UNIVERSITY OF ZAMBIA

STATUS OF BACTERIOLOGICAL, HYDROCARBON AND HEAVY METAL POLLUTION ON LAKE TANGANYIKA AND POLLUTION' S EFFECT ON PUBLIC HEALTH IN MPULUNGU AREA, ZAMBIA.

Sr. Christine Mulenga Kabumbu, SCJ

A dissertation submitted to the University of Zambia in partial fulfilment of the requirements for the award of Master of Science in Geography.

LUSAKA, JULY 2003

APPROVAL

THIS DISSERTATION BY SR. CHRISTINE KABUMBU IS APPROVED AS FULFILLING THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE (GEOGRAPHY) BY UNIVERSITY OF ZAMBIA.

NAME	SIGNATURE
Prof. B. P. PARIDA External Examiner	
Dr. Henry M. Sichingabula Supervisor and Internal Examiner	
Mark C. Mulenga Internal Examiner	
Dr. P. O. Y. Nkunika Dissertation Chairperson	

APPROVAL

THIS DISSERTATION BY SR. CHRISTINE KABUMBU **IS APPROVED AS FULFILLING THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF** SCIENCE (GEOGRAPHY) **BY UNIVERSITY OF ZAMBIA.**

NAME	**SIGNATURE**
Prof. B. P. PARIDA **External Examiner**	
Dr. Henry M. Sichingabula **Supervisor and Internal Examiner**	
Mark C. Mulenga **Internal Examiner**	
Dr. P. O. Y. NKUNIKA **Dissertation Chairperson**	

DECLARATION

I, Sr. Christine Mulenga Kabumbu, declare that this dissertation has been compiled by me and that the work recorded is my own. The sources of all material used have been specifically acknowledged and the dissertation has not been previously submitted for an academic award at any University

Signature:…………………………………………………………

Date:……31-07-03……………………………………………

TABLE OF CONTENTS

CHAPTER 4: METHODOLOGY

CHAPTER 5: ANALYSIS AND RESULTS

CHAPTER 6: DISCUSSION AND INTERPRETATION

CHAPTER 7: SUMMARY, CONCLUSIONS OF THE STUDY AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

Many thanks go to the Sisters of the Child Jesus, who had to put up with my absence both in community and apostolate and for their support during my time of study.

My deep felt gratefulness go to my conscientious and diligent Supervisor, Dr. Henry Sichingabula, of the Department of Geography, School of Natural Sciences University of Zambia, without whose advice, guidance and encouragement, this document would not have become a reality. I also thank Dr. W.D.Nkhuwa of the School of Mines my Co- Supervisor, for encouragement and advice. I also thank members of the Geography Department at the University of Zambia for the academic support.

Appreciations also go to my family mum, dad, brothers and sisters whose encouragement and support made things look easy. Special thanks go to Ernest my late young brother who was always eager to hear and chat about all my pursuits and aspirations and whose last words to me were about reaching 'higher heights'. May his soul rest in the Peace of Christ.

Many thanks go to members of staff, Mpulungu Fisheries Department, and Lake Tanganyika Biodiversity Project, Messrs. Leonard Mwape, Clement Mwelwa and Olivier Drieu and the entire crew who made it possible for me do water and sediment sampling on Lake Tanganyika by providing me with boats, equipment and technical assistance. Last but not the least, I would like to express my gratitude to World Wide Fund For Nature of Switzerland whose financial assistance made it possible for me to do this very expensive research.

DEDICATION

To the One who holds 'Masters' in all that is. The greatest Scientist surpassed by no one on the surface of the earth, the Man-God, my Master, Saviour and Lord, Jesus Christ the Nazarene. Only the good that He wills becomes possible.

ABSTRACT

This study investigated bacteriological, hydrocarbons and heavy metal pollution status on Lake Tanganyika in Mpulungu area in the period of October 1999 to March 2000. The purpose of this study was to identify the origin and sources of bacteriological, hydrocarbon and heavy metal pollution on the lake. The objectives were to (i) identify the sources and causes of bacteriological, oil and heavy metal pollution; (ii) determine the magnitude of bacteriological, oil and heavy metal pollution in the lake water; and (iii) assess the epidemiological pattern of water-borne diseases in Mpulungu area.

The responses from interviews with the people generally revealed that there are waste materials being introduced on the lake by local people as well as fishing companies. Since many people depend on the lake water for domestic use, chances are that there is a relationship between the quality of water and the spread of water related diseases in the area.

In order to determine the status of the water in Mpulungu in terms of bacteriological pollution, samples of lake and river water were analysed for coliform bacteria because this type of bacteria is used as an indicator organism for bacteriological pollution. To determine the amount of oil and heavy metals in the lake water, sediments were analysed using acetone/chloroform and Flame Atomic Absorption respectively.

Analysis of data revealed that none of the five sampling stations, on the lake, namely, Mbete Bay, Musende Bay, Ngwenya/Harbour, and Lunzua River road bridge and one township tap, had coliform bacteria below the WHO Permissible Standard for Drinking Water of 0 colonies/100 mls.

Musende Bay where all fishing companies and the harbour are situated, recorded the highest percentage of oil/g in sediments of 0.4 %/g, which was above zero Maximum Permissible levels of oil for WHO Guidelines for Drinking Water. During the study, it was found that there was a strong relationship between the percentage of oil in sediment and the percentage of fine grains in sediments.

The study found that there were minute or close to zero concentrations of copper and aluminum in Mpulungu Bays. Chituta Bay was found to contain lead at the level of (0.04mg/l) above the Maximum Permissible levels according to WHO Guidelines for Drinking Water of 0.01mg/l.

It is concluded that though at slow rate and in small concentrations, Lake Tanganyika is actually receiving substances, which might degrade and destroy the lake permanently. Lake Tanganyika being in a rift valley and located in the tropics has very high temperatures throughout the year. This high temperature favour the growth of some dangerous pathogens and also favours the decomposition of material.

It is recommended that Mpulungu Township Council should improve the water purification system, and set up good wastewater and solid waste control strategies. Finally there is need for more research on lead pollution, the relationship between water-borne diseases and coliform bacteria in the water and the assessment of the effect of pollution on biodiversity in the area.

CHAPTER 1: INTRODUCTION

1.1 Background

The theme for World Water Day Celebrations in 1996 was "Water for thirst cities". According to Lopi (1996), for many people in Zambia, there was no cause for celebration because safe and clean water for drinking is still a rare commodity. In many Zambian towns during drought years, people are usually stressed, due to non-availability of water. In some cases, people walk long distances in search of water and this water if found, is sometimes not of good quality. In instances where water is available in a water body, concern about the quality is very uncommon. As Muchelenganga (1998) puts it, the local authorities do not have the capacity to carry out any meaningful monitoring on the quality of water that they distribute to the townships and cities.

Lake Tanganyika is a vast water body but this gigantic and valuable water body cannot always provide clean and safe water for drinking. Cholera, dysentery and diarrhoea have become endemic in Mpulungu area, implying that Lake Tanganyika waters are polluted to some extent with disease causing bacteria. Availability of water is not enough, what is needed is that the water should cater for the needs of the population and not to be the source of misery as has often been the case in Zambia. This research has focused on what is at stake with regard to pollution of Lake Tanganyika. It has looked at the various factors influencing the quality of water on the lake and the consequences of water becoming depleted. Water quality monitoring is related to monitoring the quality of human health. This study investigated the quality of drinking water derived from Lake Tanganyika in Mpulungu, northern Zambia. It focused on bacteriological, oil, and heavy metal pollution from October

1999 to March 2000. Water samples were analysed for bacteriological pollution, while lake bed sediments were analysed for oil and heavy metal content. Since people utilise water for domestic purposes, waterborne disease distribution was also assessed so as to determine whether there was a relationship between pollution of water and the health of the general public in the area.

1.2 Location

Lake Tanganyika is found in the extreme northern part of Zambia. Three other riparian countries share it, namely: Congo D.R., Tanzania and Burundi. Zambia harbours the southern basin of Lake Tanganyika accounting for only 6% of this Great Rift Valley Lake. The Zambian portion of the lake lies between Longitudes 29°0′ E and 31°0′ E and between Latitudes 3°0′ S and 9°0′ S (Figure 1). This implies that Mpulungu though in the tropical region, lies not very far from the equator. Mpulungu lies at south end of the lakeshore, with Mbete Bay being the extreme southern point of the entire Lake Tanganyika.

1.3 Statement of the problem

Lake Tanganyika attracts many people due to its richness in fish species. The availability of fish has brought many traders who have settled in Mpulungu leading to unplanned settlements and crowding of people. The influx of people and unplanned settlements has in turn brought about problems of waste disposal which have been aggravated by the physical aspect of Lake Tanganyika basin: Since most settlements are along the lake, whose basin is a rock outcrop it cannot be dug or cultivated easily. This has caused problems for people as regards the provision of adequate sanitation facilities.

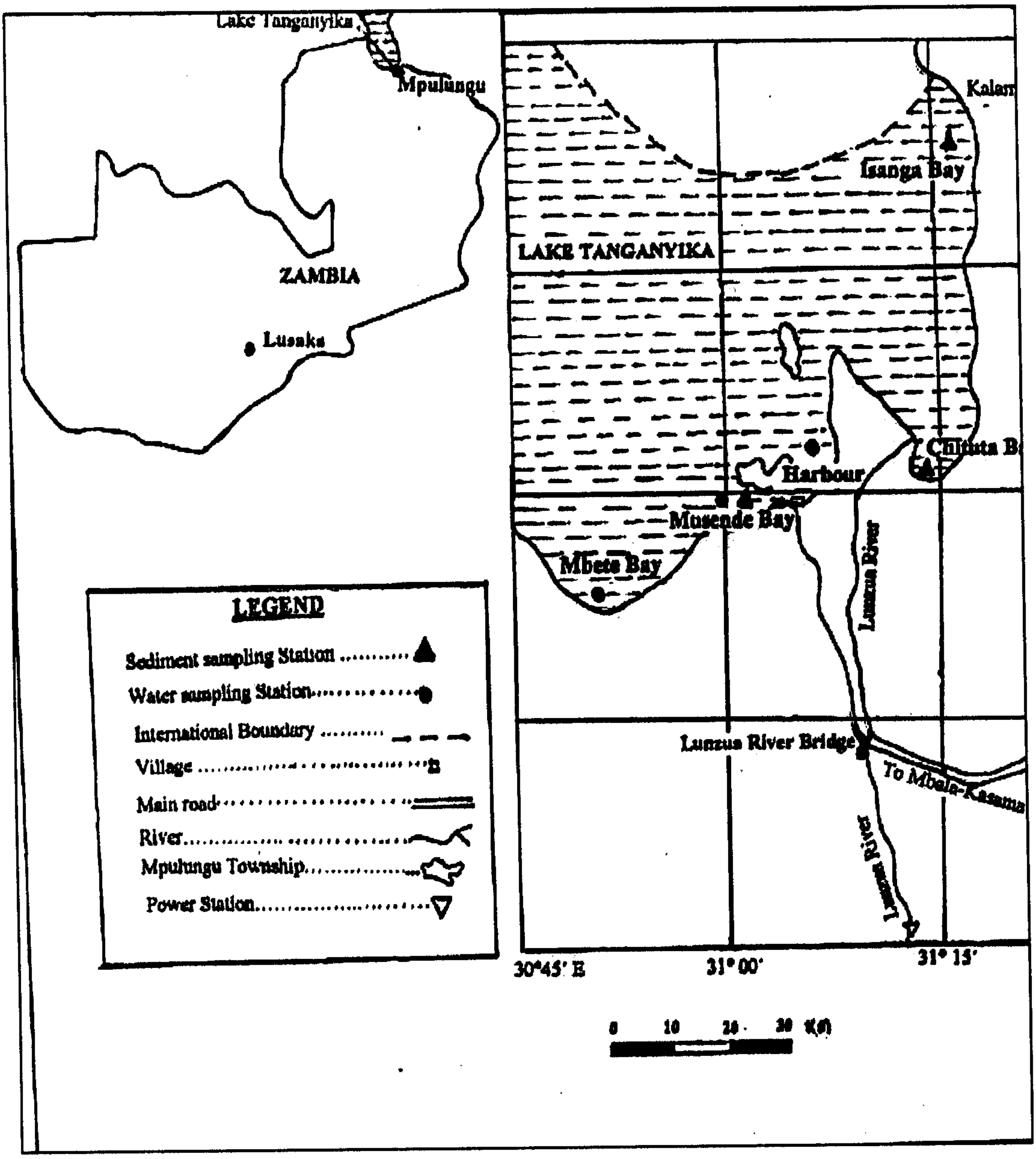


Figure 1. Location of Mpulungu area, water and sediment sampling points, on southern Lake Tanganyika basin.

Mpulungu has experienced uncontrolled disposal of waste, which is unprocessed, and raw sewage being discharged directly into the lake. The local community, having no sanitation facilities carelessly leaves waste on the land, which is carried into the lake by runoff. Many people get drinking water directly from the lake, which is definitely unsafe for human consumption. As a result, outbreaks of water-borne diseases like gastrointestinal diseases are a common phenomenon in Mpulungu (Musonda, 1998).

Careless disposal of used petroleum from vessels, ship wreckages left in the lake and poor handling of cargo at the ill-equipped Mpulungu harbour are a source of concern as far as environmental safety of Lake Tanganyika is concerned. According to Chikwama (1998), increased cargo and inappropriate handling of hazardous substances (cargo) at the harbour have led to increased pollution from toxic substances. Metal pieces and batteries are casually thrown into the lake but little do people realise what damage these do to the lake, animal, plant and human life. Deelstra (1976) cited by Hakan (1995) detected significant quantities of copper, manganese, zinc and iron in fish from Lake Tanganyika in Kigoma, Tanzania. If Lake Tanganyika fish have accumulated metals, a human disaster could easily occur at any time. Hence the need for a detailed study of the problem.

The Environmental Council of Zambia (ECZ) (1993) clearly states that, " No person may discharge or apply any poisonous, toxic, obnoxious matter, radiation or any other pollutant into the environment in contravention of Water Pollution Standards".

The problem is that despite this very sound regulation, water on Lake Tanganyika in Mpulungu is a recipient of industrial and domestic waste and as a result water related diseases continue claiming lives. These problems call for research and quick action in order to reverse the trend.

1.4 Objectives

The objectives of the study were to:

1. Identify the sources and causes of bacteriological and heavy metal pollution on Lake Tanganyika in Mpulungu area,

2. Determine the magnitude of bacteriological, oil and heavy metal pollution in the lake water and sediments and

3. Assess the epidemiological pattern of some water-borne diseases in Mpulungu area.

1.5 Hypotheses

Three study hypotheses derived from the above objectives were constructed namely: that:

1 Bacteriological, oil and heavy metal pollution is a function of anthropogenic activities and physical factors in Mpulungu area.

2 There are elevated levels of bacteriological, heavy metal and oil pollution because of the amount of biological, oil and chemical waste, discharged into the lake.

3 There is a significant relationship between levels of pollution on the lake and patterns of water-borne diseases in Mpulungu area.

1.6 Rationale

The purpose of this study was to identify sources of bacteriological, hydrocarbons and heavy metal pollution in the Lake Tanganyika catchment around Mpulungu. Although there have been many water quality studies done on the Kafue and Zambezi River basins, very little has been done on Lake Tanganyika despite its unique and special world resource, with its rare biodiversity (Michel, 1999). As such, Lake Tanganyika, which is a vast source of food, posses a health hazard whose magnitude is still unknown. The justification for this study is the need for finding ways of preserving this vast source of food and economic development for Zambia.

The few studies, which have been done on the Zambian side of Lake Tanganyika, have concentrated mainly on of fisheries (Huckabay, 1979; Aro and Mannini, 1995; Coulter, 1981, Farukawa-Tanaka, et al., 1995; Kinoshita, 1997 and Pearce, 1985). Sichingabula (1996), in his review of available data for sediment study in the Southern Lake Tanganyika, asserts that studies on sedimentary architecture of the lake sediments are few if any. Patterson (1996) also observes that, the current level of knowledge on the effects of sediment discharge on the fish community of Lake Tanganyika may be considered as close to nil. This implies that not even sediment pollution studies have been conducted before 1996. Obrdlik (1984), reported that, nothing has been published on coliform and pychrophilic bacteria of Zambian waters, but Garbrecht (1971) reports of faecal contamination in the southern end of Lake Tanganyika.

Therefore, there is need to assess the extent of pollution on Lake Tanganyika because, being an inland lake, it has no means of self-renewal in case of a major pollution. The residence time of water on Lake Tanganyika is as long as a 1 000 years (Fryre, 1972). This means that if the lake gets polluted it would remain dead for many centuries hence the need to know the current status of pollution and invigorate laws pertaining to its protection.

1.7 Limitation of the study

Since the study is concerned about sources, causes and status of pollution on the lake in terms of bacteriological, heavy metal and oil pollution and the consequence of this pollution, the study has some limitations. These limitations are that the study did not quantify fully the amount of pollution going into the lake. For instance, the study did not determine how much oil, heavy metal and human waste was being discharged into the lake. Its focus was mainly on the status of the lake in relation to the three types of pollutant sources. As such, no linkage was made between the pollutants going in the lake and the amount of pollutants found on the lake. In other words, ascertaining the source of some pollutants could not be fully established.

The next chapter reviews the literature concerning bacteriological, oil and heavy metal pollution of water bodies in Zambia and elsewhere in the world.

CHAPTER 2: LITERATURE REVIEW

2.1 Defining Pollution and Contamination

Pollution is defined as the introduction of foreign material in an environment and hence altering its natural state. Pollution degrades and even kills natural water systems through introduction of detrimental or toxic substances such as sewage waste, heavy metals, pesticides and detergents. Any impurity that makes water unfit to drink or less fit for any other use is said to contaminate the water (Deming, 1975). Water pollution according to Ciacco (1971) is the addition to a natural water body, any material, which diminishes the optimal economic use of the water body by the population, which it serves. Pollution can some times be defined as the appearance of some environmental quality for which the exposed community has inadequate information and is thus incapable of an appropriate response (Ralph, 1972). One can conclude that if through human activity water changes from its natural state and becomes unsuitable for the purpose of which it was intended, the water is then regarded as polluted or contaminated.

2.2 Water Quality and Water Resource Degradation

According to U.S. Environmental Protection Agency (1976), Water-quality standards are regulations that set specific limitations on the quality of water that may be applied to a specific use. American Public Health Association (1985) contends that, water quality is related to the suitability of water for specific beneficial uses. It is water that is free from visible suspended matter, colour, taste and odour; objectible dissolved matter and other aggressive constituents. Mann and William (1979), also assert that, potable water is one that can be used for drinking purposes with safety and satisfaction. Drinking water must be free of pathogenic bacteria, colour, turbidity, odours and it must have a relatively low temperature and be relatively free of hardness. This is the most ideal situation as far as water purity and safety is concerned.

Water quality is mainly affected by five groups of substances, that is,

- toxic substances like chemicals,
- high concentration of dissolved salts,
- suspended matter,
- acid and alkaline substances like pH,
- and organic matter derived from faecal pollution.

Generally, water quality criteria are denoted by values of dissolved substances in water and what these substances stand for in terms of toxicity and how they can be interpreted in terms of effect on humanity or the ecosystem as a whole. If a water body contained dissolved substances beyond a certain stipulated limit, then that water is not suitable for whatever purpose it was earlier intended for, be it drinking, recreation or for animal or plant life.

