9
Fluoride (mg F/l)	7	<1,5 100	1,5 - 3,0 0	3,1 - 8 0	>8 0
Nitrate (mg N. NO_3/l)	16	<2,5 69	2,5 - 10 31	10,1 - 30 0	>30 0
Sulphate (mg SO_4/l)	49	<100 98	100 - 200 2	210 - 400 0	>400 0
Chloride (mg Cl/l)	42	<200 24	200 - 600 14	610 - 800 0	>800 62

Frequency (%) of samples of specified quality. District: LINDI

Parameter	Number of samples analysed	Quality categories			
Bacteriological (Col/100ml) Faecal coliforms	75	0 80	1 - 10 8	11 - 10 5	>50 7
pH Value	147	<6,5 13	6,5 - 8,5 84	8,6 - 9,2 3	>9,2 0
Turbidity (N T U)	148	<2 38	2 - 20 42	11 - 30 11	>30 9
Colour (mg pt/l)	150	<20 71	20 - 50 15	55 - 100 5	>100 9
Total Hardness (mg Ca CO_3/l)	68	<50 59	50 - 300 12	310 - 600 16	>600 13
Conductivity (µS/cm,25°C)	125	<500 12	500 - 1000 20	1050-2500 34	>2500 34
Iron (mg Fe/l)	128	<0,2 49	0,2 - 1,0 43	1,1 - 5 7	>5 1
Manganese (mg Mn/l)	124	<0,1 21	0,1 - 0,5 18	0,51 - 2 38	>2 23
Fluoride (mg F/l)	90	<1,5 98	1,5 - 3,0 2	3,1 - 8 0	>8 0
Nitrate (mg N. NO_3/l)	123	<2,5 81	2,5 - 10 12	10,1 - 30 5	>30 2
Sulphate (mg SO_4/l)	96	<100 67	100 - 200 30	210 - 400 1	>400 2
Chloride (mg Cl/l)	65	<200 32	200 - 600 45	610 - 800 9	>800 14

Frequency (%) of samples of specified quality. District: NACHINGWEA

Parameter	Number of samples analysed	Quality categories			
Bacteriological (Col/100ml) Faecal coliforms	-	0 -	1 - 10 -	11 - 10 -	>50 -
pH Value	38	<6,5 0	6,5 - 8,5 63	8,6 - 9,2 32	>9,2 5
Turbidity (N T U)	41	<2 51	2 - 20 22	11 - 30 15	>30 12
Colour (mg pt/l)	42	<20 74	20 - 50 17	55 - 100 5	>100 4
Total Hardness (mg Ca CO_3/l)	43	<50 72	50 - 300 2	310 - 600 2	>600 24
Conductivity (µS/cm, 25°C)	42	<500 26	500 - 1000 26	1050-2500 36	>2500 12
Iron (mg Fe/l)	41	<0,2 71	0,2 - 1,0 20	1,1 - 5 9	>5 0
Manganese (mg Mn/l)	42	<0,1 43	0,1 - 0,5 40	0,51 - 2 10	>2 7
Fluoride (mg F/l)	12	<1,5 100	1,5 - 3,0 0	3,1 - 8 9	>8 0
Nitrate (mg N. NO_3/l)	30	<2,5 77	2,5 - 10 23	10,1 - 30 0	>30 0
Sulphate (mg SO_4/l)	26	<100 100	100 - 200 0	210 - 400 0	>400 0
Chloride (mg Cl/l)	14	<200 43	200 - 600 29	610 - 800 14	>800 14

