Hazardous water: an assessment of water quality and accessibility in the Likangala Catchment area in Malawi

Geoffrey Chavula[1] and Wapulumuka Mulwafu[2*]

[1] *Department of Civil Engineering, Malawi Polytechnic, P/Bag 303, Chichiri, Blantyre 3, Malawi*
[2] *Department of History, Chancellor College, P.O Box 280, Zomba, Malawi.*

ABSTRACT

Access to potable water supply remains a serious challenge to the local communities in the Likangala River catchment in southern Malawi. The quality of water resources is generally poor and the supply is inadequate. This paper discusses the results of laboratory analysis of water samples collected from selected water points in the Likangala Basin including the Likangala River itself, existing boreholes and hand dug wells, Likangala Irrigation Scheme and Lake Chilwa at Kachulu harbour. It shows that the water is grossly polluted with faecal matter which comes from the disposal of sewage effluents by different institutions in the Municipality of Zomba. On the other hand, studies conducted on household accessibility to potable water supply indicate that more than 60% of the human population living in the catchment area depends on unprotected traditional wells and the Likangala River for domestic water supply requirements. The poor quality of the water in the catchment area and the inadequacy of water supply facilities have been noted to be the major causes for the recurrent outbreaks of water associated diseases, especially cholera, that affect the local community periodically.

Key Words: access, water quality, Likangala river, Malawi

1 INTRODUCTION

The paper discusses the findings on the general quality of water resources in the catchment area of Likangala River in southern Malawi; and highlights the serious problems that the local communities face in accessing potable water supply. The paper comes out of a broader study conducted by the BASIS (Broadening Access and Strengthening Inputs Market Systems) Water Project, a research project based at Chancellor College, University of Malawi and looks at the various aspects of water resources management including policy reform, assessment, planning, development, allocation, protection, conservation and monitoring.

2 METHODOLOGY

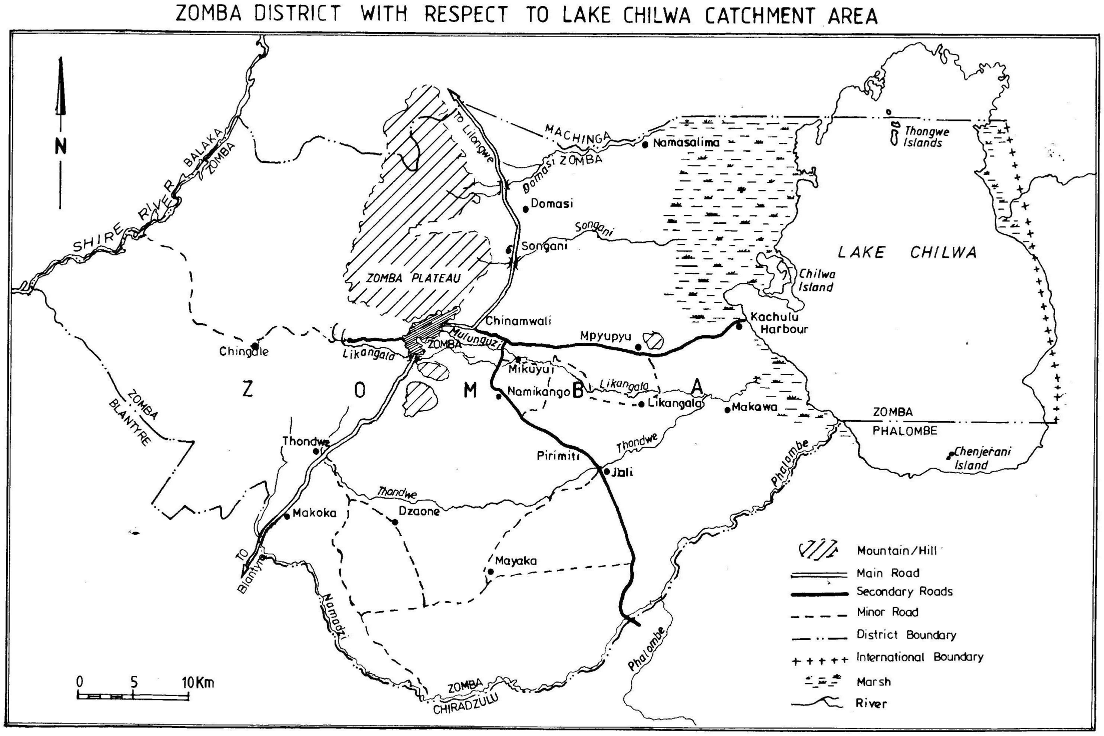
In order to assess the quality of water resources in the catchment area for domestic consumption, a team of water chemists from the Ministry of Water Development's Central Water Laboratory collected water samples. The sampling of the water points, which was done during the period March 23-24, 2000, included selected points along the Likangala River, existing boreholes and hand dug wells, Likangala Irrigation Scheme and Lake Chilwa at Kachulu Harbour. The test