Development brings about quality kind of life among the population as it provides necessary amenities for improved human life. At the same time development has many side effects as it brings about degradation of resources. Wilber (1969) points out that, the extent and degree of water pollution are increasing at a rapid rate when more industries are dumping poisons and complex toxic mixtures into natural bodies of water. Even radioactive materials are appearing as contaminants in rivers and streams. Added to this is the ever-increasing use of arsenic-containing compounds and other poisons by agriculture. There are strong cancer-causing (carcinogenic) chemicals used in the building of roads and highways. These materials are slowly washed out and enter natural bodies of water (Green, 1998).

The 'Green Revolution' has brought about a lot of deadly problems as far as pollution is concerned. In order to ensure massive production of food, humanity has brought about pesticides and insecticides on the world market most of, which are poisonous. Ciacco (1971) asserts that, various pesticides and herbicides widely used in agriculture degrade slowly or not at all when broadcast into any environment. It may be impossible to find a DDT-free area anywhere on the planet.

As population increases, there is a lot of demand for fresh water; unfortunately this fresh water is not readily available because there are many people who need it. This large population in turn depletes pure water resulting in the use of impure available water. According to Maitland (1982), as more water is used, so are more impure waters being utilised for supply to people. Most of the people especially in developing countries do not have access to clean and safe water. Urbanisation and industrialisation have created new pollution problems, untreated or partially treated sewage from urban communities and sewage overflows from over-loaded treatment plants, are discharged into rivers (Kamona, 1990).

2.3 Bacteriological pollution and health implications

There is a lot of biological contamination of water in Mpulungu; most of the faeces and urine from the local population is discharged into the water either directly or through runoff or filtering into the ground from pit latrines. Problems of colour, taste and smell of water in Mpulungu may be associated with organic content of water, which could be due to faecal matter. Too much sewage matter decomposing in the water leads to depletion of oxygen. According to Dietrich (1975), low oxygen concentrations are the most important indicators of loading with easily decomposed organic material or with excess biomass. It is this decomposition, which leads to bad taste, smell and colour of water.

The population of Mpulungu is growing at an alarming rate because fishing from the lake attracts people from all over the country. Population and economic growth often has adverse effects on the environment and this effect is usually pollution. Most of the people found in Mpulungu are too busy for personal gain to be concerned about pollution problems of the lake and as a result diseases spread so fast because people are usually not aware of the presence of disease causing micro-organisms in the water. This lack of awareness and concern for environmental issues is what had caused more damage to the same environment and at the same time brought about death to many.

The Local Authorities in Mpulungu do not have the capacity to provide clean water for the growing population. With so much sewage matter being introduced in the water, use of chlorine (Which is not even usually available in Mpulungu) is not enough to get rid of impurities and to kill all types of bacteria. Some pathogens multiply even after chlorinating (Cairncross and Feachem, 1983). In some cases, tap water is just slightly pure than water directly from the lake, stream or well. Generally speaking, water from all the sources could be unsafe, because waste material disposal is very poor in the area and so most of time high volumes of waste enter the water system directly.

In Mpulungu, there are many ways in which faecal matter enters the drinking water systems. Raw sewage may enter the pipe system at places of leakage as confirmed by measurements of the Central Fisheries Research Institute in May 1969, October 1969 and May 1970. (Garbrecht, 1971). Water infiltration from paved surfaces carry pollutants associated with cars, chemical and bacteria. Although this water would generally be of good quality, where sewer systems are also leaking, the recharge water may be of poor chemical and bacteriological quality (UNEP, 1992). Mwilwa (1998) reveals that currently, Mpulungu Township has no sewage treatment facility and the sewage ponds empty their effluent in the lake. Another form of transportation of human waste into the surface water systems is through runoff and erosion because of the moderate to steep slopes and rocky terrain of the environment.

The rubble nature of the ground makes the soil to become easily saturated during infiltration, such that runoff occurs very rapidly. Since runoff is usually accompanied by erosion (White, 1987), a lot of carelessly damped rubbish is carried and finds its way into the surface water. The water running across the surface picks up many substances as it flows back to the lake or ocean (McKinney, 1962). This includes topsoil, which finally reaches the waters as sediments. Linsley (1982) further assets that, as water moves across the land surface during or after a storm, it transports dissolved and suspended materials which have been picked up along the path of flow. In many cases, the pollutants carried to streams and lakes by surface runoff are the major contribution to water pollution.

In Mpulungu, runoff has been aggravated by the clearing of forests within the catchment including the Forest reserves (Lukama, 1998), leaving land completely bare and in turn increasing erosion. Erosion has been associated with loading water systems with sediments and these sediments carry with them all sorts of waste material. It must also be recognised that freshwater quality is impacted directly by natural and human activities outside the water sphere, such as land-use practices, erosion, and deforestation.

In a rocky environment, as water percolates through the soil, it takes dissolved waste material down into the water table. In this way, underground water gets contaminated with faecal matter. Soakaways, septic tanks and pit latrines are the main sources of groundwater pollution as water infiltrates into the soil. Frank and Siever (1994) contend that, the widespread use of septic tanks is rapidly growing in urban and suburban areas, this lack of sewer networks has multiplied the sources of contamination. In soils, which are porous, waste loaded water from sewer systems reaches the underground water systems very fast.

Having looked at waste management conditions in Mpulungu, one cannot doubt that the environment is not very safe as far as health standards are concerned. Community health is very much allied to environmental quality; the pollution of natural waters alone illustrates the relationship between cause and effect, when we consider the epidemiology of diseases such as cholera, typhoid and enteric fevers, hepatitis due to viruses, (Brock, 1979). Bryan (1994) contends that, the most important requirements related to human water consumption are those of microbiological content and hygienic acceptability. It is the poor quality of water with respect to these factors that cause the majority of water-related illnesses in developing world. Every year many people die in Zambia in places like Mpulungu due to water-related illnesses.

In 1999, the Provincial Planning Unit in Kasama carried out a survey in Mpulungu Township and all surrounding villages. One of the variables they looked at was the commonest disease, which caused death in the area. The area was divided into 9 wards and these wards comprised about 170 villages. Not a single ward failed to mention the three water borne diseases namely cholera, dysentery and diarrhoea as the common cause of death (Appendix I).

According to Mpulungu Ministry of health records, 1997 and 1998 alone reported 4 727 and 3 791 cases of diarrhoea respectively (Musonda, 1999). This trend of disease does not seem to be getting any better because the first half of 1999 had 2 563 cases of diarrhoea with 139 cases of cholera which claimed 17 lives. The figures do not include other intestinal diseases like dysentery (Appendix II).

Water in Mpulungu may not be good enough for laundry, bathing and so forth but the worst part of it is that water there transmits various kinds of water-related diseases, which from time to time has hit headlines in the Zambian media. Turk (1972) rightly points out that, the most harmful effect of polluted water on man has been that of disease transmission. Strong links have been established between contaminated water contact and the occurrence of illness such as gastrointestinal infections. O'Riordan (1995) gives an example of cholera epidemics between 1830 and 1870, which were believed to result from contaminated water supplies from the River Thames in London.

There are so many disease outbreaks associated with the use of microbial contaminated water, be it for drinking or swimming. Fair (1958), Benton and Wenner (1958), McKinney (1962), Brock (1979) and Wilber (1969), Ralph (1972), cite some diseases like, cholera, typhoid, hepatitis A, tuberculosis, dysentery, inflammation of body organs, gastro-enteritis and many other diarrhoeal diseases to mention but a few as being typical of water related illnesses. Bollenbach (1975) confirms that, the degree of pollution of water depends on the number and kind of disease-producing bacteria that have been deposited in the soil. Water seeping through an area used as a city dump picks up more bacteria of varied types than does the water that soaks into the soil of an open field from any remote place.

Apart from diseases being spread by direct contact with contaminated water, eating fish, which has been in contact with faecal contaminated water, can equally be dangerous to health. Among cold-blooded animals, freshwater fish harbour human pathogens after exposure to contaminated water and can carry these organisms to clear recreational areas (Ralph, 1972). Although fish do not suffer from any human bacterial pathogens, if faecal bacteria are very numerous in water, they may accumulate on the surfaces or in the intestines of the fish (Cairncross 1983). It is well established that fish living in water containing organic and inorganic pollutants will concentrate these substances in their tissues. People who eat such fish may be, and have been subject to poisoning (Bryan, 1994). Cases of cholera in Kasama have been reported in the Zambian media, which had allegedly resulted from eating improperly cooked fish from Lake Tanganyika in Mpulungu (Zambia Information Service, 1998).

2.4 Heavy Metal pollution and its impact on biodiversity and human population

Heavy metal pollution should be a source of worry and serious concern because even small quantities if introduced in the water body and depending on the type of metal and prevailing conditions, can prove catastrophic. According to Solomons and Fouster (1984), particulate trace metals may permanently accumulate in lakes or river systems and sediments act as a reservoir and changing environmental conditions may cause a remobilisation of the accumulated metals. The conditions of Lake Tanganyika are very conducive to metal pollution being a tropical lake with temperatures, which favour chemical and even biological reactions hence making metals to become toxic.

The physical condition of Lake Tanganyika makes it susceptible to serious pollution; it is in the tropics with high temperatures favouring decomposition of matter leading to depletion of oxygen. Huckabay (1979) quoting Fryre (1972) points out that; about three -quarters of the total volume of water in the lake is devoid of oxygen and aerobic life. It has been maintained that, with respect to fish, the most critical result of water pollution by sewage is a reduction in the amount of oxygen; this reduction is harmful and lethal to fish. Wilber (1969) asserts that, collections made over a relatively long period of time clearly show that virtually no fishes are found in an area where the mean dissolved oxygen is less than 1 or 2 ppm.

Fryre (1972) shows that, at 25° C, the oxygen content of water is only 8.3mg/1. He further asserts that, because the speed of chemical reaction is at least doubled by a rise in temperature of 10° C, the deep regions of tropical lakes act as an incubator, promoting decomposition. Green (1998), in his study on Lake Tanganyika in Kigoma also points out that, seasonal and sometimes daily changes in bacteria occur as physical, chemical and biotic conditions change in water. The change in temperature does not only affect chemical reaction but also affect bacteria growth. Under such a situation, introducing metals and other dangerous wastes in Lake Tanganyika would have very serious repercussions.

Some metals, in themselves are very harmless even if they can be present in the lake but can prove to be toxic if they mix and react with other metals (Solomons, 1984). Salvato (1958), in his experiment on the Great Lakes found that a mixture of metals proved to be very toxic to fresh water algae in lake water. He sighted the presence of copper and silver in water to be quite deadly to marine organisms. Copper is very abundant in Zambia and so it is possible for it to occur in the same water environment with other metals with which it can react.

Heavy metals are quite dangerous to human health if they accumulate in the body. Heavy metals for instance, cadmium and lead are known to produce serious diseases of the nervous system even when they accumulate in the body in low concentrations. This aspect is also important when fish and mussels contaminated with heavy metals are used for human nutrition (Dietrich, 1975). Metals like copper, zinc, lead, mercury, arsenic and other industrial products are also toxic to animals and may cause death or sublethal pathology of liver, kidneys, reproductive, respiratory and nervous systems of aquatic animals (Southwick, 1976). This is the reason why metals, which accumulate, need not be allowed in water in high concentrations and this can be done through constant check of concentration levels of metals in Zambian waters.

2.5 Hydrocarbon pollution

Oil, though can be seen to be less toxic as could be certain chemicals, can prove to have adverse effects on human as well as aquatic life. Oil gets into water bodies through a variety of ways, which according to Wilber (1969) include: discharge from barges and ships and accidental or careless handling of cruse oil in transportation. Oil can cause mortality and even extinction of certain animal species, as some animals are restricted from normal mobility once they get coated with oil. For example birds fail to fly when their feathers get coated with oil. If a bird fails to fly, starvation is inevitable, as it has no access to food. Breeding also becomes impossible for the birds resulting in the reduction in population. This is a disturbance in the ecosystem and leads to distraction of biodiversity.

Apart from the effect oil can have on biodiversity, water polluted with oil is equally dangerous to human beings, the only difference is that oil contaminated water is unpalatable to human beings due to the smell, as a result poisoning through oil in water is not very easy (Giles and Living ston, 1960).

2.6 Economic implication as regards degradation of Lake Tanganyika

Lake Tanganyika, the world's second largest (volumetrically), deepest and oldest lake (Bannister, 1998), Zambia shares only 6% of this precious lake. This lake is likely to be degraded if no proper measures are taken to prevent careless introduction of toxic and dangerous substances in it. It would be most unfortunate if this nation had to wait for a series of epidemics, poisoning and illness from polluted water before taking vigorous action at all levels of government to clean up our natural waters and to control rigidly any further attempt to pollute these waters.

Lake Tanganyika is a very valuable lake as far as the economy of the country is concerned but very little is done to conserve it and improve on its economic sustainability for the people of Zambia. Apart from Lake Tanganyika being a source of livelihood for many Zambian, it is also a tourist attraction but tourists would not be interested in visiting unhygienic resorts. Reduction in tourists will definitely make Zambia lose out economically. The very people the lake is sustaining are destroying it while at the same time endangering their lives. Societies pay a much higher cost for the consequences of environmental neglect (UNEP, 1995).

Besides the lake being a source of economic development for the country, what is to be realised by the stakeholders is that quality of water has a lot of impact on the health and quality of the population. Kings (1996) points out that the quality of water that we ingest as well as the quality of water in our lakes, streams, rivers and oceans is a critical parameter in determining the overall quality of our lives.

In this study, the interest was in bacteriological, mineralogical and hydrocarbon pollution on Lake Tanganyika, the levels of these parameters in the lake reveal the quality of water on Lake Tanganyika and its suitability for domestic consumption. The literature review has shown generally the relationship between human health and quality of water. Water, which contains abnormal quantity of any substance, be it biological, chemical or physical more than the natural content of water can have a detrimental effect on human health. This study sought to quantify the actual pollutants present in the water on Lake Tanganyika and to see the relationship so far in lives of the people in Mpulungu. The study wanted to reveal whether the quantity of any particular pollutant actually corresponded to numbers of people affected.

The next chapter describes the location, climate, relief, water motion, bathymetry, geomorphology, soils, vegetation, land use as well as socio-economic conditions of local people in south Lake Tanganyika basin.

CHAPTER 3: DESCRIPTION OF THE STUDY AREA

3.1 Climate of Mpulungu

Mpulungu is located on the lakeshore of Lake Tanganyika and this lake being a rift valley lake, Mpulungu Township is situated in a rift valley it self. As characteristic of tropical lakes, Lake Tanganyika water has constant high temperatures and very often above 25°C. These high temperatures and humid conditions are aggravated by the fact that Lake Tanganyika is in a rift valley and not very far from the equator.

Mpulungu area, like the rest of Zambia, experiences 3 typical seasons namely: the cold and dry season from May to August, the hot and dry season from September to November and also the warm and wet season from November to April. Mpulungu experiences warm/hot weather conditions throughout the year, with very mild winters.

3.2 Special identity of Lake Tanganyika

Lake Tanganyika is the second largest of the African lakes, the second deepest (1 470m) and the longest lake (north-south extension of 670 km) of the world and since it dates back to the Miocene period, it is also one of the oldest lakes in the world. According to Lezzar (1999), the oldest parts of the lake are the central and northern which are 17.5 million years and 12.4 million years respectively, with the southern end being the youngest at 3.8 million years. The lake is divided into a series of interconnected half-graben basins, which are the northern, central and southern basins. Lake Tanganyika is said to contain about 18% of the world's fresh surface water (Michel, 1999).

3.3 Annual Limnological Events of Lake Tanganyika in Mpulungu

One of the physical characteristics of Lake Tanganyika according to Plisneir (1999), quoting Johnson and Odada (1996), is that the rift valley circulation being unidirectional affects the circulation pattern and mixing of water. According to Beadle (1981), it is this unusual characteristic of mixing of water from which the lake derived its name. Tanganyika, which means 'Ku tanganganya' in Swahili, ("to mix"). Due to movement of winds, water from below (deep waves) comes to the surface and surface water goes down. Plisnier (1996), points out that, the trade wind that originates from the Indian Ocean has a significant effect on the southern part of the lake and is responsible for launching the upwelling (Figure 2), which is necessary for the seasonal primary production. It is this upwelling that makes nutrients to circulate to different trophic levels and hence making Lake Tanganyika one of the richest ecosystems on earth. A summary of the main annual limnological events on Lake Tanganyika is illustrated in Figure 3.

3.4 Bathymetry and Drainage Patterns

Lake Tanganyika is an inland fresh water lake, with very few big rivers draining into it. The three big rivers draining into the lake are Lufubu River in Zambia, Malagarasi River in Tanzania and Rusizi River in Burundi. The Lake has only one outlet, which is the Lukuga River in the D.R.Congo, which starts from the middle part of the western coast and flows westwards to join the Congo River draining into the Atlantic Ocean (Plisnier, 1999). This is the only river into which the lake discharges its waters. According to Hecky and Degens (1993), the Lukuga River outlet serves primarily to maintain a relatively constant lake water level.

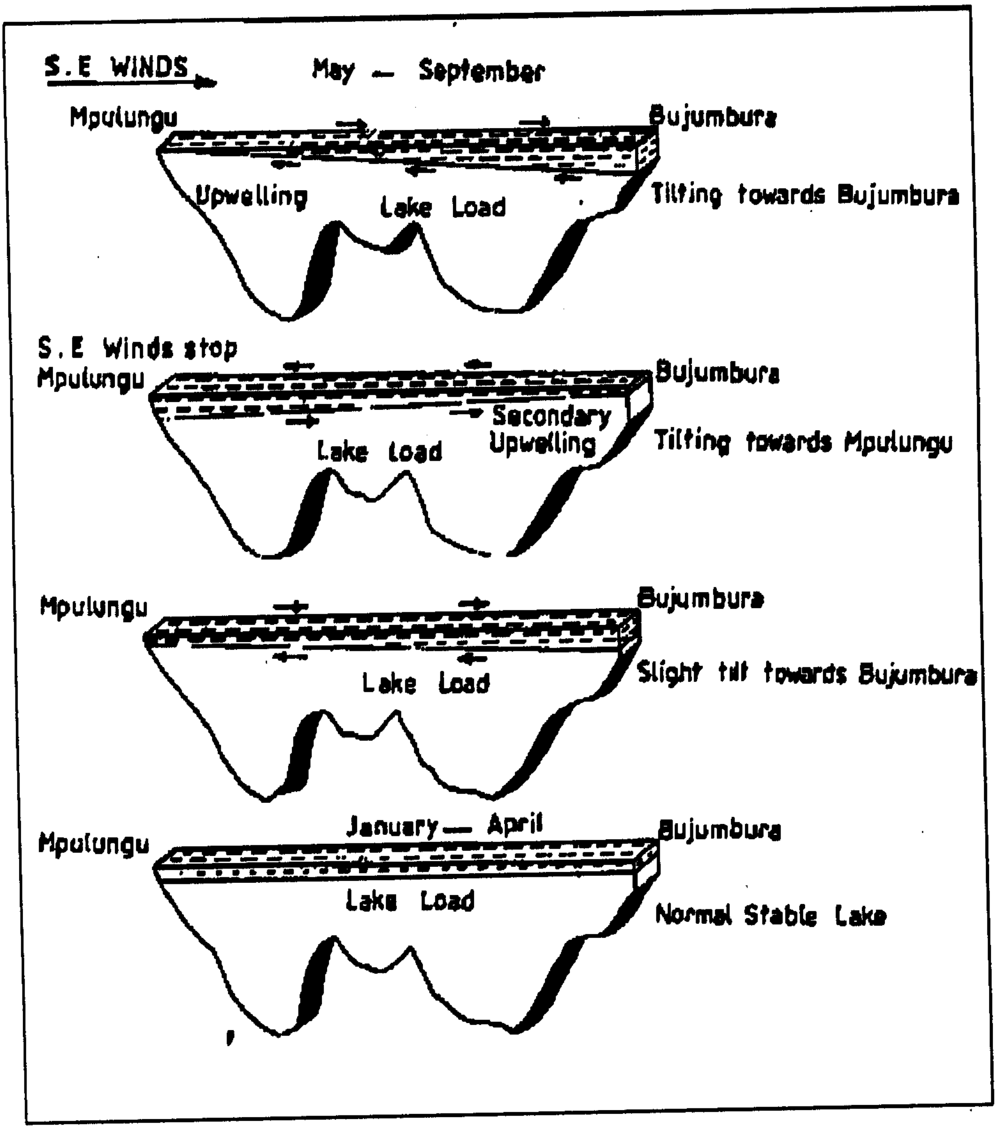


Figure 2. Limnological cycle of Lake Tanganyika.