Frequency (%) of samples of specified quality. District: LIWALE

Parameter	Number of samples analysed	Quality categories			
Bacteriological (Col/100ml) Faecal coliforms	–	0 –	1 - 10 –	11 - 10 –	>50 –
pH Value	7	<6,5 29	6,5 - 8,5 71	8,6 - 9,2 0	>9,2 0
Turbidity (N T U)	7	<2 29	2 - 20 57	11 - 30 14	>30 0
Colour (mg pt/l)	7	<20 43	20 - 50 29	55 - 100 28	>100 0
Total Hardness (mg Ca CO_3/l)	4	<50 100	50 - 300 0	310 - 600 0	>600 0
Conductivity (µS/cm, 25°C)	7	<500 86	500 - 1000 14	1050 - 2500 0	>2500 0
Iron (mg Fe/l)	7	<0,2 0	0,2 - 1,0 86	1,1 - 5 14	>5 0
Manganese (mg Mn/l)	7	<0,1 57	0,1 - 0,5 29	0,51 - 2 0	>2 14
Fluoride (mg F/l)	3	<1,5 100	1,5 - 3,0 0	3,1 - 8 0	>8 0
Nitrate (mg N. NO_3/l)	7	<2,5 86	2,5 - 10 14	10,1 - 30 0	>30 0
Sulphate (mg SO_4/l)	3	<100 100	100 - 200 0	210 - 400 0	>400 0
Chloride (mg Cl/l)	6	<200 100	200 - 600 0	610 - 800 0	>800 0

Frequency (%) of samples of specified quality. District: KILWA

Parameter	Number of samples analysed	Quality categories			
Bacteriological (Col/100ml) Faecal coliforms	6	0 83	1 - 10 17	11 - 10 0	>50 0
pH Value	45	<6,5 33	6,5 - 8,5 40	8,6 - 9,2 9	>9,2 18
Turbidity (N T U)	43	<2 35	2 - 20 35	11 - 30 16	>30 14
Colour (mg pt/1)	43	<20 63	20 - 50 16	55 - 100 7	>100 14
Total Hardness (mg Ca CO_3/1)	28	<50 79	50 - 300 4	310 - 600 14	>600 3
Conductivity (μS/cm,25°C)	21	<500 38	500 - 1000 31	1050-2500 10	>2500
Iron (mg Fe/1)	47	<0,2 38	0,2 - 1,0 47	1,1 - 5 13	>5 2
Manganese (mg Mn/1)	45	<0,1 76	0,1 - 0,5 24	0,51 - 2 0	>2 0
Fluoride (mg F/1)	23	<1,5 100	1,5 - 3,0 0	3,1 - 8 0	>8 0
Nitrate (mg N. NO_3/1)	44	<2,5 64	2,5 - 10 25	10,1 - 30 11	>30 0
Sulphate (mg SO_4/1)	22	<100 95	100 - 200 5	210 - 400 0	>400 0
Chloride (mg Cl/1)	19	<200 32	200 - 600 37	610 - 800 11	>800 20

Appendix B. Costs of laboratory equipment.

Item	Quantity	Cost (TAS)
Refridgerator 3201	1	5 600
Refridgerator 1401	2	3 400
Desiccator and plate	1	2 400
Autoclave	1	12 000
Incubator	1	20 000
Conductivity meter	3	25 200
PH-meter	3	11 200
Hatch - kit	1	48 500
Balance	1	40 000
Water-bath and cover	1	21 000
Hot plates	3	10 900
Stop watch	1	1 100
Distillation unit	1	30 500
Bunsen burner	1	500
Vacuum pump	1	1 100
Field incubator	1	14 000
Glassware and other access.		140 000
Total, value in Europe		439 600
Add 20 % for handling and transport		87 900
Total cost = TAS 527 500 (say 530 000)		
Annual cost over 5 years = TAS 106 000		

Appendix E. Bacteriological, chemical and physical analysis cost calculations, model two.

1. Bacteriological

- Laboratory tests at TAS 4,4 per sample
- Field tests at TAS 50,0 per sample

From model two, range of sampling is 74 to 2 290 samples per year. Without a field incubator, the laboratory is currently handling about 200 bacteriological tests. With a field incubator the number of samples analysed may be expected to reach 500 at the present operational level. Also due to resampling from those sources showing contamination and increased sampling frequency in certain areas due to outbreak of water-borne diseases, the upper limit may be increased to 3 500 samples.