*Corresponding author: wmulwafu@chanco.unima.mw

results were then compared with the standards set by the World Health Organization (WHO), Malawi Bureau of Standards (MBS) and the Ministry of Water Development (temporary guidelines) for drinking water supply.

The local community's accessibility to potable water supply was done through field surveys and general observations. BASIS Research Assistants assigned to specific cluster areas within the basin collected the data. The findings were then compared with policy guidelines for rural water supply set by the Malawi Government where each borehole, hand dug well and tap is designed to serve a population of 250, 125 and 120 people within a per capita consumption of 27 litres per person per day, and within a walking distance of 500 - metre radius to the nearest water point.

ZOMBA DISTRICT WITH RESPECT TO LAKE CHILWA CATCHMENT AREA



3 DESCRIPTION OF CONSTITUENTS AND RESULTS

3.1 Water quality

The term "water quality" is commonly used to describe the non-aqueous components of a volume of water, and comprises suspended sediment, biota and dissolved species (salts). It is the quantity of these non-aqueous constituents that determine the suitability of the water for the intended purposes, including domestic consumption. The water samples collected from the catchment

area were thus analyzed for the physical, chemical and biological parameters. The results were then compared with the standards set by WHO, MBS and the Ministry of Water Development (temporary guidelines) for drinking water supply (see Table 2).

While the results show that the physical and chemical composition of the water does not pose any threat to human life, the findings from bacteriological test indicate that the water is grossly polluted with faecal matter. Observed values of faecal coliform counts range from 16–9,000 per 100 ml. This renders the water unsuitable for human consumption as the faecal coliform/streptococci counts are well in excess of the recommended standards by WHO, MBS and the Ministry of Water Development (temporary guidelines).

It is apparent from the results that such a bacteriological contamination of water makes it hazardous to human life. Thus the local communities are vulnerable to diseases that are transmitted by drinking contaminated water such as cholera, dysentery, and blood diarrhea. The Lake Chilwa area is one of the places in Malawi that periodically reports cases of cholera outbreaks, and this is supported by the poor quality of the water that people drink.

Another serious health hazard in the catchment area is scabies. Scabies is a skin disease that flourishes where people use inadequate water for personal hygiene. Its prevalence is clear testimony to the problems of people in the Basin in gaining access to adequate water supplies.

Water pollution is attributed to the malfunctioning of the sewage treatment, which discharges raw sewage into the Likangala River. This had been going on for more than seven years from the time the plant broke down. The improper siting of hand-dug wells is another cause of the poor water quality. Most of the hand-dug wells are not covered with concrete top slabs; neither are they backfilled with clay or cement grout to prevent pollutants from getting washed down into the wells from the surface. In addition, the buckets that people use for drawing water are rarely washed before use.

3.2 Access to potable water supply

Our research on accessibility to water show that more than 60% of the local community in the catchment area does not have access to potable water supply (see Table 1). The catchment area has a very small number of boreholes, which hardly meets the existing demand for water. This has compelled some households to construct and own private wells (about 47% of all water sources in the Likangala catchment). Water shortages are most severe during wet season when most of the traditional wells get filled up with floodwater and the peak of the dry season when the water table recedes drastically. As a result, women walk long distances to the nearest boreholes, or to private wells where each household may be forced to spend more than MK70.00 (or US$1) per day to buy water. Due to inadequate water for personal hygiene, the outbreak of scabies sometimes affects people in the study area.