Source: (Plisnier and Coenen in print as at July 1999)

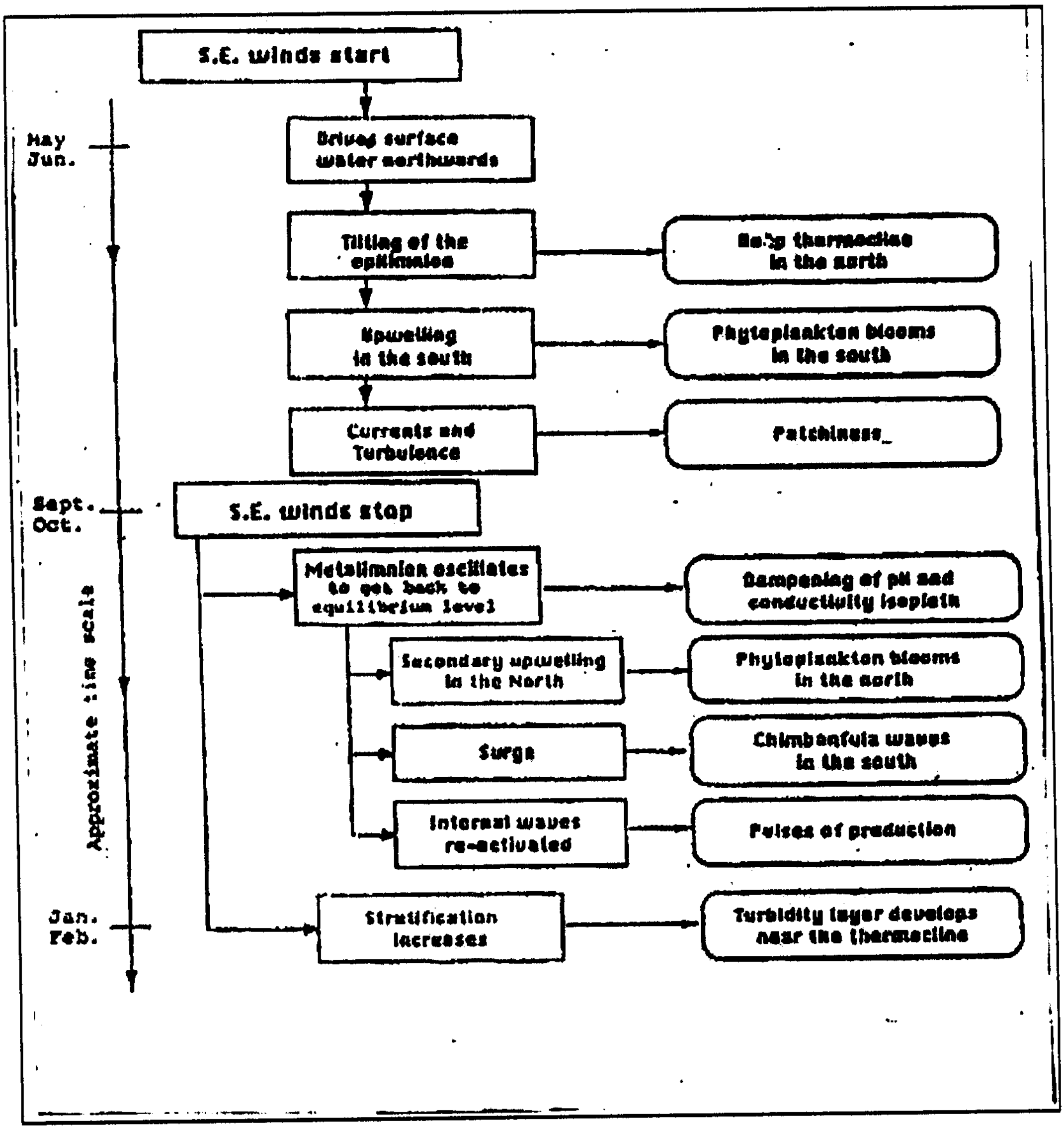


Figure 3. **Summary of the main annual limnological events on Lake Tanganyika.Source: (Pliesnier, 1999)**

Though Lake Tanganyika is an open basin lake, its cycle of renewal is mainly through evaporation because not much water leaves the lake. Lake Tangyika being a rift valley lake is generally deep but its deepest point is the Alexander Delcommune Deep with a depth of 1,470 m (Lezzar, 1999) (Figure 4). The lake is divided into three zones, which are the Littoral, the Benthic and Pelagic zones. The lake being a rift valley one is generally deep, but its deepest point is the Alexander Delcommune Deep with a depth of 1,470 m (Lezzar, 1999) (Figure 4). The lake is divided into three zones, which are the Littoral, the Benthic and Pelagic zones.

3.5 Geomorphology of Southern Lake Tanganyika Trough

Rocky and hilly features border Lake Tanganyika since it is in a rift valley. The surrounding areas of the lake are mainly mountainous with poorly developed coastal plains. The few areas of Mpulungu, which are fairly flat, the soil/grounds are predominantly rubble, coarse, spacious and porous. Tanganyika basically is very steep-sided. Mpulungu sub-basin is a continuation of the Great East African Rift System, which extends up to the Lake Mweru Wantipa and Lake Mweru making up the South Tanganyika Troughs Complex. The extension of faulting further south has been prevented by the presence of the Mbala Block (Lezzar, 1999). The lake margin is characterised by low slopes with elevation between 610 m and 1220 m. Most of the area surrounding Mpulungu lies between 1220 and 1830 m above sea level. The highest mountain ranges of about 1820-m are found in the Mbala Highlands the source of Kalambo River which drains into the lake.

Along the shoreline are also v-shaped valleys due to faulting. Ichingabula (1999) states that subsequent erosional processes have modified the fault lines and blocks. Most of the

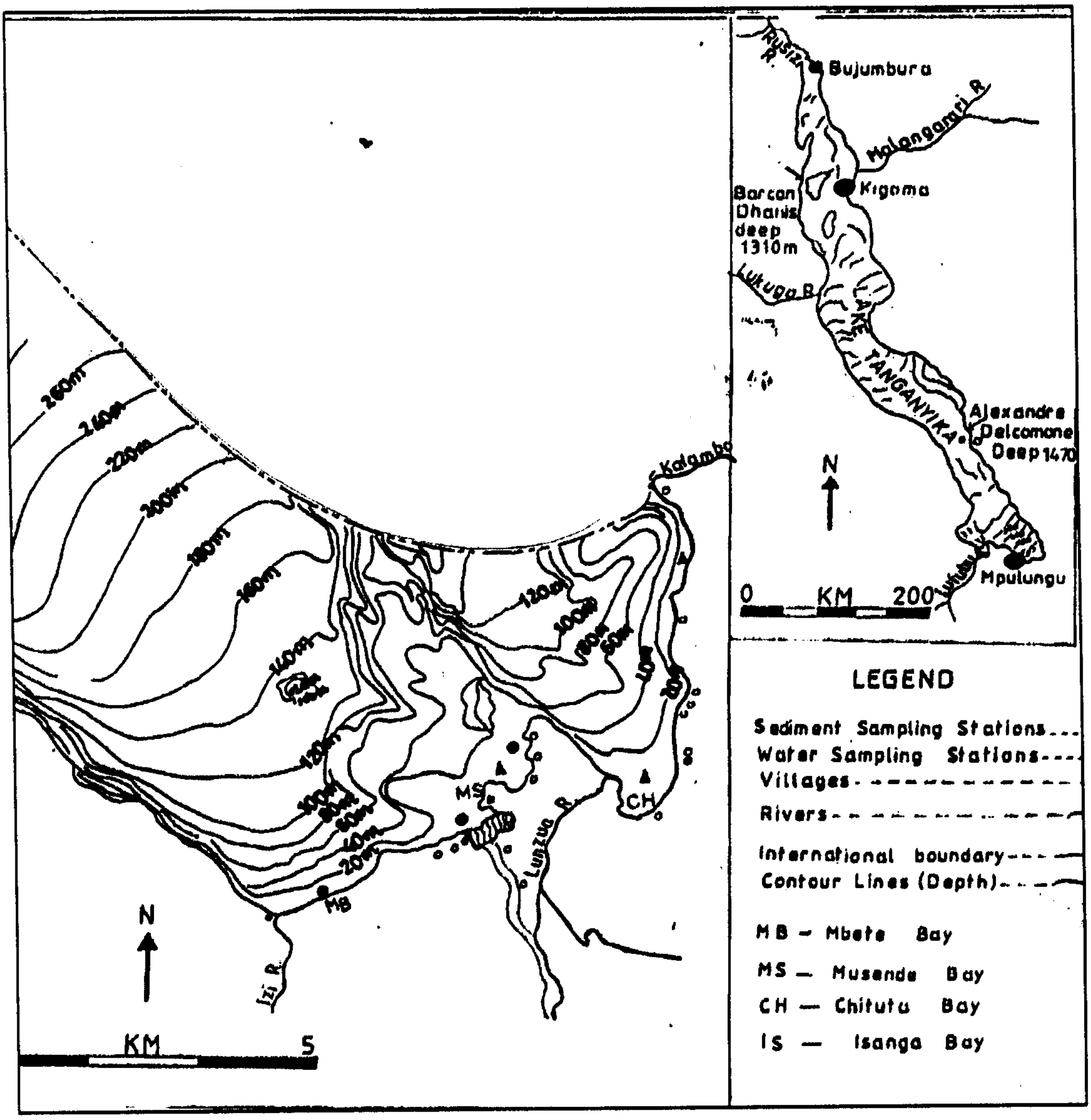


Figure 4. Bathymetric (a) and drainage map (b) of Lake Tanganyika.

Adapted from (Capart, 1949)

settlements in Mpulungu area are just on the slope of the mountain ranges surrounding the lake (Plate 1). These settlements are often found near perennial and ephemeral streams, which cut across the escarpments to drain their waters into the lake.

3.6 Soils and vegetation

The south Lake Tanganyika basin has four dominant soil types with leached sandveldt covering about 90% of the total area. Around Mpulungu there is rocky and rubble type of soil, which is just as a result of weathering, processes acting on the rock material. The leached red clays are most prominent in Mbala area where the red colour cannot be missed at all and often cause roads and cleared places to be very slippery and muddy. Flood plain soils occur along the river courses such as the Lufubu River.

3.7 Land use

Most of the flat land in Mpulungu area is utilised for either settlement or crop production. Most of the people are peasant farmers relying mainly on crops such as groundnuts, beans etc., which do not require use of fertilisers. Since most of the soils are leached, people practice slash and burn type of agriculture (*Chitemene* system) and utilise potash from burnt trees as fertiliser (Plate 2). Crops grown under this system include cassava, millet, groundnuts, sorghum and maize. Beans is the most widely grown crops, which are the main source of income.

According to Northern Province Statistical Office Report (1999), 71.4% of the villagers keep goats while about 32.1% keep pigs and 22.0% keep sheep. Cattle raring are unpopular as only about 8.4% of the people in Mpulungu area keep them. In the

Plate 1. Physical characteristics of Mpulungu area surrounding Lake Tanganyika, (a) steep slopes and v-shaped valleys.

Picture by Sr. Christine Kabumbu, March 2000.

Plate 2. Slash and burn cultivation (*Chitemene*) system in the vicinity of Lake Tanganyika in Mpulungu.

Photograph by Dr. Henry Sichingabula, September 1997.

few cases where cattle are reared, Lukama (1999) has pointed out that they have caused uncontrolled grazing leading to encroachment into the protected forest area.

Other forms of land use in Mpulungu area include wildlife conservation in the Nsumbu National Park located on the northwestern side of Mpulungu. About 13% of the south Lake Tanganyika basin is a National Park, which includes part of the lake (Zulu, 1998). A big portion of land in Mpulungu area is not populated since it is a Forest Reserve. However, according to Lukama, (1998), people are encroaching in the Forest Reserve in search of virgin land and more trees for slash and burn cultivation and timber. As the population increases, more and more land is required for *Chitemene* agriculture, which causes further encroachment on Forest Reserves.

The different methods employed in data collection and analysis of factors influencing water quality on Lake Tanganyika in Mpulungu area are discussed in the next chapter.

CHAPTER 4: METHODOLOGY

4.1 Types and sources of data

In this section, the different types of data and methods used to collect and analyse samples are discussed. Two types of data were collected, primary and secondary data. The primary data, which was collected through fieldwork, included water and sediment samples, interviews, and questionnaires that were administered to collect data on people's views on pollution on the lake in Mpulungu area. An interview guide was used in some cases considering that the literacy level in the area is very low. The reason for the use of interviews and questionnaires was to obtain qualitative information on the study just as the laboratory analysis of water and sediments for various pollutants gave quantitative information.

During field observations, photographs of certain strategic sites were taken to illustrate what cannot be seen from the map. The sites included the harbour, the water intake and outlet, village settings and settlement patterns along the lake and scenes depicting human activities along the lakeshore. Secondary data was collected from various stakeholders who had material relating to Lake Tanganyika and its water in general, health, geology, relief, settlements, and land use patterns of the south Lake Tanganyika basin. Some errors inherent in the different methods of sample collection and analysis are also discussed. The details of data collection are given in the following sections.

4.2 Primary Data Collection

4.2.1 Water Sample Collection

In order to assess the quality of water in Mpulungu, water samples were collected during the dry and wet seasons from October 1999 to March 2000. Samples were collected from 5 stations within Mpulungu area, namely: - Musende Bay which has the Council's sewer inlet and large settlement on the bank (Plate 3); Mbete Bay which also has a large settlement along the lake; and Ngwenya which encompasses the harbour as well as the Council's water intake (Plate 4). Other samples were collected from a tap at the convent of the Sisters of the Child Jesus, situated few metres from the Township's water tank. The other samples were collected from Lunzua River Road Bridge along the main road from Mbala to Mpulungu. The choice of the site was that it was the closest place to the road and was easily accessible.

The total number of water samples collected per month was nineteen. Fifteen water samples were collected from the lake from 3 bay stations and two water samples each collected from the tap and the Lunzua River Bridge. From each bay station, 5 samples were collected at different points, which varied in depth and distance from the shore (Figure 5). The locations compared were the 100 metres from the shore (5 metres below the surface) and 230 metres from the shore (10 metres below the surface). Location one (1) (100 m offshore) consisted of 2 points namely: surface and 5 m bottom, point two (2) (232 m offshore) consisted of three points namely: surface, 5 m (mid point) and 10 metres bottom.

(a)

(b)

Plate 3. Location of sewage discharge point on Lake Tanganyika in Mpulungu, (a) Location of the council's sewer outlet (discharge pipes is under water, centre of photograph) (b) Musende Village on the southern shore of Lake Tanganyika,metres away from the council's sewer outlet.

Photograph by Sr. Christine Kabumbu, February 2000.

(a)

(b)

Plate 4. Location of Mpulungu Township water intake, (a) Water intake point in the water and a powerhouse on the shore, (b) Ngwenya Market (some 300 metres away from the water intake, on the left of the photo).

Photos by Mr. C. Makasa, March 2000.

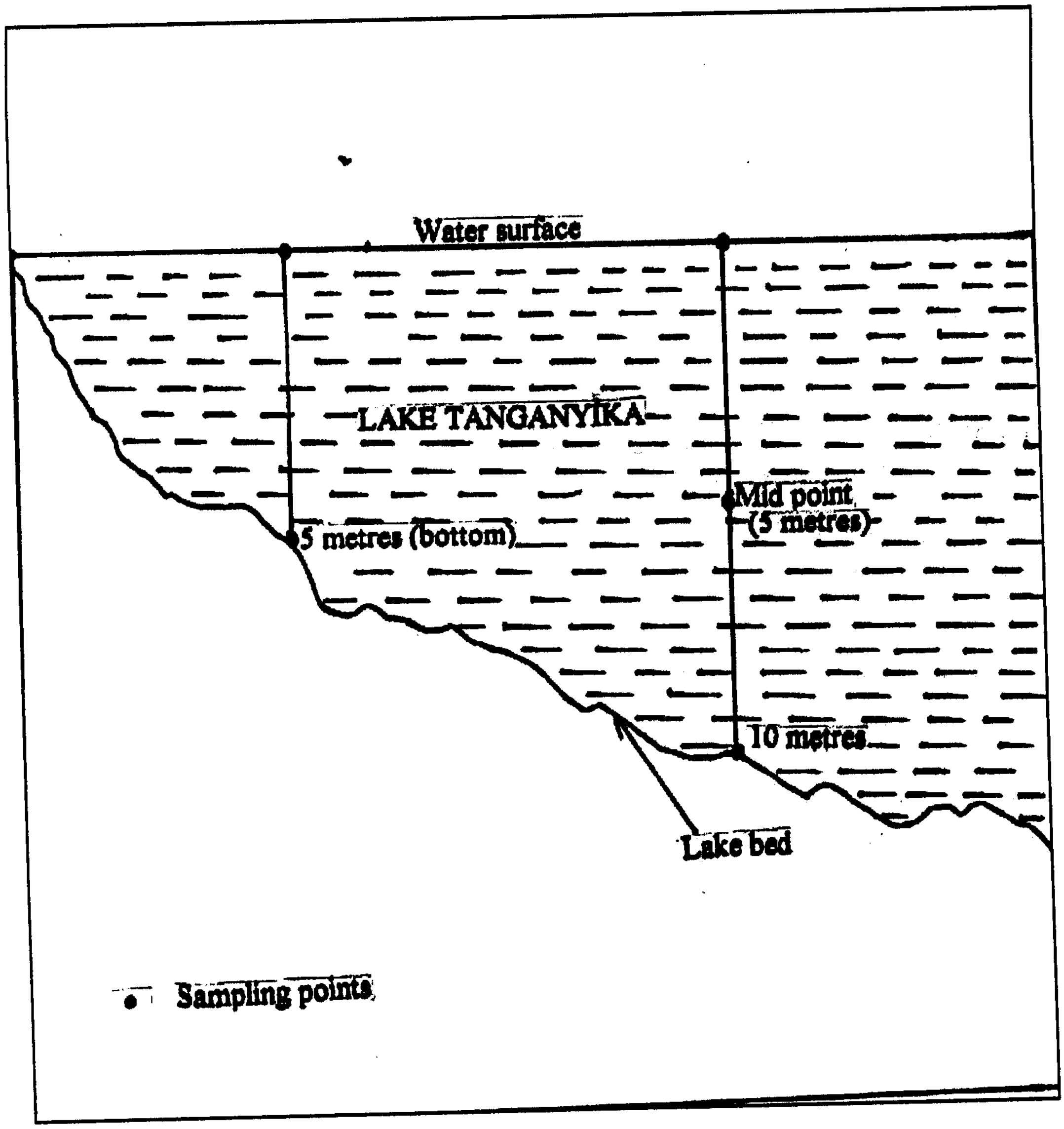


Figure 5. Sketch cross section of water column from surface to the bottom.