Assuming that 50 % of the samples will be analysed in the field, the following estimates can be taken:

- Laboratory costs	= 250 x 4,4 to 1 750 x 4,4
	= TAS 1 100 to 7 700
- Field costs	= 250 x 50,0 to 1 750 x 50,0
	= 12 500 to 87 500
- Total costs	= 13 600 to 95 200

2. Chemical and physical

Cost of making 10 tests as shown in appendix C is TAS 53,60.

Range of sampling from model two is 77 to 2 130 samples for chemical and physical analysis. The laboratory is currently taking about 300 samples, so this will be taken as minimum in the cost calculations. The upper limit may be taken as 2 300 samples.

- Annual costs	= 300 x 53,6 to 2 300 x 53,6
	= 16 080 to 123 280
About TAS	= 16 000 to 125 000

Appendix F. Bacteriological, chemical and physical analysis cost calculations, model four.

1. Bacteriological

Number of samples per year is 14 200. With 4 mobile units and one laboratory, this will be about 2 840 samples per unit and laboratory. The present situation at Mtwara laboratory is about 200 samples per year.

- Costs of laboratory analysis
  = 2 840 x 4,4 = 12 500
- Costs of field analysis
  = 11 360 x 50,0 = 568 000

Total bacteriological costs = 580 500 (580 000)

2. Chemical and physical

- Number of samples = 4 420
- Cost of analysis = 4 420 x 53,60 = 236 912

Total chemical/physical costs = TAS 240 000

Total analysis costs = TAS 790 000

Appendix G. Transport cost calculations, models two and four.

Model two

At the lower limit when sampling is limited to schemes serving more than 5 000 peoples, average distance to be covered is about 1 800 km. This will cost about TAS 12,85 x 1 800 = TAS 23 130.

At the upper level of operation when sampling is carried out to the smaller schemes at least once yearly, the average distance covered is about 12 000 km, costing about TAS 150 000.

Model four

One round trip of sampling for the two regions, covers a distance of about 12 000 km. According to the model, if an average of 6 round trips are taken as from tables 6.9 and 6.10, then a distance of about 48 000 km is to be covered per year. This will cost about TAS 616 800, say TAS 620 000.

Appendix H. Sample format for reporting of sanitary inspections on a hand pump well.

A handpump well should be as remote as possible from any polluting source such as latrines, septic tanks, sewage discharges, agricultural drainage water discharge and also animal activities.

1. Date of inspection ____________________

2. Village ____________________ Ward ____________________ District ____________________

3. Well number ____________________

4. Name of well caretaker ____________________

	YES	NO
5. Is the pump working?	☐	☐
6. Is the cover slab in place?	☐	☐
7. Any visible cracks on the cover slab?	☐	☐
8. Any fangus growing on the cover slab?	☐	☐
9. Do people wash on the cover slab?	☐	☐
10. Do people bath on the cover slab?	☐	☐
11. Is there a washing slab provided?	☐	☐
12. Is drainage water from the well properly guided away?	☐	☐
13. Is drainage water from washing slab properly guided away?	☐	☐
14. Is there any gardening around the well?	☐	☐
15. Is the garden properly kept?	☐	☐

	YES	NO
16. Any animal activities around the well?	☐	☐
17. Any evidence of children playing with the pump?	☐	☐
18. Is the pump body loose? (Try to shake it)	☐	☐
19. Is there any new construction activity within 150 m radius from the well?	☐	☐

20. What type of construction?

____

21. Who is doing it?

____

22. Are there in the village people suffering from diarrhoea?	☐	☐

If yes, how many?

____

23. Does the village have a water committee?	☐	☐
24. Does the committee take interest in the sanitary inspector's activities?	☐	☐
25. Is the committee active in water source protection?	☐	☐

26. Any other information?

____

____

____

____

27. Name of sanitary inspector

____

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