Table 1. Water Sources in the Likangala Catchment Area

Cluster	Covered well	Open well	Boreholes	Taps
Urban	2	5	2	2
Peri Urban	Nil	1	4	3
Estates	3	5	2	2
Irrigation	4	8	3	Nil
Fisheries	3	3	2	Nil

3.3 Hydrochemistry

Although water resources comprise several dissolved minerals, only a few are analyzed in order to assess its suitability for various purposes. These include major cations (sodium, potassium, calcium, magnesium, iron and manganese), major anions (carbonates, bicarbonates, chloride, sulphate, nitrate and fluoride), minor elements, and other variables such as alkalinity, pH, hardness, total dissolved solids and electrical conductivity.

Studies on the hydrochemistry of water resources in the catchment area were conducted in 1980 by Bath and in 1986 by the Ministry of Water Development through the National Water Resources Master Plan. These studies show that the mineral content of water resources in the Likangala River Basin is generally low and acceptable for human consumption although the lakeshore areas exhibit slightly higher mineralization than the plateau area. Parameters of concern are sodium and chloride as evidenced by data for Lake Chilwa at Kachulu Harbour (500 and 388 mg/l, respectively) and Likangala Health Center (400 and 573 mg/l, respectively). Table 2 shows standards set by WHO, MBS and Ministry Development (Temporary) for drinking water supply.

3.4 Total Dissolved Solids

Total dissolved Solids (TDS) is a summation of the total solute content of a water and is expressed in mg/1 (Younger, 1989). It is commonly measured by the evaporation of a known volume of sample and weighing the residue.

From the water points that were sampled in the catchment area between March 23–24, 2000 there is an indication that TDS values are generally low except for water samples collected at Kachulu Harbour and Likangala Health Center, 1463 mg/l and 1458 mg/l, respectively.

However, Bath (1980) and the National Water Resources Master Plan (1986) concluded that water points constructed in alluvial aquifers generally show high TDS values. It may therefore be necessary to collect more water samples in the catchment area to prove this hypothesis which seems to be supported by the existence of low hydraulic gradients in the Lake Chilwa Plain.

High TDS values suggest that water has been in contact with either the riverbed or the aquifer formation for a sufficiently long time to necessitate the dissolution of the minerals. The long residence time in the case of groundwater may imply the existence of low hydraulic gradients with subsequent low flow velocities, or low transmissivities due to the nature of the aquifer material. Both theories seem to apply to the borehole at Likangala Health Center as it is located in the Lake Chilwa Plain which is characterized by flat topography, and that some lithological logs from existing boreholes show the persistence of clays and fine sands (Bath, 1980).

3.5 Electrical Conductivity

Specific Electrical Conductivity (EC) is defined as the ability of a unit length and cross section of a substance to conduct electricity at a specified temperature (Younger, 1989). Conductivity arises from the presence of dissolved ions in the water. As the concentration of dissolved salts in the water rises so does the conductivity, and thus this parameter is often used to estimate total dissolved solids using the approximate relationship: TDS (mg/1) = EC * 0.65, where EC is measured in microsiemens. This is usually measured on site using a battery driven meter.

Generally EC values of the sampled water points are very low and most of the recorded values are less than 400 μS. It is only the borehole at Likangala Health Center (3015 us/cm) and the water sample collected at Kachulu Harbour (2969 us/cm) that have unacceptable values of electrical conductivity.