Two tap water samples wee collected. In one of the two samples, sodium Thiosalphate was added immediately after water sample was collected in order to dechlorinate the water (in case the water was chlorinated) and prevent chlorine from acting on bacteria, the other sample had no Sodium Thiosalphate added to it. The difference in bacteria count was to help know whether or not the water in the township was really chlorinated or not.

4.2.2. Sediment Sample Collection.

Sediments were used as a means of assessing the amount of oil pollution on the lake. The reason for this choice was that sediments act as a reservoir in water and can preserve a pollutant long after it had been introduced in the lake. For example, in the case of oil, Brown and Lynch (1978) discovered in their research on "tanker tragedies", at the time of the oil spill, that the residual components of heavier oil may sink to the bottom and may be incorporated into sediments, shells or sand. Based on this understanding, sediments were used to ascertain the evidence of oil and heavy metal contamination in the lake.

Sediment samples were collected from three bays namely: Musende Bay (Fishing Companies and the Harbour), Chituta Bay at the mouth of Lunzua River and Isanga Bay in which Kalambo River drains (Figure 1). Sediments were collected using the grab sampler shown in Plate 5. Due to unevenness of the lake's bed sediments were collected randomly from different depths, the deepest being 21 m. Shell concentrations increased with depth such that it was difficult to obtain representative sediment

Plate 5. Sediment Sampling using a grab sampler on Lake Tanganyika, Kigoma (Grab sampling)

Photo by Barnabus Musonda, 1999.

samples from depths greater than 12 m. Most of the sediments collected were clustered in the 1- 10-metre depth range.

4.2.3 Structured Interviews

Since the study focused the effect of pollution on public health some residents of the town were interviewed in order for them to air their views on the same. The number of respondents for this study was 100 people. Since the population of Mpulungu urban and peri-urban is about 65 000, a sample of 100 represents 0.2% of the urban and peri-urban population was sampled. In order to have a good representation from each area of Mpulungu urban and peri-urban population, the following procedure was followed with regard to numbers of people interviewed or given a questionnaire: 20 residents of Mpulungu Township were sampled, and 10 from each of the 5 outlying villages namely MUSENDE, POSA, KASASA, NKUMBULA and MUZABWELA. Chosen due to their proximity to Mpulungu Township and their being accessible (Figure 6).

Thirty questionnaires were administered to people from Ministries of Health, Education, Agriculture and Departments of Fisheries, Marine and Waterways and Community Development within Mpulungu District. There was a special questionnaire for the six fishing companies within Mpulungu namely: St. George, Sopelac, Samaki, Mpulungu, San Andrea and Sabbra (Figure 6). Five questionnaires were given out to each fishing company in order to have a wider representation from each company.

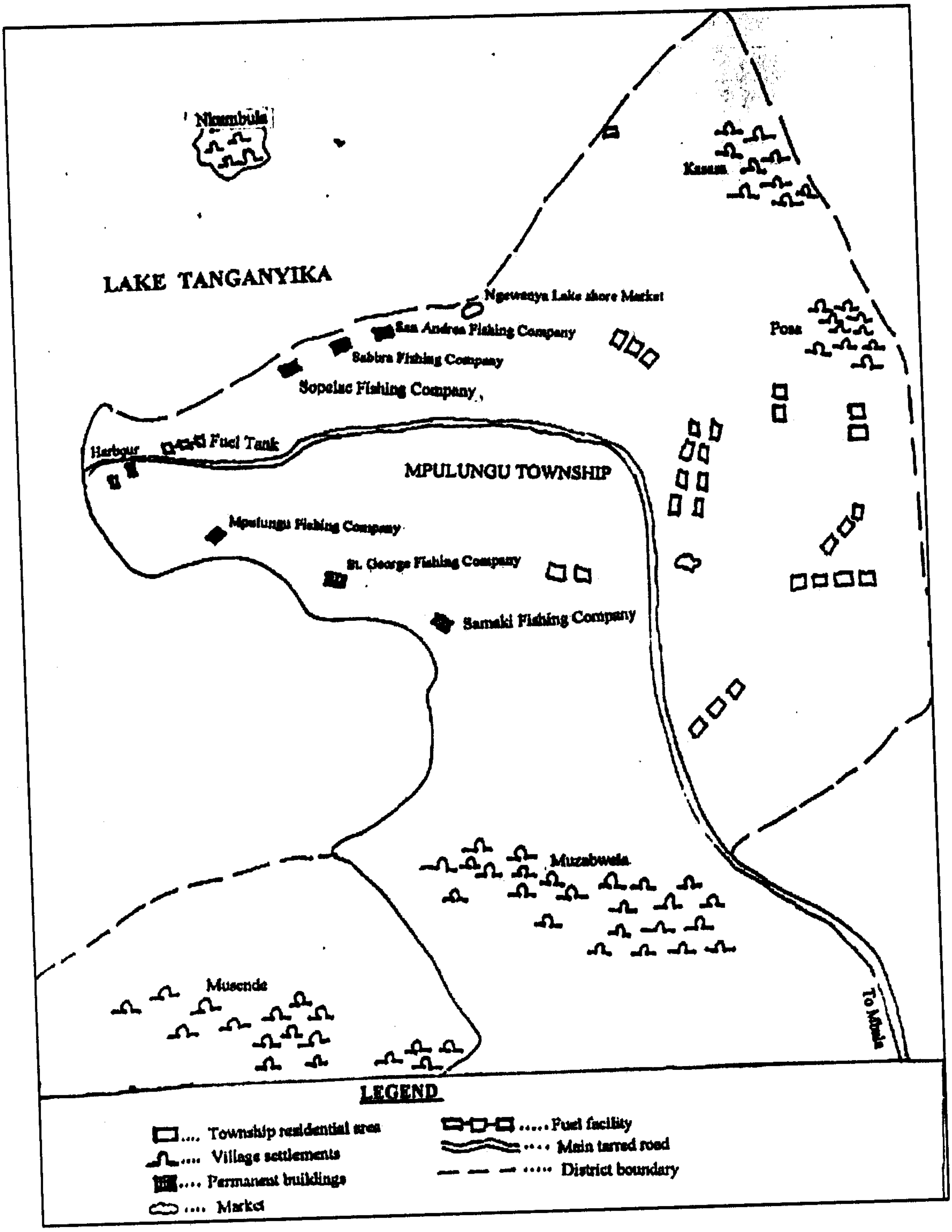


Figure 6. Sampling points (areas where interviews were conducted): Mpulungu Township, Fisheries and surrounding villages

4.3 Secondary Data Collection

4.3.1. Archival Data

Different types of data were collected from various stakeholders of Lake Tanganyika within and outside Mpulungu. Data on water-borne disease distribution, health and hygiene awareness campaigns, water quality studies and sanitation situation in Mpulungu were obtained from Mpulungu District Health Department and the District Hospital.

As the harbour is one of the suspect sources of pollution on the lake, information was obtained from the Department of Marine and Waterways. Data collected included the number of cargo ships, cargo storage facilities, number of passengers passing through the harbour and on the type of cargo passing through the harbour. Since at the same harbour there is petroleum storage and a filling facility right on the shore, a check was made for some possible areas of leakage. Another physical check was done on the handling of petroleum from the tank on land onto the vessels on the lake in order to establish the efficiency of the facility.

Information concerning lake water quality, water abstraction, sewage treatment, sanitation, solid waste disposal and water distribution in the township was obtained from Mpulungu District Council. This was to establish the possible sources of water pollution in the township and to find out what effort the council was making in reducing pollution and as well as keeping water safe for the public.

The Fisheries Department in Mpulungu is very much acquainted with the Lake Tanganyika since a lot of research concerning the lake in relation to fishing has been done through the same department. Most of the activities concerning the fishing industry in Mpulungu are monitored by the Fisheries Department. The vital information obtained from there include: catch trends, fish processing and marketing, fishing impact on water quality, lake water levels and on studies undertaken by various organisations and the department itself on Lake Tanganyika.

More information was also obtained from Lake Tanganyika Biodiversity Project whose objective is 'Pollution Control and other Measures to Protect Biodiversity in the Lake Tanganyika (LTBP Workshop, 1998). A lot of information on sediment pollution, studies done on the south Lake Tanganyika Basin as well as maps on the geology, geomorphology, relief and land use and deforestation of the south Lake Tanganyika basin were obtained (Sichingabula, 1998 and 1999). Some information was acquired through paper presentations during seminars organised by the Lake Tanganyika biodiversity Project in Lusaka, (Lukama, 1998).

The Northern Province Planning Unit is responsible for all activities taking place in all districts of the province. Information on the activities of District Water, Sanitation and Hygiene Education (D-WASHE) in Mpulungu was obtained. Other data obtained was on (land use), population, settlements, refugee movements, economic and social development.

Valuable information was also obtained from the Nyanza Project in Kigoma Tanzania through a course on the biology, geology, limnogeology, palaeontology, limnology and sedimentology of Lake Tanganyika, which the author attended in July – August 1999.

Other varied data on water pollution studies in general was obtained from the University of Zambia Library, the Forestry Department in Lusaka and the Environmental Council of Zambia.

4.4 Analytical methods

4.4.1 Water Sample Analysis

Each of the samples of water was analysed for pH, Dissolved Oxygen and temperature before they were taken to Water Affair's Laboratory in Kasama located 200 kilometres from Mpulungu for faecal and total coliform analysis. The samples had to be transported in a thermal bag and analysed within a period of 10 hours after collection. Coliform test was done because coliform is a good indicator organism for water that has received contamination of an intestinal origin (American Public Health Association, 1985). The Membrane Filter Procedure was used with 100 mls of water to analyse for faecal and total coliforms.

4.4.2 Lake Sediment Analysis for Hydrocarbons

Sediments were analysed for oil using two methods. The first was using Chloroform Reflux, and was done in the Chemistry Department, at the University of Zambia. This method was used because through refluxing, all possible oil molecules in a sample could be dissolved and released in chloroform. Since this method involved using chloroform which is not an ozone layer friendly chemical it was used with a lot of reservation due to the danger it could pose to the environment and to the analyst if exposed too long to the chemical.

The other simple but good method used was Acetone, which involved dissolving oil, filtration and evaporation (Orem, 1999). In this method, the concentration levels of oil in a sample was calculated as 100 times the weight gained by the preweighed flask containing filtered sample divided by the original sample weight as shown in the formula below.

$$\frac{\text{Weight gained by the flask}}{\text{Original sample weight}} \times 100 = \text{Oil levels/g (\%)}$$

Both of these methods were sensitive to minute concentrations of oil but the second was preferable, owing to its simplicity, fastness and that it left behind evidence of oil residue in containers. Testing for sensitivity of the methods, two sediment samples from Lake Chibesa, a very pristine inland lake in Kasama rural were analysed along side the lake's sediments and the results showed no sign of oil with complete dryness of the containers after use of Acetone. The first sediments were analysed for oil using the two methods in order to test the methods for precision, the results were identical.

4.4.3 Grain Size Analysis

In order to establish the relationship between grain size content of sediment and the distribution of oil, a simple method to establish the percentage of fine grains in sediments was used. Sediments were wet-sieved through the 63 μm nylon screen so as to find the percentage of the particles finer than 63 μm in each sediment sample. The dry samples were weighed before wet-sieving and then dried and then were finally re-weighed. The fraction lost, through sieving which was mainly clay and silt, was calculated as a percentage. This agrees with Briggs, (1977) who contends that, after shaking, the sediment retained on each sieve and in the pan can be weighed and recorded as a percentage of the total sample weight.

The 63 μm fraction was chosen because it can allow only the clay and silt particles to pass through. The clay and silt particle sizes were singled out to be the criteria for assessing oil distribution, because they have a very large surface tension on which oil easily adheres. Therefore, knowing the percentage of the fine grains in each sediment was an indicator for the distribution pattern of oil in (surface) sediments on the lake as the expectation was that sediments with high percentage of fine grains had higher levels of oil concentration.

4.4.4 Sediment Analysis for Heavy Metals

The sediments were analysed by Flame Atomic Absorption (spectrometry) by the Geochemical Analytical Laboratory in the School of Mines at the University of Zambia. This method involves subjection of a dissolved sample to a flame, where the droplets are then desolvated, vaporised and atomised to produce an atomic state of the metal of interest. This atomised metal is transported to an observation beam of the spetrophotometer where the concentration levels are read. Detailed explanation of the mechanism involved in atomisation process is too complex to be discussed here.

4.5 Limitations of the study

4.5.1 Sediment Sampling

The sediments collected from the 3 bays were not from a uniform depth due to the fact that each bay had its own morphology. Some localities were covered with shells, rocks, and plants, this made collection of sediments using a grab sampler almost impossible. Consequentially, it was impossible to collect sediments from a depth deeper than 12 metres because at such depths, the lake floor was covered with shells, which the grab sampler could not penetrate. The collection of sediments therefore was limited to very shallow depth from where the bulky of the sediments were sandy. Therefore, assessing the distribution of oil and heavy metals according to depth and fine grain size was limited.

4.5.2 Certainty about other Sources of Hydrocarbons

The study was limited as it only concentrated on surface sediments and attributed the entire possible hydrocarbon found on the lake to be a result of (represent) anthropogenic activities. Considering the presence of hydrocarbons from a natural source or that hydrocarbon pollution on the lake could be as a result of leakage from natural oil traps under the lake was not taken into account.

4.5.3 Water Sample Handling and Transportation

Water samples had to be transported from Mpulungu to the laboratory in Kasama for analysis. Mpulungu being humid and with very high temperature conditions, samples could have been affected while on transit despite the fact that samples were preserved in a cooler box. Additionally, time taken on transit was rather long, about 5-6 hours on the road before samples could be analysed. This time lapse from the time of sample collection to the time of analysis could have had some influence on the number of bacteria still alive at the time of analysis.

4.5.4 Heavy Metal Analysis

Use of Flame Atomic Absorption (spectrometry) was not very appropriate, as it is not sensitive to minute concentration levels of metals. Since concentration levels were very low in many sediments, use of Graphite Furnace Atomic Absorption method (not available at the time of analysis) would have been better as it is more sensitive to minute concentrations (Sichilima, 2000).

One general limitation was the lack of choice in the methods for bacteriological and heavy metal analysis due to lack of alternative equipment at the University of Zambia and the Water Affairs Laboratory in Kasama.

The next chapter discusses results of data analysis.

CHAPTER 5: ANALYSIS AND RESULTS

5.1 Introduction

This chapter discusses results of analysis of total and faecal coliform, pH, Dissolved Oxygen, and temperature, hydrocarbons and heavy metals data. The results which are presented graphically and statistically illustrate the mean concentration levels of total and faecal coliform for each month from October 1999 to March 2000, for Mbete Bay, Musende Bay and the Harbour/Ngwenya sampling points. Coliform levels are illustrated in relation to water temperature, dissolved oxygen, pH, depth and distance from the shore. Concentration levels of hydrocarbons and heavy metals in the sediments are discussed together with results of analysis of responses to questionnaires.

5.2 Physical factors contributing to pollution

During the study, respondents where questioned about the physical factors contributing to pollution on Lake Tanganyika (Appendix IIIa and IIIb). The observations by the respondents included factors like the sloping terrain of the land, which causes waste to easily drain into the lake, and 20 respondents (31.7 %) cited this. Seventeen respondents, (27 %) cited the hot weather, which recurs throughout the year, as one of the factors contributing to pollution. The reason being that certain bacteria thrive in warm conditions. Another factor cited was the presence of rocks which prevented people from digging deep pits which resulted in these shallow pits to overflow easily in the rainy season spilling waste into the lake reported by 16, (25.4

%) of the respondents and that there was no drainage out-let for the lake to help filter the water on the lake 10, (15.9 %).

5.3. Anthropogenic factors contributing to pollution on the lake

5.3.1. Settlement patterns: Observations

Villages in Mpulungu are made up of clusters of small family homesteads, (Plate 6). In most cases, each homestead is made up a main house, 1 or 2 smaller houses for children, a kitchen house, a small structure made of grass for bathing/sanitary purposes and a pit latrine. Most of these homestead's structures are only 4 m apart.

The pattern of Mpulungu Township is a bit different from that of villages. Most of the households in the township are in the high-density area with very few in the low-density zone. About 80% of the households have water-operated toilets connected to a council sewer system and out of these, about 40 % have cisterns.

5.3.2 People's views about settlement patterns.

Respondents described settlement patterns differently. Villages were described as being considerably spacious by only 4 respondents, (6.3 %), crowded, 12 (19.0 %) while others observed that the villages were very crowded 47, (74.6 %). In general, it was concluded that Mpulungu villages are clustered. With regard to the settlements in the township of Mpulungu, a moderate crowded environment was observed. The observations indicated 6, (9.5 %) spacious, 15, (23.8 %) as being clustered and 5, (7.9 %) as being very crowded. The township was therefore said to be moderately crowded.

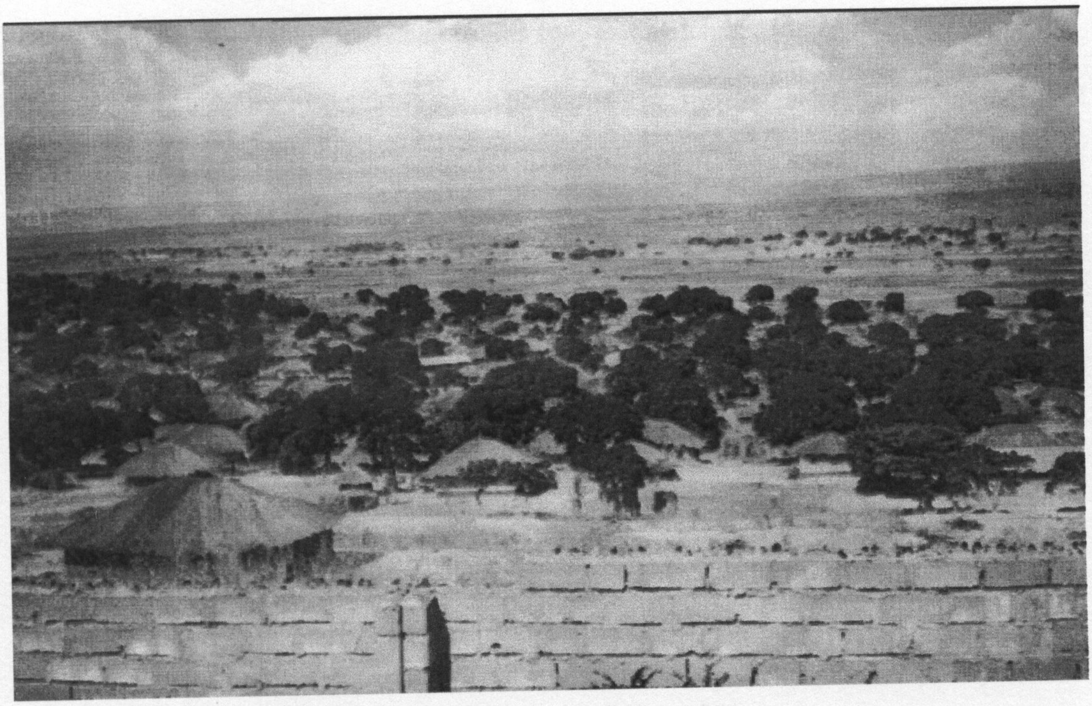


Plate 6. Clustered settlement patterns in Mpulungu Photo by Sr. Christine Kabumbu, February 2000.