3.6 pH

Although water molecules are quite stable chemically, they still tend to break down or dissociate into their component parts, H^+ (hydrogen ions) and OH^- (hyroxyl) ions. Water is said to be either acidic or alkaline depending on the relative concentration of hydrogen ions (Driscoll, 1986). Hydrogen ions in water cause it to act as an acid. The capability of water to neutralize acid is called alkalinity. Hence pH is an expression of hydrogen ion activity i. e. pH = - log10 [H^+ (mg/1)]. Thus water with a pH value greater than 7 is said to be alkaline whereas water with a pH value less than 7 is said to be acidic. Water with a pH value of 7 is said to be neutral. High pH (> 8.5) can lead to scale deposition depending on the hardness of water while low pH (< 4) can cause corrosion in pipe systems.

Most of the water samples collected from water points in the catchment area have pH values lying between 6.4 and 7.3. However, the borehole at Likangala Health Center has a pH value of 8.3 whereas the water sample collected from Lake Chilwa at Kachulu Harbour has a value of 8.8.

3.7 Bicarbonate and Carbonate

Bicarbonate and carbonate are usually grouped together for purposes of discussion. They contribute essentially most of the alkalinity of water. Water will generally contain bicarbonate and carbonate except where it is strongly acidic e.g. where pH is less than 4.5. The relative amount of these two anions largely depends on the pH of water, with bicarbonate increasing as the pH decreases. Most natural waters will contain much more bicarbonate than carbonate. Hem (1986) states that bicarbonate concentrations of over 1000 mg/1 commonly occur in waters that are low in calcium and magnesium, and especially where processes releasing carbon dioxide such as sulphate reduction are taking place in groundwater reservoirs.

From the sampled water points, the bicarbonate content is much higher than carbonates; with Kachulu Harbour showing highest value of bicarbonate content of 754 mg/1.

3.8 Chloride

Chloride is mainly derived from sedimentary rocks, particularly the evaporates (e.g. halite). Small amounts occur naturally in rainfall. Pollutant chloride is very common and occurs in human, animal and industrial wastes. The differential permeability of clay is considered to be a major factor in the behaviour and composition of saline water resources associated with fine-grained sediments. Chloride held back when the water molecules pass through the clay layer might accumulate till high concentrations are reached. In such circumstances the clay layer also influences the residual concentration of cations mostly calcium. However, the most common type of water in which chloride dominates have high sodium content. This is true of the water samples collected at Likangala Health Center (573 mg/l) and at Kachulu Harbour (388 mg/l).

3.9 Iron

Most water supplies contain some iron because iron is common in many igneous rocks and is found in trace amounts in practically all sedimentary environments (Driscoll, 1986). The iron content of water is important because even small amounts can seriously affect the usefulness of the water for domestic and industrial purposes. Iron in water may cause staining of plumbing fixtures, staining of clothes during laundering, incrustation of well screens, clogging of pipes and may cause the water to have a bitter taste. These problems are mostly associated with the sudden change from ferrous (dissolved) to ferric (semisolid) iron. Ferric oxides and oxydroxides come out of solution and coat surrounding surfaces. These coatings are precipitated from solution during aeration and also occur as rust on metal surfaces exposed to the atmosphere. Major sources of iron are the dissolution of rich cements in sandstones and the dissolution of mafic minerals in igneous rocks. Studies done by Smith-Carington (1983) in the Bua catchment suggest that Fe is initially present as complexes and subsequently precipitates out due to oxidation after prolonged standing or boiling. The iron content of the water samples is generally low and ranges from 0.08–1.98 mg/1 and does not pose any threat to human life.

3.10 Manganese

Manganese resembles iron in its chemical behaviour but is less abundant than iron. Drainage of wastewater from mines and metallurgical operations commonly contain abundant manganese as soluble manganous bicarbonate, which changes to insoluble manganese are more objectionable and harder to remove than those from iron. Manganese bicarbonate precipitates out of solution as a black, sooty deposit when carbon dioxide is liberated from the water being pumped from the well. All the collected water samples have trace amounts of manganese.

3.11 Sulphate

Sulphates are mainly derived from the oxidation of pyrite in igneous and sedimentary terrains, and the dissolution of gysum and angydrite in sedimentary environments. Some organics will release sulphate on breaking down thus making sewerage contamination a possible explanation for high sulphate content in water if no natural source is obvious. Waters with high sulphate content, especially when in combination with magnesium, are unsuitable for human consumption because of the laxative effect, although inhabitants are likely to have a higher than average natural tolerance.

The sampled water points show that sulphate levels are very low, with values ranging from 4.1–43.7 mg/l, which is far below the 400 mg/l limit recommended by WHO for drinking water supply.

3.12 Nitrate

Main natural sources of nitrate are decaying legumes and other organic matter, although large amounts may originate from sewerage and nitrate fertilizers. Nitrate can be harmful to infants, causing methaemoglobinaemia i.e. the baby's skin turns blue due to lack of oxygen. However, medical studies conducted in other African countries where nitrate content in groundwater resources exceed 100 mg/l have not produced any evidence of adverse effects in infants with regard to infantile cyanosis in babies who are mostly breast fed (Lakudzala, 1993).

All collected water samples have nitrate values much less than 45 mg/l and therefore the water is not harmful to infants and not polluted with agrochemicals. It may be necessary in future to collect more water samples in the estate sector in order to assess the impact of agrochemicals on water quality.

3.13 Fluoride

Important natural sources of fluoride are apatite, mica, amphiboles and fluorite. Locally volcanic or fumarolic gases may be an important source. It is important to know the amount of fluoride in water used by children. If fluoride content in groundwater lie between 2 – 10 mg/l consumers are subject to dental fluorosis, and if they are greater than 10 mg/l skeletal fluorosis is likely (National Water Resources Master Plan, 1986). However small amounts of fluoride are beneficial in helping to prevent tooth decay. Recent studies in medical research have shown that regular ingestion of small amounts of sodium fluoride by pregnant women provides remarkable protection against tooth decay in babies long after birth (Driscoll, 1986). All water samples show trace amounts of fluoride.

3.14 Hardness

Hardness might be considered the soap-consuming property of water, because no suds can be produced in hard water until the minerals causing hardness have been combined with soap (Driscoll, 1986). The minerals that are removed by soap remain as an insoluble scum. Hardness in water is primarily caused by calcium and magnesium cations, although some heavy metals such as iron and manganese also consume soap. The principal chemical sources for the calcium and magnesium ions are the compounds of calcium and magnesium bicarbonate, carbonate and sulphates.

Hardness in water may be divided into two types namely carbonate (permanent hardness) and non-carbonate (temporary hardness). Carbonate hardness includes that portion of the calcium and magnesium that combines with bicarbonate and the small amount of carbonate presents. Non-carbonate hardness is the difference between total hardness and carbonate hardness. It is caused by those amounts of calcium and magnesium that combine normally with sulphate, chloride, and nitrate ions plus the slight hardness contributed by minor constituents as iron. Notwithstanding the soap wasting nature of hard water, people are recommended to drink slightly hard water in order to prevent incidence of heart diseases.

All water samples collected from the study area have hardness values which range from 70 – 495 mg/l, values which are less than 500 mg/l recommended by WHO as the upper limit for drinking water supply.

3.15 Bacteriological quality

Of far more serious consequences than the health hazards associated with chemical substances in drinking water are diseases related to contaminated water which are spread by a biological agent of disease (pathogen). Excreta may contain viruses, pathogenic bacteria, parasitic protozoa and helminthes (worms), in varying concentrations depending on the health and age of the individual. If excreta pollute a water source, these organisms may be drunk with the water and hence cause infection.

Water point construction practices are the single most important factor determining whether or not contamination will occur (National Water Resources Master Plan, 1986). Bacteriological examination of properly constructed boreholes with good sanitary completion has shown that, on the whole, the water quality is very good with faecal coliforms usually less than 5/100 ml and commonly zero. Poorly constructed boreholes are often highly polluted because it is possible for wastewater to gain access to the boreholes. In addition, water can be contaminated at the point of collection because people's hands touch outlet pipes for the hand pumps where water issues out from the well, and at home after collection from the boreholes due to poor storage. This emphasizes the need for hygiene education to preserve the water quality.