5.3.3 Domestic and individual factors

During the study, a number of human factors contributing to pollution on lake Tanganyika were pointed out by the respondents which portrayed a picture that many individuals did contribute quite a lot to the degradation of the lake. Some of the activities singled out were the following: defecating and urinating directly on the lake 25, (39 %) doing laundry on the lake using different types of detergents 15, (23.8 %), throwing solid waste like old bicycles, batteries, plates, vehicle parts and other metallic items 13, (20.6 %) and finally, washing on the lake domestic utensils which were oily and greasy 10, (15.9 %).

5.4 Waste Management

5.4.1 Disposal of waste in Mpulungu Villages and Township

Mpulungu Township though small has people doing all sorts of activities like selling all kinds of merchandise, which produce a lot of waste matter, which in turn needs to be well managed or disposed of. The problems in Mpulungu lie in where most of the waste produced within and around the town is finally deposited. Most of the waste goes into the lake including plastics. People may try to dig dumping pits but they tend to be shallow and as a result the litter gets scattered on grounds. In areas where garbage slabs are built, it takes time to collect garbage.

5.4.2 Fish processing waste disposal site

Company workers were asked where waste fish matter of the company was thrown, 74.3% (26) indicated that they threw waste back into the lake; 14.3 % said they buried it in the ditches and 11.4 % said they threw it in bins.

Apart from fish products being thrown back into the lake, there are many other anthropogenic activities, which contribute to degradation of the lake (Table 1).

Table 1. Method of waste disposal by community and council in Mpulungu.

Response	Frequency	Frequency (%)
Thrown in the bush	15	23.8
Thrown into the lake	25	39.7
Thrown in ditches	14	22
Buried	9	14.3
Total	63	100

Table 1 illustrates the different methods employed in Mpulungu area in getting rid of waste material. The most prominent method shown is the throwing of waste into the lake as it proves to be the most effective way of hiding the waste. The next in popularity is the method of simply dumping the waste matter in the bush where it sometimes accumulates to alarming proportions as it awaits the rainy season to wash it down into the lake. The local council has no capacity to properly manage the waste in the township as the highest percentage of the waste is thrown in the lake or left in the bush.

5.5 Sources of water supply

Despite the fact that the lake receives so much waste, it is the source of most of the water used for domestic purposes in Mpulungu. People get water either directly from the lake or as piped water, which is pumped, from the lake. Waste matter like sewage and domestic solid waste go into the lake from which water is in return collected. Figures 8 and 9 show the location of the water intake point in relation to other points depicting human activities. The location of the sewage discharge is also shown with a village quite close to the point of discharge. Table 2 shows the extent to which the people in the village depend on the lake for domestic use.

Table 2. Water sources for Mpulungu households.

Response	Frequency	Percentage (%)
Lake (directly)	25	39.7
River	7	11
Well	2	3
Tap	29	46
Total	63	100

5.6. Status of Lake Tanganyika water in Mpulungu

5.6.1 People's views and attitude towards water

People in Mpulungu were questioned on how they viewed the water they used in terms of suitability, more especially for domestic purposes. Water in Mpulungu area was suspected to be contaminated by the people themselves due to the fact that a lot of waste material finds its way into the lake. Table 3 illustrates what the public thinks about the suitability of the water that they use for domestic purposes.

Table 3. Suitability of water for drinking in Mpulungu.

Response	Frequency	Percentage %
Not polluted	1	1.6
Slightly polluted	10	15.8
Quite polluted	32	50.8
Very polluted	20	31.7
Total	63	100

Even if 85.7% of the people in Mpulungu depended on lake water for domestic use, either directly or indirectly from the tap, more than half of the people viewed the lake as either quite polluted or very polluted. Even with this knowledge, the lake is the main source of domestic water.

With the general knowledge that the lake was polluted, asked as to whether the people boiled their water for drinking or not, it was found that 43 (68.3%) said they did boil, while 20, (31.7%) did not. It was observed that all the people who indicated that water was very much suitable for drinking, four were getting it from the lake and they indicated that they boiled their drinking water. Similarly, those who had said the water was moderately suitable (5) also indicated that they were getting their water from the lake and that they were boiling their drinking water.

Of those respondents who said the water was just slightly suitable for drinking, 17, (85%) said they were getting their water for drinking from the lake, two were getting it from the river and only one was getting it from the tap, they all however, boiled their water for drinking. Those who said the water was not at all suitable, 14 (41.17%) were receiving theirs from the tap and these fourteen boiled their drinking water, 20, (58.8%). Those who said the water was not at all suitable for drinking were receiving water from the tap these twenty, 58.8 % said they were not boiling water for drinking.

The reasons advanced for not boiling water for drinking by 20 (31.7%) was that water was purified by chlorine, which was added to the water. Those who had indicated that they boiled the water, 22 (34.9%) said water was too contaminated to be drunk directly. Eleven (17.5%) just felt the need to boil water for drinking because there was no chlorine added in the water to remove the impurities while 10 respondents (15.9%) boiled water for drinking because they were uncertain about whether the water in the township was treated with chlorine or not and boiling was just a way of not taking chances.

Contaminated water does not only affect human beings when this water gets into the stomach and in turn causes water-borne diseases but bad water can cause illnesses even when it just touches the skin as it can cause 'water-washed' diseases. In view of the latter type of diseases, the population was asked about its views regarding the water on Lake Tanganyika in terms of suitability for swimming. With regard to this, 13 respondents, (20.6 %) said the water was very much suitable for swimming, 5 (7.9 %) said it was moderately suitable, 20 (31.7 %) indicated that the water was slightly suitable while 25 (39.7 %) contended that the water was not at all suitable for swimming.

From the look of things, people in Mpulungu are conscious of the status of water on lake more especially in crowded places where water look turbid, is full of solid matter and has a foul smell.

5.6.2 Total and faecal coliform pollution

One of the study's focus was assessing the status of bacteriological pollution on the lake and this was done for 6 months (October 1999 to March 2000) in five stations. The study assessed the mean monthly levels for each station, mean levels for each point for all stations, and mean levels for each point in relation to distance from the shore for all stations, were determined (Table 4). This was in order to establish a clue on which stations in Mpulungu had the highest average bacteria counts, in which month bacteria levels were high, which specific points had high levels and at what distance from the shore the levels increased.

5.6.2.1 Distribution of coliform bacteria in Mpulungu Stations

The results revealed that Lunzua River Station had the highest mean total and faecal coliform levels of 82 and 32 colonies respectively, followed by Mbete station with 59 total coliform colonies, followed by harbour/Ngwenya, with 35 total coliform colonies, which was followed by tap water with 31 coliform colonies and the least was Musende station with 18 total coliform colonies. There was no station without coliforms (Figure 7). This meant that all the water sources were contaminated, only the extent of contamination varied.

5.6.2.2 Seasonal concentration of coliforms and disease outbreaks

For comparison purposes, here the responses of the respondents concerning the seasonality of diseases in Mpulungu are illustrated. During the interview, 57.1% of the respondents reported that diseases broke out mostly in the wet season. Others indicated that these diseases occurred throughout the year (13), 20.6%, (10) 15.9 % said they were most prevalent in the hot and dry season and only four, 6.3 % said they occurred in the dry and cold seasons. More than half of the respondents cited the wet season as having more disease outbreaks. Laboratory results recorded December and March which are wet months as having the highest levels of coliforms.

Figure 8 reveals that the distribution of coliform is not uniform throughout the year. There were monthly variations showing that there are less coliforms in water bodies in the on set of rains, and since samples were collected at the beginning of the month there was not much rainfall to cause any runoff. On average the highest faecalcoliform counts were on the other hand recorded in December and not in February.

Table 4. Water analysis results per station and per month

TOTAL COLIFORM COUNT

Distance & depth	Sample no.	Month	Mbete	Musende	Harbour	Tap	Lunzua R	Mean/mo
		November						
100 m- 0	1		9	4	10	1	2	
100m-5	2		10	20	31	13	4	
232m-0	3		6	6	21			
232m-5	4		5	7	9			
232m-10	5		3	6	8			
	Mean		**6.6**	**8.6**	**15.8**	**7**	**3**	**8.2**
		December						
100 m- 0	1		40	49	0	5	9	
100m-5	2		51	56	42	6	3	
232m-0	3		3	3	25			
232m-5	4		250	18	31			
232m-10	5		30	74	62			
	Mean		**74.8**	**40**	**32**	**5.5**	**6**	**31.6**
		January						
100 m- 0	1		4	1	4	97	96	
100m-5	2		25	1	4	89	84	
232m-0	3		3	2	10			
232m-5	4		2	1	7			
232m-10	5		23	3	2			
	Mean		**11.4**	**1.6**	**5.4**	**93**	**90**	**40.3**
		February						
100 m- 0	1		6	22	12	22	67	
100m-5	2		4	166	600	17	35	
232m-0	3		20	17	45			
232m-5	4		800	32	7			
232m-10	5		46	20	35			
	Mean		**175**	**51.4**	**139.8**	**19.5**	**51**	**87**
		March						
100 m- 0	1		0	0	6	45	120	
100m-5	2		186	3	34	67	57	
232m-0	3		5	0	0			
232m-5	4		0	4	2			
232m-10	5		25	13	2			
	Mean		**43.2**	**4**	**8.8**	**56**	**88.5**	**33**
	Mean/station		**62.2**	**21**	**40.36**	**36.2**	**47.7**	

Table 4 continued

FAECAL COLIFORM COUNT

Distance & Depth	Sample no.	Month	Mbete Station	Musende Station	Harbour/ N station	Tap water	Lunzua R. station	Mean/ Month
		October						
100 m- 0	1		0	0	1	0	0	
100m-5	2		1	1	1	0	0	
232m-0	3		0	0	0			
232m-5	4		0	0	0			
232m-10	5		0	0	0			
	Mean		0.2	0.2	0.4	0	0	0.16
		November						
100 m- 0	1		0	3	4	3	1	
100m-5	2		4	10	36	10	0	
232m-0	3		0	0	19			
232m-5	4		0	3	0			
232m-10	5		0	2	2			
	Mean		0.8	3.6	12.2	6.5	0.5	4.72
		December						
100 m- 0	1		28	3	0	0	3	
100m-5	2		12	0	18	4	2	
232m-0	3		0	0	68			
232m-5	4		180	3	20			
232m-10	5		10	69	10			
	Mean		46	15	23.2	2	2.5	17.8
		January						
100 m- 0	1		1	0	1	43	32	
100m-5	2		0	0	1	42	45	
232m-0	3		1	0	0			
232m-5	4		0	5	0			
232m-10	5		3	0	0			
	Mean		1	1	0.4	42.5	38.5	16.7
		February						
100 m- 0	1		0	14	3	6	32	
100m-5	2		1	42	110	7	21	
232m-0	3		2	5	3			
232m-5	4		2	9	1			
232m-10	5		2	9	0			
	Mean		1.4	15.8	23.4	6.5	26.5	14.7
		March						
100 m- 0	1		6	1	5	10	18	
100m-5	2		62	4	12	2	22	
232m-0	3		0	0	0			
232m-5	4		0	1	0			
232m-10	5		18	2	2			
	Mean		17.2	1.6	3.8	6	20	9.7

Key to distance & depth column of table 4

100m-0 = sample collected from a point 100 metres from the shore at the surface

100m-5 = sample collected from a point 100 metres from the shore at the depth of 5 metres

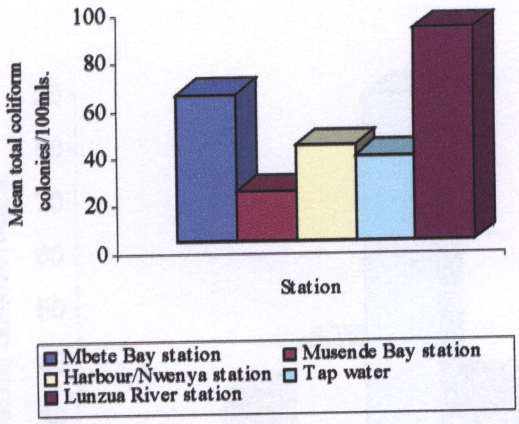
232m-0 = sample collected from a point 200 metres from the shore at the surface

232m-5 = sample collected from a point 200 metres from the shore at the depth of 5 metres

232m-10 = sample collected from a point 200 metres from the shore at the depth of 10 metres

Analyses conducted at Water Affairs – Kasama

(a)



(b)

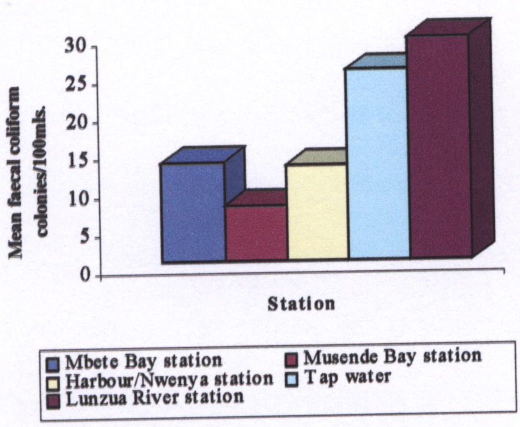


Figure 7. Mean Coliform bacteria counts at different Stations on Lake Tanganyikain Mpulungu, (a) Total coliform, (b) Faecal coliform

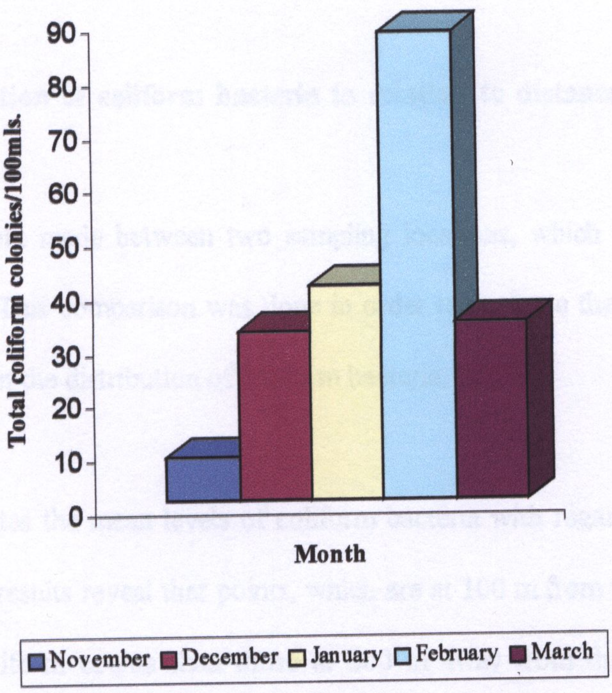


Figure 8. Monthly mean distribution of coliform in Mbete, Musende, Harbour/Ngwenya, Lunzua and Tap Stations in Mpulungu, (a) Total coliforms and (b) Faecal coliforms, October 1999 to March 2000.

This might have been necessitated by the fact that rains had just started becoming heavy, and so there was runoff, which washed down into the lake, all the faecal matter which might have accumulated on the land throughout the dry months.

5.6.2.3 Distribution of coliform bacteria in relation to distance from the shore and depth

Comparisons were made between two sampling locations, which varied in distance from the shore. This comparison was done in order to evaluate the effect of distance from the shore on the distribution of coliform bacteria.

Figure 9 illustrates the mean levels of coliform bacteria with regard to distance from the shore. The results reveal that points, which are at 100 m from the shore, recorded higher value/coliform counts than those at 200 m away from the shore. One quite revealing factor is the difference in the coliform counts between 5-m depth at 100-m offshore and 5-m depth at 200 m offshore. Even if the 2 points were at the same depth, the point closer to the shore still recorded higher levels. The same thing applied to the 2 surface points at different distances from the shore, the surface point at 100 m from the shore recorded higher values than the one (its counterpart) further from the shore. This could have been due to proximity to the point of introduction of waste. In general, both points at 5-m depth recorded higher values than the 10-m depth points.

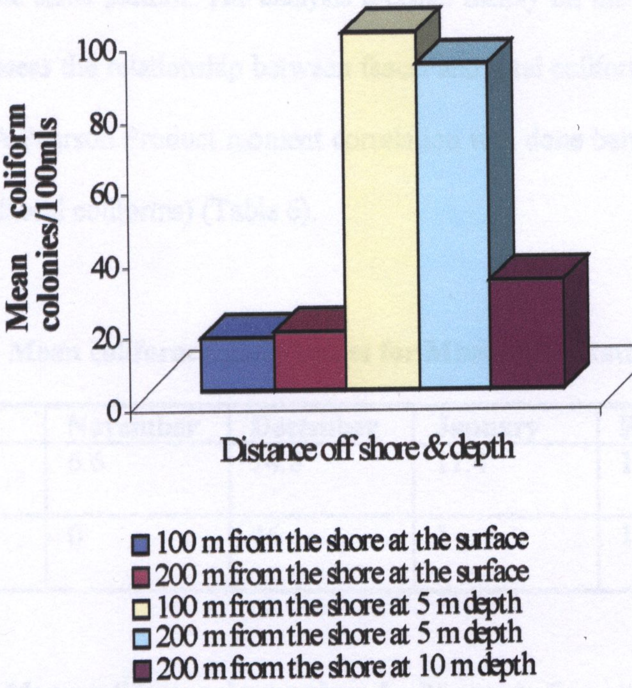


Figure 9. Distribution of coliform bacteria in relation to distance from the shore at Mbete, Musende, Harbour/Ngwenya, Lunzua River and Tap stations in Mpulungu.

5.6.2.4 Relationship in distribution between total and faecal coliforms on Lake Tanganyika

Data was analysed to see whether the distribution of total and faecal coliforms followed the same pattern. The analysis focused mainly on the stations on the lake in order to assess the relationship between faecal and total coliforms distribution (Tables 5a, b, c). A Pearson Product moment correlation was done between the two variables (total and faecal coliforms) (Table 6).

Table 5a. Mean coliform colony values for Mbete Bay Station

	November	December	January	February	March
Total coliform	6.6	74.8	11.4	175	43.2
Faecal coliform	0	46	1	1.4	17.2

Table 5b. Mean coliform colony values for Musende Bay station

	November	December	January	February	March
Total coliform	8.6	40	1.6	51.4	4
Faecal coliform	3.6	15	1	15.8	1.6

Table 5c. Mean coliform colony values for Harbour/Ngwenya station

	November	December	January	February	March
Total coliform	15.8	32	5.4	139.8	8.8
Faecal coliform	12.2	23.2	0.4	23.4	3.8

Table 5d . Mean coliform colony values for Tap water

	November	December	January	February	March
Total coliform	7	5.5	93	19.5	56
Faecal coliform	6.5	2	42.5	6.5	6

Table 5e. Mean coliform colony values for Lunzua River station

	November	December	January	February	March
Total coliform	3	6	90	51	88.5
Faecal coliform	0.5	2.5	38.5	26.5	20

Table 6 Results of correlation coefficients between total coliforms and faecal coliform in Mpulungu sampling stations

Sampling Station	**Correlation coefficients**
Harbour/Ngwenya Station	0.823
Musende Station	0.683
Mbete Station	0.273
Tap water	0.859
Lunzua River Station	0.899

Since faecal coliforms are just one of the types of coliforms found within the total coliforms bacteria, the number of faecal coliforms is some times dependent on total coliform numbers. However, total coliforms are very much independent of faecal coliform counts. There could be cases when there are many total coliform colonies but with no faecal coliform like the case of Mbete Station in November. In February, Mbete Bay Station had a mean of 175 total coliform against 1.4 mean colony of faecal coliform. In other words, there were blooms of total coliforms without a corresponding bloom of faecal coliform. February results of Mbete show the largest variation between the two variables.