The sampled water points show unacceptable levels of faecal contamination, see Table 3. These results may help to explain why Likangala River Basin experiences chronic outbreaks of cholera. Apart from the poor construction of water points, and the contamination of water through methods of collection, the discharge of raw sewage into the river is a serious source of water pollution.

4 DISCUSSION

The results of the water samples show that there is serious faecal pollution of water resources in the Likangala catchment area. This confirms the assertion that rivers flowing through cities in Malawi are grossly polluted. The problem of water pollution in the catchment area has been compounded by the indiscriminate disposal of solid wastes into the Likangala River by people living in the urban area (especially the area around Mpondabwino) and the breakdown of the sewage treatment plant for the Municipality of Zomba. This has led to raw sewage being discharged into the Likangala River. And yet people living downstream of these sewer outfalls draw this water for domestic consumption. In addition, it is the same polluted water that is abstracted for use in the Likangala Irrigation Scheme before it is discharged into Lake Chilwa.

It was observed that all the hand-dug wells where water samples were collected for laboratory analysis were neither covered with top slabs nor fitted with hand pumps. Every person coming to draw water from the water points used their own buckets which, in most cases, were not properly washed prior to being used for drawing water. Water washed down from the upland areas was able to find its way into the wells. It is therefore not surprising to note that test results show high levels of faecal contamination.

As a long-term solution to faecal pollution, it is imperative that all the hand-dug wells should be covered with slabs and fitted with hand pumps. In the interim, the Ministry of Health and Population through village health committees is conducting hygiene education campaign in the catchment area by advising people to treat their water with chlorine in what is known as a "pot-to-pot chlorination". This approach has helped to prevent the outbreak of cholera the year 2001. However, it should be pointed out here that it is too early to make pronouncements on the success of the system. Obviously, the scheme is not sustainable, as the Ministry has to purchase chlorine regularly for distribution to the people. The prevention of serious pollution is a more effective method than treatment of the negative effects of pollution.

Generally, water collected from boreholes is considered free from biological contamination because of the natural filtration process that takes place during groundwater replenishment. However, the borehole at Likangala Health Centre shows high levels of faecal contamination. Groundwater pollution has been caused by the hydraulic continuity that exists between the overflowing septic tank located upstream of the borehole and the borehole itself. Although the Ministry of Health and Population is in the process of constructing a new storage tank for the Health Centre, there is an urgent need to prevent wastewater from the septic tank from draining into the well. This might involve constructing a new borehole at a distance greater than 60 m from the septic tank and upstream of it; or by emptying the septic, and ensuring that its contents do not spill over.

Another serious health hazard that is causing untold suffering on the lives of people living in the Likangala catchment area apart from cholera, diarrhoea and dysentery is the prevalence of scabies. Scabies is a skin disease that flourishes where people use inadequate water for personal hygiene. This is a clear testimony that many people living in the Basin do not have access to adequate water supplies. This problem can only be solved if additional water points are constructed in areas where the disease is rife.

The small number of boreholes and hand-dug wells located in the Basin does not meet the huge demand for water. As a result, women walk long distances to fetch potable water or spend huge sums of money on buying water from privately owned hand dug wells.

5 INTERACTION WITH POLICY MAKERS

The BASIS Research Team organized a one-day workshop for members of the Zomba District Assembly in March 2001 with a view to briefing them on the appalling quality of water resources in the catchment area as well as the poor accessibility of potable water supply by the local community. The workshop not only created a sense of awareness among the policy makers about the poor water quality but also assisted them in formulating solutions for arresting the pollution and increasing the number of water points in the Basin, mainly boreholes and protected hand dug wells.

BASIS researchers view the holding of the one-day workshop for members of the District Assembly as a step towards achieving sustainable management of water resources in the catchment area, especially in the area of water pollution control and the provision of potable water supply to the local community.

6 CONCLUSION

As far as the assessment of water quality and accessibility to potable water supply is concerned, the study has shown that the water is heavily polluted with faecal matter and that more than 60% of the human population in the study area still depend on unprotected water points. Values of the chemical parameters found in the water are generally within the recommended limits for drinking water supply by the WHO, MBS and the Ministry of Water Development. However, this is not true of faecal coliform and faecal streptococci counts, which are far in excess of the recommended limits. These high levels of faecal content render the water unsuitable for human consumption.

Water pollution arises from two major sources, namely the indiscriminate disposal of solid wastes and raw sewage into the Likangala River by people living in the Municipality of Zomba; and the poor construction of water points. Therefore there is an urgent need to redress the situation if the incidence of cholera outbreak and other water-associated diseases are to be reduced or avoided.

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APPENDICES

Table 2. Water Quality Standards – Maximum Permissible Levels

(i) Constituents of Health Significance

CONSTITUENT	UNIT	WHO GUIDELINE	MBS GUIDELINE	WATER DEPARTMENTS TEMPORARY GUIDELINE
Arsenic	mg/L	0.05	0.05	0.05
Cadmium	mg/L	0.01	0.01	0.01
Chromium	mg/L	0.05	0.05	0.05
Cyanide	mg/L	0.05	0.05	0.05
Fluoride	mg/L	1.5	2	3
Lead	mg/L	0.05	0.05	0.05
Nitrate	mg/L	45	100	100
Selenium	mg/L	0.01	0.01	0.01
Faecal Coliform				
a) treated piped water	Count/100ml	0	0	0
b) untreated piped water	Count/100ml	0	0	50
c) un piped supplies	Count/100ml	0	0	50

(ii) Constituents and Characteristics of Aesthetic Significance

CONSTITUENT	UNIT	WHO GUIDELINE	MBS GUIDELINE	WATER DEPARTMENTS TEMPORARY GUIDELINE
Magnesium	mg/L	150	150	200
Calcium	mg/L	200	200	250
Aluminium	mg/L	0.2	0.2	5
Chloride	mg/L	600	600	750
Colour	TCU	15	15	50
Copper	mg/L	1.5	2	2
Hardness	mg/L CaCO	500	500	800
Iron	mg/L3	1		
Manganese	mg/L3	0.5		
PH Min.		6.5		
Max.		8.5		
Sodium	mg/L	200	200	500
Total Dissolved Solids	mg/L	1000	1000	2000
Sulphate	mg/L	400	400	800
Zinc	mg/L	15	15	15
Turbidity	NTU	5	5	25

Table 3. Bacteriological Test Results of Water Samples Collected During the period 23rd - 24th March, 2000 in the Likangala River Basin compared with standards by WHO, Malawi Bureau of Standards and Ministry of Water Development (Temporary Guidelines)

Sample Source, Type and Location	Faecal Coliform Count per 100ml	WHO	MBS	Ministry of Water Development	Remarks
1. Shallow well at Naphambo Village	5000	0	0	50	Water not suitable for human Consumption
2. Borehole at Naphambo Village	16	0	0	50	Water fairly suitable for human consumption
3. Likangala River at Naphambo Village	3000	0	0	50	Water not suitable for human consumption
4. Borehole at Thundu School	108	0	0	50	Water not suitable for human consumption
5. Likangala River at Mpondabwino	5300	0	0	50	Water not suitable for human consumption
6. Tap at Mikuyu Prison	700	0	0	50	Water not suitable for human consumption
7. Nanchengwa well along Likangala River at Namakoka	2000	0	0	50	Water not suitable for human consumption
8. Shallow well at Mlangali Village	2000	0	0	50	Water not suitable for human consumption
9. Main canal at Likangala Rice Scheme	4000	0	0	50	Water not suitable for human consumption
10. Rice Plot No. 6 at Likangala Rice Scheme	4800	0	0	50	Water not suitable for human consumption
11. Shallow well in Likangala Rice Scheme	6000	0	0	50	Water not suitable for human consumption
12. Tap water collected from one of the staff houses at Likangala Health Center	8000	0	0	50	Water not suitable for human consumption
13. Lake Chilwa at Kachulu Harbour	9000	0	0	50	Water not suitable for human consumption