There are times also when the majority if not all of the total coliforms found can turn out to be faecal, depending on the quantity of faecal matter present in the water. For instance January, Musende Station had a mean of 1.6 total coliforms and out of this, a mean of 1 was faecal. Another outstanding case is that of tap water samples in November where the sample without sodium thiosulphate had 13 total coliform count and out of these, 10 were faecal.

In all stations and months except for November in Mbete Station, all samples contained at least 1 or more faecal coliform. Generally, in Harbour/ Ngwenya, Tap water and Lunzua River Stations there was a corresponding distribution of total and faecal coliforms (Correlation coefficient of 0.823, 0.859 and 0.899 respectively). For all total coliforms found, there was an average number of faecal coliforms present. Harbour/ Ngwenya Station had a kind of normal distribution of coliform followed by Musende with a correlation coefficient of 0.683.

5.7 Status of Tap water in Mpulungu

There were some uncertainties as to whether piped water in Mpulungu was chlorinated or not. Some people had to boil water not because they were sure of the purification status of the water, but due to uncertainties. Other people did not see the need for boiling drinking water because they were convinced the water was clean enough due to added chlorine. Yet others also did boil water, as they were sure that water in the township was not chlorinated. Some people may have boiled water because the water was too contaminated and too turbid with low pH, so much so that putting little chlorine did not make much difference

5.7.1 Comparison of results for water samples with and without sodium thiosulphate

The uncertainties about the purity (status) of water prompted the researcher to carry out a test to assess whether the water had enough chlorine to make some difference in chemical and biological reaction of water through the effect of sodium thiosulphate. Table 7 shows the results of this comparison.

Table 7. Tap water analysis results

	TOTAL COLIFORM		FAECAL COLIFORM	
Month	**Sample with sodium thiosulphate**	**Sample without sodium thiosulphate**	**Sample with sodium thiosulphate**	**Sample without sodium thiosulphate**
November	1	13	3	10
December	5	6	0	4
January	97	89	43	42
February	22	17	6	7
March	45	67	10	12
Mean	**34**	**38.4**	**12.4**	**12.6**

A Pearson product moment correlation (r) was conducted in order to assess whether the difference in concentration levels of coliforms in tap water samples with and without sodium thiosulphate was significant. The assumption was that water, which was treated with sodium thiosulphate, should have had higher coliforms counts than the untreated one. The reason being that the sample without sodium thiosulphate still had chlorine (was not dechlorinated), and so the chlorine should have acted on any bacteria in the water samples, while the samples with sodium thiosulphate was dechlorinated hence allowing the thriving of bacteria. Table 8a and b below show a correlation between water samples, which were treated with sodium thiosulphate and the ones, which were not treated.

Table 8. Statistical relationship between water with and without sodium thiosuphate.

(a) Total coliform

r	Observations	F	Significance
0.948	5	26.34	0.05

(b) Faecal coliform

r	Observations	F	Significance
0.946	5	25.45	0.05

Significance of the relation between sodium thiosulphate treated water samples and the untreated water samples was tested at 0.05, chosen because according to Hampton (1994), this level represents a fairly reasonable compromise between the type I error and the type II error. For total coliform, (r = 0.948) and for faecal coliform, (r = .946), both of which were very strong correlations. With degree of freedom of 3, at significant level of 0.05 and one tailed test, the critical value of Pearson's r = 0.73. Since the calculated values of r for both total and faecal coliforms were higher than the critical values, the Ho therefore, was rejected. This meant that there was no significant difference in concentration levels between sodium thiosulphate treated water samples and the untreated water.

Using ANOVA, F- test in Table 8(a) and (b), with calculated F values of 26.34 for total coliform and 25.45 for faecal coliform, 1 was the numerator and 3 was denominator for both coliform, at 0.05 levels of significance for both. The critical F value was 10.13, which was less than the calculated F values for both coliforms. In this case, the Ho was rejected implying that there was no significant difference in the coliform levels of sodium thiosulphate treated water and that, which was not treated.

Since the difference was insignificant both with correlation and ANOVA, it could have meant that even the water with no sodium thiosulphate did not have anything to prevent bacteria from thriving. In other words, the water might have had very low levels of chlorine as to allow some more resistant bacteria to remain alive or that there was no chlorine added at all, otherwise, the levels of bacteria in the two samples should have differed greatly. Figure 10 shows the coliform counts in samples with and without sodium thiosulphate and revealed a situation where coliforms were even slightly higher in all samples not dechlorinated (without sodium thiosulphate). The ideal situation should have been that the water with no sodium thiosulphate should have had less or no bacteria at all.

5.8 Physical Water Quality

Dissolved oxygen, temperature and pH are physical characteristics of water, which play a big role in the distribution of various water pollutants. Since factors influencing pollution on the lake were to be established, water was tested for these parameters (Appendix IV). Correlation between physical factors and concentration levels of coliforms were done in order to ascertain whether there was a significant relationship between these variables. The summary of correlation analysis is presented in Tables 19.1, 2 and 3, showing the relationship between bacteria, DO, pH and temperature for the three stations.

Table 9.1.Correlation matrix for physical parameters for Harbour/Ngwenya Station.

Parameter	Total coliform	Faecal coliform	DO	pH	T°C
Total coliform	1				
Faecal coliform	0.8252	1			
DO	-0.0550	-0.0793	1		
pH	0.1877	0.1900	0.0214	1	
T°C	-0.1085	0.2013	-0.2225	-0.0234	1

There was a weak positive relationship between faecal coliforms and temperature, (0.2013), a weak negative relationship between dissolved oxygen and temperature (-0.2225), very weak relationship between faecal coliforms and pH (0.1900) and very weak relationship between total coliforms and pH (0.1877). The rest of the variables had no significant relationship at all. For example, there was no significant relationship between coliform levels and DO, no relationship between DO and pH and no significant relationship between pH and temperature. The relationship between total and faecal coliforms has already been discussed in section 5.5.6.

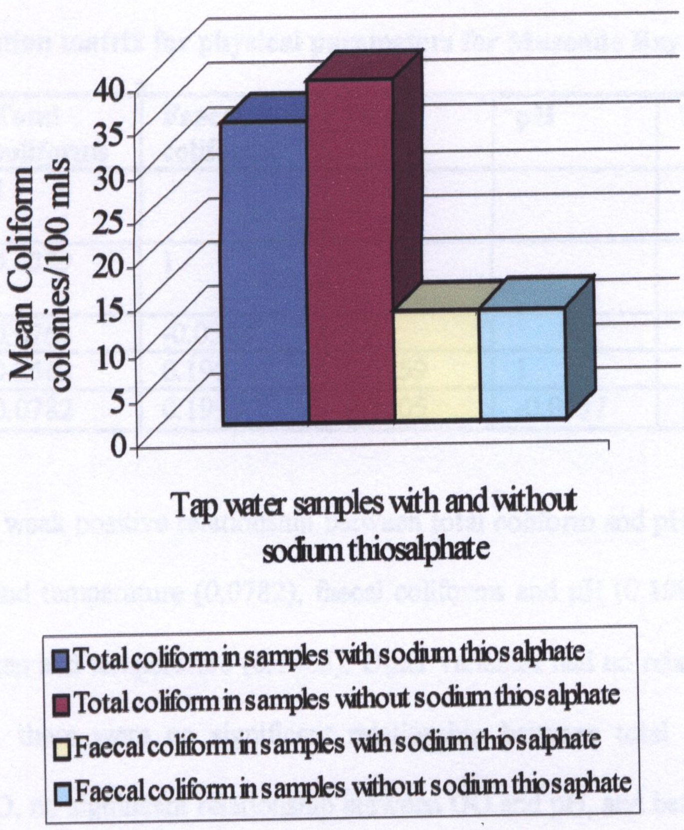


Figure 10. Concentration levels of coliform in tap water samples with and without Sodium Thiosulphate in Mpulungu Township.

Table 9.2 Correlation matrix for physical parameters for Musende Bay Station

	Total coliforms	Faecal coliforms	DO	pH	T°C
Total coliform	1				
Faecal coliform	0.6829	1			
DO	0.0768	-0.0578	1		
pH	0.2562	0.1987	0.0759	1	
T°C	0.0782	0.1993	0.1405	-0.0337	1

There was a very weak positive relationship between total coliform and pH (0.2562), faecal coliforms and temperature (0.0782), faecal coliforms and pH (0.1987) as well as dissolved oxygen and temperature (0.1405). Other variables had no relationship at all. For instance, there were no significant relationship between total and faecal coliforms with DO, no significant relationship between DO and pH, and between total coliforms and temperature. The relationship between total and faecal coliforms is already discussed in section 5.5.6.

Table 9.3 Correlation matrix for physical parameters for Mbete Bay station

	Total coliforms	Faecal coliforms	DO	pH	T°C.
Total coliforms	1				
Faecal coliforms	0.2734	1			
DO	-0.1057	-0.0518	1		
pH	0.2835	0.0028	-0.3696	1	
T°C	-0.0668	0.3892	0.4453	-0.3907	1

Table 10c shows a weak relationship between total coliforms and pH (0.2835), a moderate negative relationship between pH and temperature (-0.3902), a moderate positive relationship between DO and temperature (0.44) and a strong relationship between faecal coliforms and temperature (0.3892). There was no relationship between total coliforms and temperature, faecal coliforms and pH and faecal coliforms and DO.

Among the three stations, Mbete had more variables recording moderate relationships compared to the other two stations that had very few variables having some relationships. In all the 3 stations, there were some relationships between temperature and faecal coliform with Mbete recording the highest relationship of at least 0.389162.

Implications of these results are discussed in Chapter 6.

5.9. Hydrocarbon contamination on Lake Tanganyika

5.9.1 Sources of oil pollution

One of the factors contributing to pollution in the lake is the use of petroleum products that are mostly used by the fishing companies. With regard to this, companies were asked which products they used. The responses indicated that all sorts of petroleum products such as petrol, diesel, engine oil, and kerosene were used.

The purpose of the study was to establish whether there was any hydrocarbon pollution on Lake Tanganyika or not. People were asked questions concerning evidence of oil pollution on the lake. Various responses were given with (57), 90.5% of the respondents affirming oil pollution, indicating that there was overwhelming evidence of oil pollution on the lake. Out of all these respondents only 6 (9.5%) said there was no evidence of oil pollution.

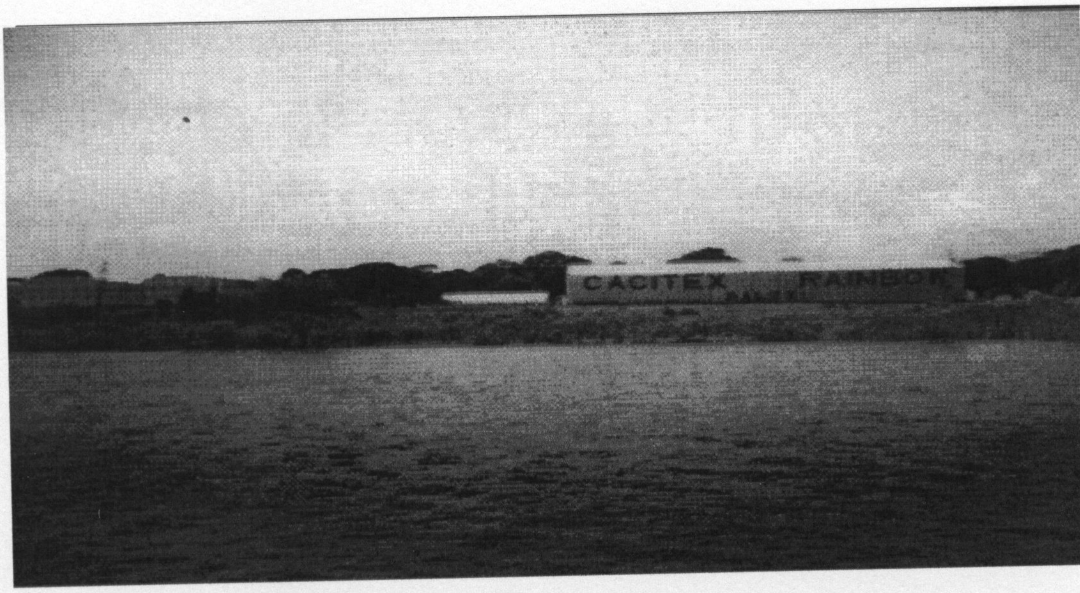
Both the community and the fishing companies agreed unanimously that there is evidence of oil pollution on the lake. Out of all the respondents of the two questionnaires, 98.6 % agreed to the fact that evidence of oil pollution was there on the lake Table 10 reveals the sources of this oil pollution within Mpulungu. Though not mentioned by the community or the fishing companies, the oil tank at the harbour could be one of the sources of pollution on the lake. Plate 7 shows that the transit point of crude oil for export is right on the lake and so chances of spillage are quite high.

Table 10. Sources of oil pollution on Lake Tanganyika in Mpulungu.

No. Response	Frequency	Percentage %
1. Leakage from boat engines	10	15.9
2. Bilge water mixed with oil thrown overboard	23	36.5
3. Oil spills into the water when boats are being repaired on the lake	26	41.3
4. Used oil thrown on the lake	30	47.6
5. Oil left on land is washed into the lake	9	14.3
Total		100

The research further probed from the companies the specific areas in which petroleum was used. Answers included boat engine, cold rooms, generators, winches and water pump. Three respondents (8.6%) said they used petroleum only in one of these areas; one company (2.9%) used it in two of the above-mentioned areas, eight companies (22.9%) used it in about three areas; seven companies (20%) used it in four areas and

(a)



(b)

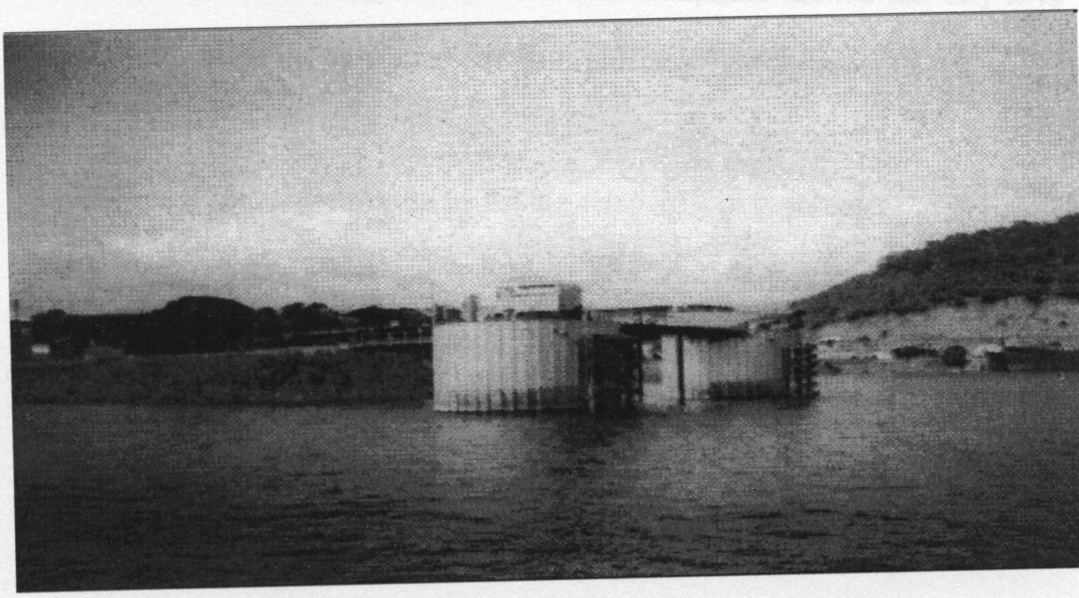


Plate 7. Crude oil transit point at the harbour on Lake Tanganyika in Mpulungu.

Photograph by Sr. Christine Kabumbu, December 1999.

sixteen (45.7%) used it in all the mentioned areas. It could thus be established, as shown, that majority of the companies use petroleum in about three or more areas.

From the look of things all seems to be well on the Zambian side of Lake Tanganyika since there are no major industries and that the few companies in Mpulungu have taken pollution control measures.

The study revealed the different areas in which the fishing companies in Mpulungu use different petroleum products. The areas included engines, generators, water pumps, winches, cold rooms and night lamps. The same companies showed that they have different ways of getting rid of used petroleum products.

5.9.2 Disposal of used petroleum by fishing companies in Mpulungu

The companies were asked with regard to how they dispose of used petroleum products. Ten (28.6%) of the responses showed that they filled it into drums, 51.4 % (18) claimed it was dumped off shore while 20 % (7) said that they gave it to the local people for pest control.

Regarding how petroleum was disposed of and whether the respondents were suspicious of oil pollution on Lake Tanganyika, 10 of the respondents who had said they filled the oil into drums also said they suspected oil pollution on the lake. Even those who had said they dumped it off shore 51.4% also indicated that they suspected oil pollution on the lake. Five of those who had said they gave it to local people for pest control also said they were suspicious of oil pollution on the lake. Only 2, (5.7%) claimed not to be suspicious of any oil pollution on Lake Tanganyika.

In response as to whether petroleum was used and about whether people suspected oil pollution on Lake Tanganyika, 94.3% who had said they used one or two forms of petroleum products in various areas, did say that they suspected oil pollution on lake Tanganyika. Only (2), 5.7% were not suspicious of oil pollution on Lake Tanganyika.

The methods employed in discarding oil do not really guarantee the prevention of oil getting into the lake. Dumping oil offshore by the majority of the workers simply means that that same oil gets washed back into lake. The study revealed that some oil gets into the hands of local people, such that that chances of mishandling are very high and finds its way into the lake either as part of runoff or just thrown back into the water.

5.9.3 Distribution of hydrocarbons in surface sediments

Levels of oil on Lake Tanganyika in Mpulungu were determined through analysing surface sediments and the results were shown as percentage per gram of dry sediment (Table 11)

Apart from establishing the levels of oil in sediment (Figure 11), attempts were made to see whether there was a relationship between depth and the percentage of fine grains in a sediment sample had with the patterns of distribution oil in the sediments. This relationship is illustrated in Figures 12.1 and 12.2, where percentage oil levels are plotted against depths at which sediments were collected and percentage of fine grain particles in each sediment sample.

Each of the oil graphs (Figures 12.1 and 12.2) are shown with r^2 values in order to determine how much each of the two variables namely depths and percentage of fine grains accounts for the concentration levels of oil in each bay. The result is that in Musende Bay, the coefficient of determination $r^2 = 0.464$, meant that only 46% of the distribution of oil was accounted for by depth of the lake from where the sediments were collected. This implied that 54% were caused by other factors, which influenced the distribution of oil.

5.9.4 Analysis of hydrocarbon distribution according to depth and percentage of fine grains in sediments

An analysis was carried out to assess the effect of depth of the lake and the percentage of fine grains in sediment. A simple correlation analysis was done to determine the relationship between the named variables. Table 12 illustrates the biviriate correlation analysis between oil levels, depths and percentage of fine grains in sediment samples. Since there were 2 variables namely, depth and percentage of fine grains, a simple Correlation Analysis was done just for Musende Bay, which had significant levels of oil in order to establish the influence of both variables on the distribution patterns of oil. Significance was tested at 0.05.

Table 11. Results of analysis for oil in surface sediments

STATION	DEPTH (m)	OIL %	FINE GRAINS %
Musende Bay	1.1	0.2	25
Musende Bay	1.2	0.1	21
Musende Bay	3.1	0.1	26
Musende Bay	3.5	0.4	43
Musende Bay	4.3	0.1	16
Musende Bay	5.1	0.3	30
Musende Bay	6.9	0.4	37
Musende Bay	7.2	0.4	48
Musende Bay	7.7	0.4	43
Musende Bay	9	0.4	68
Musende Bay	1.5	0.3	32
Chituta Bay	3.4	0.15	27
Chituta Bay	4.7	0.15	17
Chituta Bay	5	0.1	11
Chituta Bay	5.2	0	23
Chituta Bay	5.5	0.15	26
Chituta Bay	6	0.1	16
Chituta Bay	6.9	0.05	12
Chituta Bay	7.8	0.05	21
Chituta Bay	10	0.15	23
Isanga Bay	2	0.15	22
Isanga Bay	4.7	0.15	19.7
Isanga Bay	5	0.2	24
Isanga Bay	6.4	0.15	70
Isanga Bay	8.4	0.2	29
Isanga Bay	10	0.2	20
Isanga Bay	15	0.25	8
Isanga Bay	21	0.2	46

Analysis conducted in the Chemistry and Geography Departments, University of Zambia

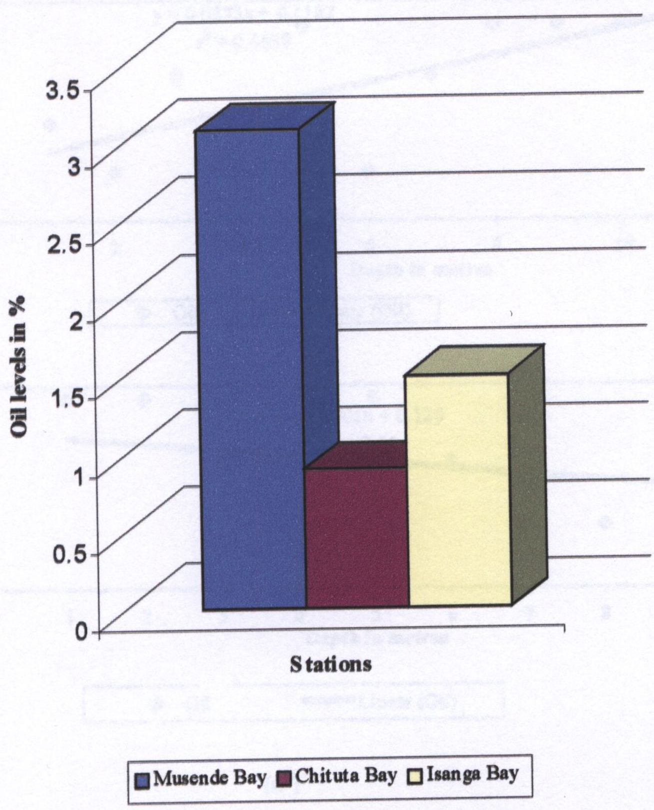


Figure 11. Mean oil concentration levels in Mpulungu Bays.

October and November 1999.

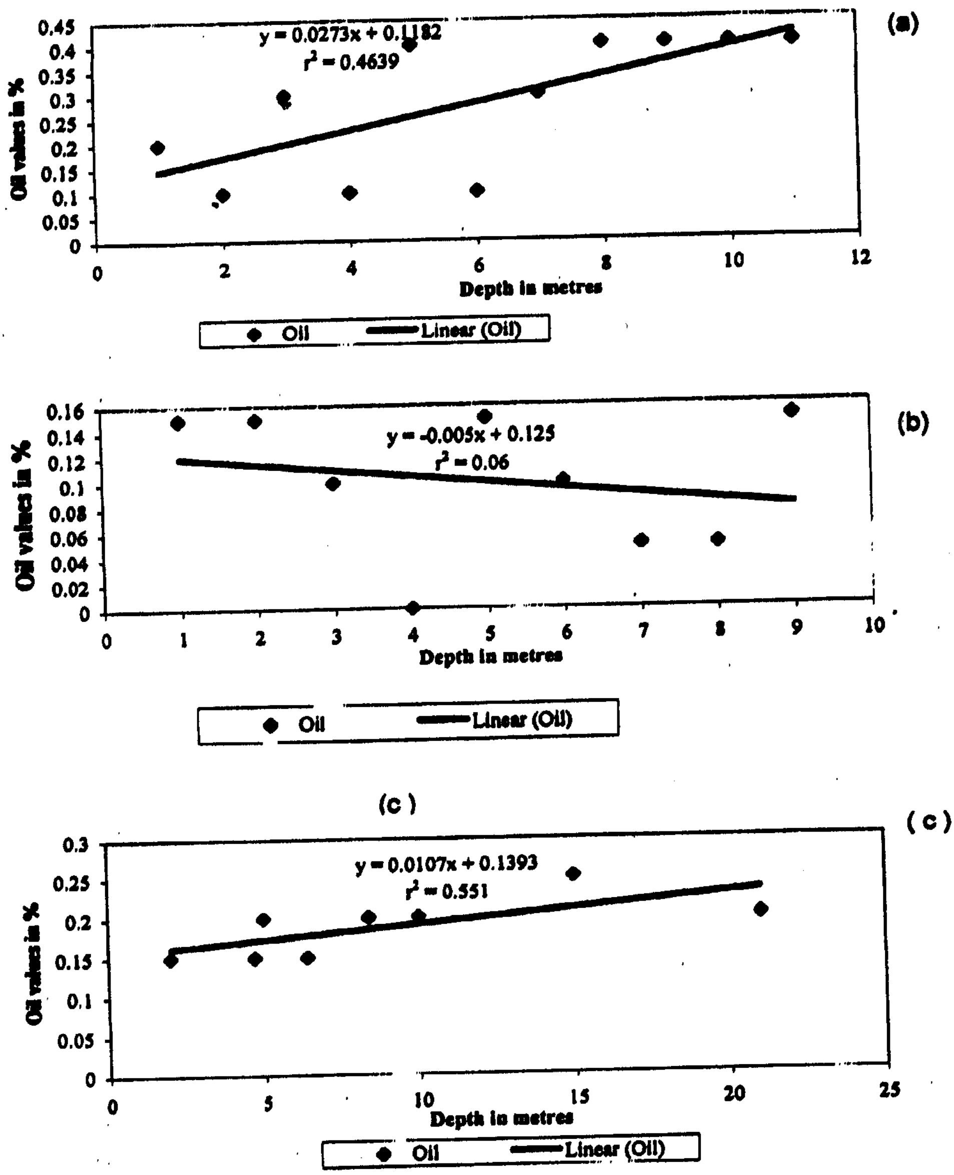


Figure 12.1. Relationship between concentration levels of oil and percentage of fine grains in sediments on Lake Tanganyika in Mpulungu at (a) Musende Bay, (b) Chituta Bay and (c) Isanga Bay.

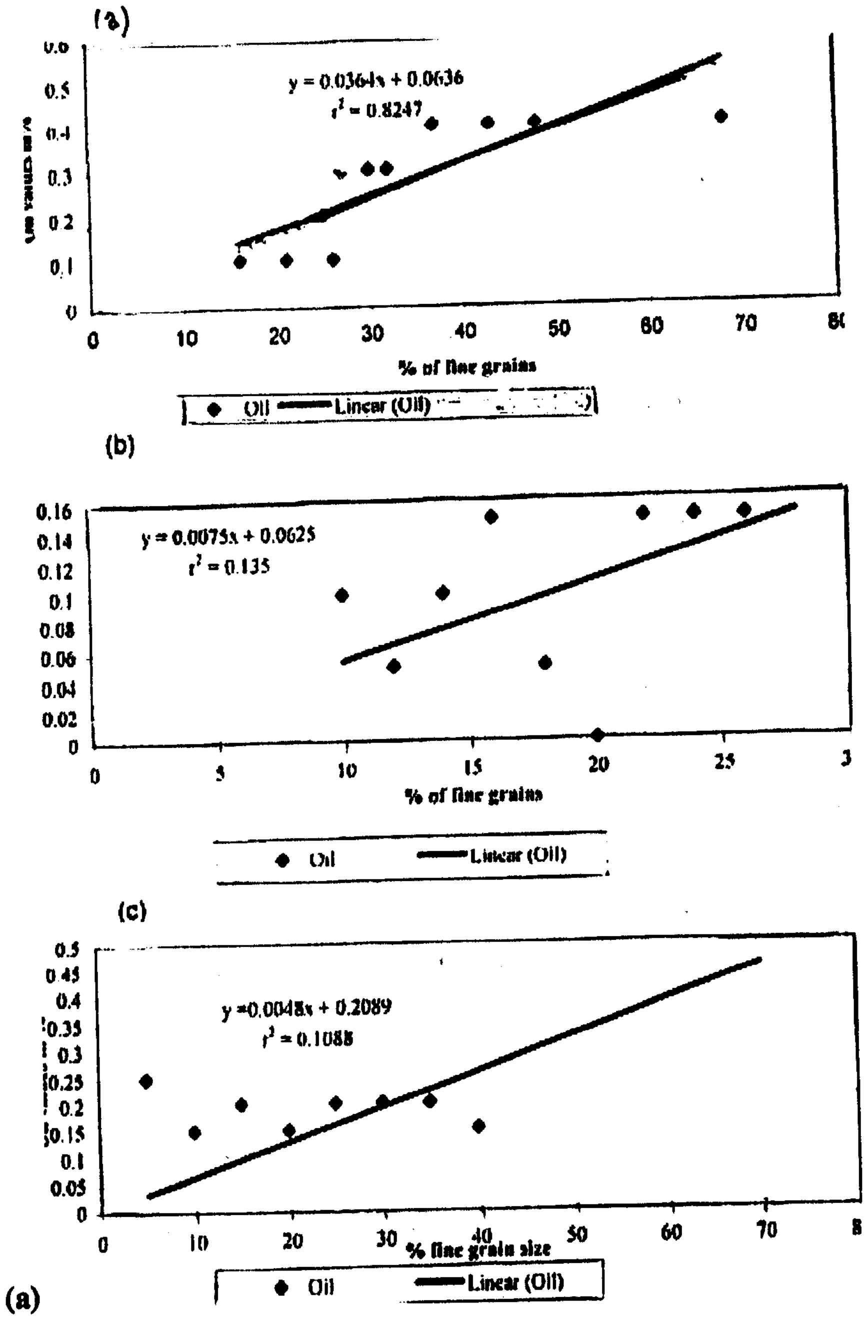


Figure 12.2. Relationship between concentration levels of oil in sediments and depth on Lake Tanganyika in Mpulungu at (a) Musende Bay, (b) Chituta Bay and (c) Isanga Bay.

Table 12. Correlation matrices for oil analysis parameters on Lake Tanganyika in Mpulungu area.

a. ***Musende Bay***

Paramete r	Oil	Depth	Fine grain
Oil	1		
Depth	0.678	1	
Fine grain	0.813	0.950	1

b. ***Chituta Bay***

Parameter	Oil	Depth	Fine grain
Oil	1		
Depth	-0.086	1	
Fine grain	-0.268	0.944	1

c. ***Isanga Bay***

Parameter	Oil	Depth	Fine grain
Oil	1		
Depth	-0.388	1	
Fine grain	0.457	0.988	1

There is a strong positive relationship between all the variables in Musende Bay. The concentration of oil followed the distribution of fine grains (0.813) as well as the depth of the lake. From the results, there was a very strong relationship between the distribution of fine grains in sediments and the depths of the lake (0.988). The greater the depth of the lake, the finer the grains and the more oil there was in the particular sediments.

There was a very strong relationship between depth of the lake and the distribution of fine grains in Chituta Bay (0.944) and a weak relationship between the concentration of oil and the distribution of fine grains in the sediments (-0.268). There was no relationship between oil concentration and the depth in Chituta Bay (-0.086).

In the case of Isanga Bay, there was a very strong positive correlation between depth of the lake and distribution of fine grains in sediments (0.988). However, there was only a moderate positive relationship between oil levels and percentage of fine grains in the sediments (0.457) and also a moderate weak relationship between depth and oil levels (-0.388). Isanga Bay results did not follow the fact that the higher the percentage of finer material, the higher the amount of oil trapped due to attraction force. The deeper the lake got the lesser the levels of oil though finer the grains became. This simply meant that there was very little evidence of oil because if it were present, it would have followed the distribution of fine grains and depth. In this case, the finer and deeper the lake became, the less the percentage of oil.

5.10 Heavy Metal pollution on Lake Tanganyika

Asked whether the respondents had evidence of heavy metal pollution on Lake Tanganyika in Mpulungu, 93% answered in the negative. Heavy metal pollution cannot easily be noticed with naked eyes as oil can, and so one cannot be sure as to whether the water is polluted or not. Despite the fact that the local community does not seem to be aware of any metal pollution, the same community is quite aware of the possible ways companies and individuals can be sources of heavy metal pollution on the lake.

In the questionnaires administered, 51.4% of the respondents cited rusted boats to be a source of pollution, 28.6% pointed out that shipwrecks left in the lake were a source of metal pollution, throwing of metal pieces like old pipes, batteries and so forth was cited as a source of pollution by 11.4% of the respondents. The other 8.6% of the respondents mentioned loose particles from old boat left on the shore and dust particles as boat keep on grinding against surfaces as a source of heavy metal pollution.

As regards heavy metal pollution, respondents were asked whether they had experience of someone who got sick after drinking water contaminated with metals (chemicals). Sixty, (95.2%) said that there was no evidence, while only three 3, (4.8%) responded in the affirmation that there was evidence of chemical poisoning from lake water. Similarly, there were low responses with regard to the actual presence of heavy metal pollution on Lake Tanganyika with (50), (79.4%) of the respondents indicating the lack of evidence of heavy metal pollution and only (13), 20.6% indicated that there was evidence. Of those who said there was evidence of heavy metal pollution on the lake some of the possible sources of such pollution included unpainted boats at the harbour, old boats damped in the lake, ship wreckage left on the shore, dropouts from the cargo at the harbour and also from metallic items thrown carelessly as waste into the lake.

Regarding how the companies contributed towards heavy metal pollution, (5), 14.3% of the respondents said it was slightly polluted and (12), 34.3% said it was quite polluted. Of those who had said it is quite polluted, 8 also said that their company contributed through rusted boats and metal sheets, which got dissolved into the water. Four of those who had said the lake was quite polluted mentioned that their company contributed through grinding of boat metal, which got into the water as dust. One of the respondents, who had said it is quite polluted and (9), 25.7% who had said the lake was much polluted, indicated that their companies contributed to heavy metal pollution on the lake through old boats left on the shore which got worn out and whose loose particles got dissolved in the water.

One possible source of heavy metal could be rocks in the lake that could dissolve if water is very acidic. This possible source can be ruled out though because during this study, the average pH of the water was 8.5, which was neutral.

5.10.1 Painting of boats by fishing companies

Rusting of unpainted boats was one of the possible sources of heavy metal pollution if boats are left anchored in the water and rust is released into the water. Paint especially the anti-fouling type, contains a lot of lead (pb) Wilber (1969) which can in turn pollute water as the paint gets worn out from the boats. Companies were asked how often they painted their boats and what type of paint was used in order to determine whether paint and boat rusting had an effect on the lake, (15), 42.9% of them said they paint their boats once in a year. Twenty, (57.1%) said they painted their boats after two years. As regards the paint used for painting boats, the responses were that, 13, (37.1%) said they used Red Oxide paint. Twenty-two, (62.9%) said they used oil paint.

Thirteen 13, (37.14%) said they used Red oxide paint and only two of those who said they used oil paint said they paint once a year. Twenty, (57.1%) of those who said they used oil paint, mentioned that they painted their boats after two years .It can thus be said that those who used oil paint took at least 2 years to paint the boats while those who said they used Red Oxide had to paint the boats at least once a year.

5.10.2 Heavy metals in surface sediments

Laboratory findings for surface sediment in on Lake Tanganyika in Mpulungu are presented in Table 13. Figure 13 illustrates mean concentration levels for copper, lead and aluminium for each station with Chituta Bay recording the highest in heavy metal levels. Figure 14 also illustrates the levels of a particular metal for all the bays, with lead recording the highest metal in the area. This was done in order to establish which bay had the lowest or highest levels of concentration for each particular metal.

5.11 Suggestions on Waste Management and conservation of Lake Tanganyika in Mpulungu

5.11.1 Measures by the Local Authority in Mpulungu

The people were asked on how best the waste (rubbish) issue could be tackled in Mpulungu so as to put pollution of the lake under control. The possible ways suggested included the following: (i) improving on the sewage system in Mpulungu which people felt was wanting 29, (46%), (ii) serious environmental campaigns and awareness by the Ministry of Health 14, (22.2%), (iii) the District council to do regular garbage removal in the township 9, (14.3%), (iv) the government to provide waste management equipment to
the council for garbage disposal 5, (7.9%) and finally (v) to encourage the construction of VIP (Ventilated Improved Pit Latrines) in the villages 1, (1.6%).

Table 13. Results of analysis for heavy metals in surface sediments.

STATION	DEPTH in meters	COPPER - mg/l	LEAD- mg/l	ALUMINIUM Mg/l
Musende	1.5	0.078	1.19	0.44
Musende	5	0.124	0.2	0.5
Isanga	5	0.136	0.04	0.03
Chituta	6	0.099	4.06	0.21
Chituta	10	0.035	0	0.02
Chituta	5	0.051	0	0
Chituta	3.4	0.19	0.42	0
Musende	9.3	0.1	0	0.08
Musende	2.5	0.	0	0
Chituta	8	0.496	38.2	0
Isanga	9	0.189	0.07	0.07
Isanga	7	0.12	0.09	0

Analysis conducted in the Metallurgy Department, University of Zambia

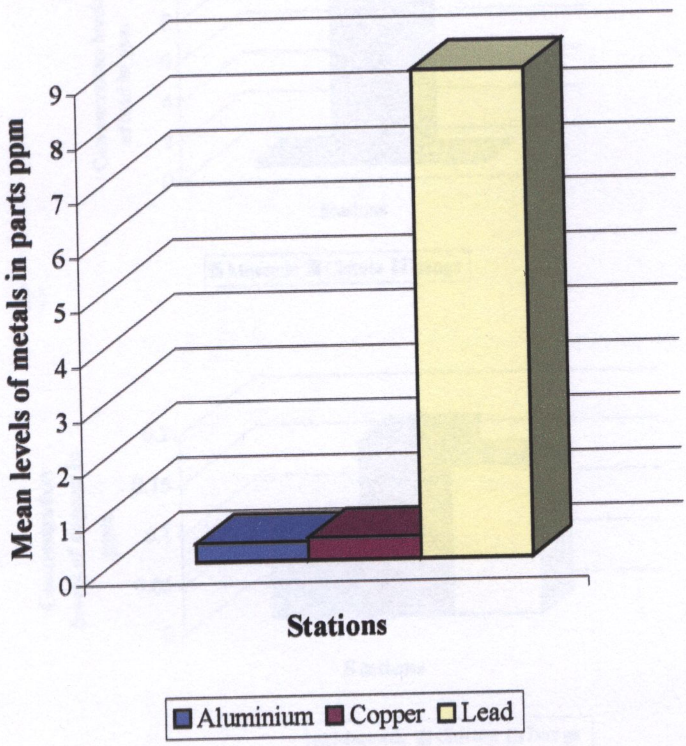
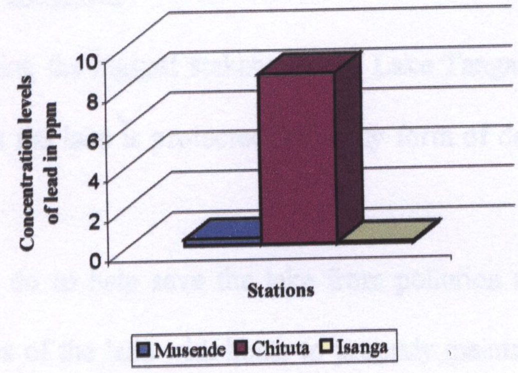
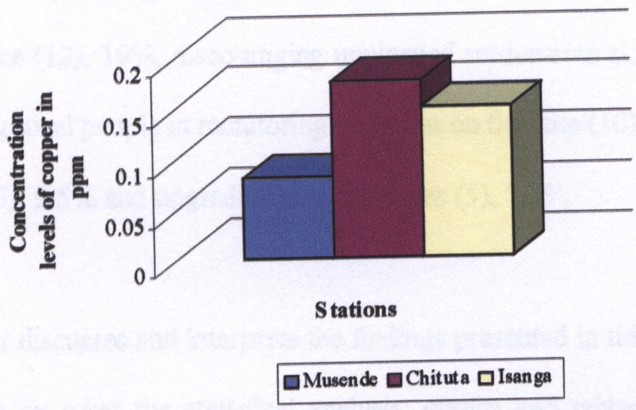


Figure 13. Combined plot of heavy metals concentration levels in Musende, Chituta and Isanga Bays.



(b)



(c)

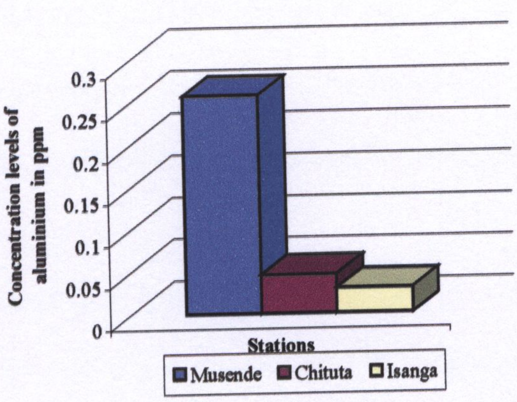


Figure 14. Mean concentration levels of heavy metals in Mpulungu Bays.

(a)Lead, (b) Aluminium and (c) Copper

5.11.2 Government measures

The Government being the biggest stakeholder of Lake Tanganyika has a big role to play in ensuring that the lake is protected from any form of degradation. Concerning what the

Government should do to help save the lake from pollution (20), 31.7% advocated encouraging all users of the lake with boats to properly maintain the boat by painting them to avoid rusting, make a deliberate policy to help minimise the number of boats sailing on the lake (12), 19%, discouraging unplanned settlements along the lake (10), 15.9%, involving local people in monitoring pollution on the lake (10), 15.9%, building a modern port (6), 9.5% and upgrading trading places (5), 7.9%.

The next chapter discusses and interprets the findings presented in this chapter so as to make inferences on what the statistical analysis, graphs and tables presented imply regarding oil, bacteriological and heavy metal pollution on Lake Tanganyika.

CHAPTER 6: DISCUSSION AND INTERPRETATION

6.1 Introduction

The quality of an environment hinges on how waste products are handled. In the case of a water body like Lake Tanganyika, in Mpulungu, the lake depends on how environmentally friendly the stakeholders are. The previous chapter has shown how waste is managed in Mpulungu by the local authorities, companies and individuals. Apart from the physical aspect of Lake Tanganyika and its surrounding areas having an effect on pollution occurrence and distribution, most of the pollutants found on Lake Tanganyika in Mpulungu is due to anthropogenic activities. In this period of economic hardships what is in any businessperson's mind is to make ends meet regardless of who is affected. The "good business" syndrome seldom takes account of the human toll inflicted by any adverse method to obtain whatever one hopes to get. Cartledge (1994) contends that through greed and ignorance, water has become a bringer of disease and death rather than life. Lungu (1998) also mentions that the threats of degradation of biodiversity in Mpulungu comes from the accelerating rate of environmental change caused by human activities which is much faster than the fauna's adaptive capabilities.

6.2 Bacteriological pollution in Mpulungu

Coliforms do not in themselves entail a hazard, but coliform in water indicates that faecal matter has entered a water body and that the water is liable to contamination with dangerous organisms. In Mpulungu where over 50 % of the population depends on water from the lake and yet not a single sampled station has a mean total or faecal coliform colonies below zero. For instance the tap water samples recorded the second highest number of faecal coliform colonies, this is seemingly a risky situation because this is the water people in the Township depend on.

Analysis of results showed that all the stations recorded coliform above WHO maximum permissible levels. With such water containing so much coliform, one would not expect a very health population in the area. Links have been established between sewage contaminated water and the occurrence of illness such as gastrointestinal infections (Chapman, 1992). In Mpulungu, Cholera is a common phenomena and the presence of faecal coliforms in sampling stations in this study leaves no doubt that there is a link between water quality in the area and the occurrence of cholera and other water related diseases. For instance, during the months of December to March when the faecal coliforms counts were high, the cholera cases were equally high (Table 14). This corresponds with the responses from the respondents where 57.1% the responded that diseases mainly broke out during the wet season. The more the coliforms count in the water, the higher the prevalence of diseases in the area.

6.2.1 Variations of coliform levels in Mpulungu Stations

The results reveal that Lunzua River Station had the highest mean levels of both total and faecal coliform of 88 colonies/ 100mls (Figure 7). An explanation for this phenomenon could be that the few people living along the upper part of the river have no proper sanitary facilities and as a result, they use the upper part of Lunzua River for all washing and sanitation. On the other 3 stations located on the lake itself, the highest coliform levels were recorded at Mbete Bay with mean total and faecal

Table 14. Recorded cholera cases in Mpulungu, 1999 – 2000

No.	Month	No. of cases in 1999	No. of cases in 2000
1	January	76	9
2	February	17	4
3	March	38	15
4	April	7	0
5	May	0	1
6	June	0	No record
7	July	1	"
8	August	0	"
9	September	0	"
10	October	0	"
11	November	0	"
12	December	0	2
	Total	**139**	**31**

Case distribution of cholera in 2000

No.	Location	No. of Cholera cases
1	Kasasa	3
2	Kapoko	1
3	Nakaku	2
4	Mbete	1
5	Kapembwa	3
6	Kabyolwe	10
7	Iyendwe	11
	Total	**31**

Source: Mr. L. Musonda (Mpulungu District Health Information Officer) coliform colony values of 88 and 35 respectively. Musende Bay despite the fact that it has the sewer outlet point recorded the lowest mean levels of total and faecal coliform colony values of 17 and 5, out of all the five stations.

A possible explanation for this could be that the sewage matter being discharged undergoes some natural purification at some point before it finally reaches the lake. If there wasn't any purification of the sewage matter along the way, the coliform values in Musende Station should have been the highest as was actually expected. The other explanation is that the work of D-WASHE (District Water, Sanition and Health Education) which has been working in Muzabwela and Musende villages close to the sewer inlet has had some positive impact. This had been done through environmental awareness lessons, which have conscientised people in matters concerning health and the environment. This has helped in reducing the amount of faecal matter entering the lake from the two villages (Provincial Statistical Office, 1999). Mbete Bay Station despite the fact that it was far from the sewer inlet had the highest coliform counts, implying that raw sewer matter was present in the water from Mbete and Kasakalawe villages along the lake.

6.2.2 Total coliform versus faecal coliform

From October 1999 to March 2000 when the study was done, the common feature was that faecal coliform levels had similar trends as that of total coliforms. In most cases, when total coliform levels were high, so were faecal coliforms except for December and February. For total coliforms, February had the highest mean levels of 120 colonies/100mls, while faecal coliforms had the highest mean values of 20 colonies/100mls in December.

The explanation for this trend could be that, throughout the year in Mpulungu most of the human waste was deposited on land as reported by some respondents, whereby some of it was buried in very shallow ditches. Also, most of the accumulated faecal matter was mobilised by heavy rains and consequently, most of this waste got washed into the lake by the first heavy rains in December. This partly accounts for high faecal coliforms in December compared to other months. Conversely, though February had high total coliform levels, very little faecal coliform were observed possibly due to exhaustion of matter accumulated throughout the year, and limited accumulations during the rainy season.

6.2.3 Coliform bacteria in tap water

The Mpulungu Township Council had stated that chlorine was added to the water supply in Mpulungu Township (Mwilwa, 1998). By adding chlorine to the water, the presence of any coliform organisms was presumed to have been killed. This implies that, the presence of any coliform organisms, even in very low concentrations, in a chlorinated water supply is indicative, not necessarily of a health hazard but certainly of failure in the water purification system (Cairncross and Faechem, 1983). What was observed was that both water samples, to which was added sodium thiosulphate, to deactivate chlorine and the one with no sodium thiosulphate had no significant difference in terms of coliform levels. The implication was that if the council was chlorinating water, the chlorine did not have any effect on water and if there was any it was very minimal.

Since chlorine was added to the water in Mpulungu, the implication is that the pathogens in the water were resistant to chlorine. This is consistent with Klein (1976)'s contention that, pathogenic micro-organisms are not reliably removed from water by simply adding a chlorinator to the treatment plant, because of the resistance of some pathogens to chlorine and the tendency for bacteria to multiply after chlorinating. Therefore, the need to remove pathogens should be borne in mind when selecting the type of treatment works to build. The solution currently is that more chlorine should be added to the water than what is currently used and water sampling for coliform tests should be done on regular basis, which is not currently the case, to assess whether or not chlorine is really getting rid of the bacteria.

The other argument would be that part of the problem leading to high levels of bacteria despite chlorinating could be emanating from water system itself. This is an old system characterised by broken taps and pipes where a bacterium can easily enter. Adding chlorine to the water cannot do much if bacteria finds its way into the system at certain points along the way.

6.3 Suitability of water for domestic and recreational purposes

Since the results of the study indicate that the mean levels of coliform are above the maximum permissible levels of 0 colonies/100 mls, for both the Zambian and WHO Standards (1994), it can safely be concluded that it is not safe to directly drink water from Lake Tanganyika in Mpulungu. According to Masters (1974) as regards water for recreational activities, many States in America recommend a limit of 1000 coliform organisms per 100 mls. In the case of Lake Tanganyika, the highest amount of coliform recorded in this study was 800 colonies per 100 mls. Therefore, what was recorded in Mpulungu Stations was below the limit cited by Masters (1974) as permitted in many U.S.A States. In comparison with the U.S.A criteria for allowing water to be used for recreational purposes, Lake Tanganyika according to the results of this study was found to be suitable for water contact recreational activities.

6.4 Effect of physical factors of water on bacteriological pollution

This study focused mainly on physical aspects which included temperature, pH and dissolved oxygen in assessment of bacteriological pollution. Temperature can influence the growth of bacteria, which thrives at a certain high temperature but also die if the temperature gets too cold. According to Friery (1971), continuous high temperatures of water on Lake Tanganyika contribute to speeding up of the process of decomposition, which in turn creates depletion of oxygen through Biological Oxygen Demand since decomposition requires a lot of oxygen. Bridgewater and Mumford (1979) contend that biological processes accelerate by a factor of 2-3 for every 10°C rise in temperature within the range 5°-40°C. In addition, solubility of oxygen in water will be reduced. These factors together may cause a serious reduction in oxygen levels.

According to the results of this study, nearly all the physical variables of pH DO and temperature had very weak relationships with the coliform bacteria except for Mbete

Bay with a moderate relationship between temperature and faecal coliform. Considering the relationship between pH and temperature, except for Mbete with a moderate relationship, the two variables were very weakly related in the other two stations. This was the same for DO in relationship to temperature except again for Mbete Bay with a correlation of

(r = 0.445). With regard to pH in relation to DO, the situation was the same with Mbete Bay Station still having a stronger relationship between the two variables

Mpulungu District Health Records for cholera cases distribution for the beginning of 2000 reported one case of cholera in Mbete village in February with none reported in the other two stations. It appears that in February despite the fact that faecal coliforms were very few, the very few had among them the vibro cholerae, which cause cholera. Since there is a slightly strong relationship between temperature and DO, (supported by Wilber, 1979) that the concentration of dissolved oxygen varies with temperature), chances are that there was favourable oxygen and temperature amount which favoured the growth of coliform including the cholera bacteria. In the other two stations the physical variable and coliform were very much independent of each other (Table 12).

Mbete Bay in all the results behaved in a different way from the other stations, which means that this station has something peculiar about it. The most outstanding being that this bay is about 15 km away from the nearest of the other two stations whilst Musende and the harbour stations are only 2 km apart. Despite the fact that three of the stations where on the same lake, they had particular factors (in this case distance, human habitation and physical environment), that influenced their behaviour. This conforms to Kimball (1975)'s contention that it is important to realise that one of the unique marks of estuary bays and harbours is that each must have specific studies done on it. The variations in these parts of the water body make it difficult to extrapolate information.

6.5 Oil pollution in Musende Bay

The results in Chapter 5 show that the highest mean oil levels were found in Musende Bay in which the harbour is located with fishing companies (Plate 8) and a crude oil storage facility and transit point. The presence of these companies and facilities justifies the presence of high levels of oil in the bay. The fishing industry, including transport vessels are the main sources of oil pollution in Mpulungu just as is the case in many harbours. The fishing companies found in Musende Bay, through fish processing can be sources of oil/grease pollution. Lake Tanganyika if not jealously guarded will soon be a waste asset because in some cases oil is deliberately introduced on the lake as a by-product. For example, Tanzania Electricity Corporation (TANESCO) on the shore of Lake Tanganyika in Kigoma, introduces used oil directly into the lake without any prior treatment (Plate 9).

This habit of disposing of oil on the lake is underlined by Giles and Livingston (1960) who asserted that, the danger of fatal contamination from the poisonous substances seems to lie chiefly in the gas plants and petroleum distils, which on one occasion or another, if not

(a)

(b)

Plate 8. Anthropogenic activities contributing to oil pollution on Lake Tanganyika, (a) Mpulungu Harbour and (b) Mpulungu Fishing Company in Mpulungu. Photo by Sr. Christine Kabumbu, February 2000.

Plate 9. TANESCO oil outlet point on Lake Tanganyika in Kigoma, Tanzania.

Photo by Sr. Christine Kabumbu, July 1999.

regularly, find it convenient to let certain products drain into the nearest body of water (Plate 9). Hakizinana (2000) reported that in Bujumbura there are 50 petrol stations and 20 garages and most of these are just in residential area and unregistered, which implies that industrial contaminants are emitted into the lake carelessly more especially in Bujumbura Bay. This situation should be a cause for concern because pollution in Burundi will still have an effect on Zambian water, as water is dynamic. Whether the pollutant is introduced in another country, chances of the whole lake getting degraded are high.

According to Menz (2000), although Zambia has not yet experienced industrial pollution as an issue on its part of the lake, there is a general consensus that pollution could emerge as a serious problem for the riparian countries. Though pollution cannot be seen as serious on the Zambian side, but the situation could be different because the Maximum Permissible level of oil for WHO Guidelines for Drinking water is Zero. The mean amount of 0.35 %/g of sediment simply shows that water in Musende Bay in Mpulungu cannot be regarded as palatable or suitable for human consumption.

6.6 Status of heavy metal pollution on Lake Tanganyika

Substances, which are toxic even at very low concentrations, include heavy metals, such that even in minute levels can prove to be fatal to human, animal and plant life. The results in Chapter 5 reveal that there is lead pollution on Lake Tanganyika more especially in Chituta Bay. Copper and aluminium are almost none existent. According to Figure 21, lead has been shown to be above the permissible levels with a maximum value of 0.47 mg/l as compared to the other two metals.

6.6.1 Lead Pollution

Lead is one of the most toxic metals even when ingested in very minute concentrations. According to Dietrich (1975), lead is known to produce serious disease of the nervous system even when it accumulates in the body in low concentrations. This is quite dangerous because in Mpulungu, fish is used widely for human nutrition. The presence of lead in sediments also portrays a gloomy picture because water from the lake is used for domestic purposes in Mpulungu by more than 50% of the population.

Water, which is being used for human consumption, need not contain such toxic substances like lead, Cairncross and Faechem (1983) assert that, a substance, which accumulates in the body and causes neurological disease or cancer must have a threshold of zero as the target. Lead is a cumulative poison and even small concentrations, if continuously present in drinking water may lead to serious illness or death (Turk, 1972). Appendix V reveals that apart from waterborne diseases in Mpulungu, there are other diseases like nervous and blood disorders whose origin cannot currently be ascertained. Thus, more research is required in this area.

6.6.2 Possible sources of lead in Mpulungu Town

Mpulungu though not an industrial town, which manufactures metallic materials, has possible sources of lead pollution. These include materials and activities taking place in the town. For instance, most of the pipes used in water systems are made of lead, paint, which is used in painting boats, contains lead. Certain pesticides like lead arsenate spray can contaminate both surface and ground water. Vehicle exhausts from trucks ferrying cargo to and from the Harbour, can be sources of lead pollution. Appendix IV shows the numbers of heavy-duty vehicles passing through the harbour throughout the year.

Other possible sources of lead include dropouts from explosives, which pass through the harbour (Appendix Via, b and c). Other most common but dangerous products are batteries that are often handled and disposed of with very little care. According to Bridgewater and Mumford (1979), it is recommended that battery cases be washed free from lead-containing materials before disposal. Otherwise they should be disposed of as poisonous waste. This also means they should not even be burned under uncontrolled conditions on domestic fires or thrown in the water as is often done in many places. This burning and throwing of battery waste into the lake could be one source of lead on Lake Tanganyika in Mpulungu.

The oldest serving ship on Lake Tanganyika is the S.S. Liemba, which has been operating on the lake for more than 80 years. Boats have anti-fouling coatings and this anti-fouling coating contains toxic metals like lead (Anon, 1952). This anti-fouling coating disappears in the water after a long period of traversing the waters such that eventually gets into the water as metal pollution. There is also a possibility that the anti-fouling paint of the S.S. Liemba could have contributed to lead pollution in the surface lake sediments.

6.6.3 Lead in Chituta Bay

In the last chapter, it was reported that, Chituta Bay recorded the highest levels of lead among the three stations. As shown in Figure 1, Chituta Bay is in between Musende and Isanga Bays, and that it is so much off the main lake such that it is almost cut off. It is the extreme south of the entire Lake Tanganyika. Despite the fact that this bay is isolated and is expected to be pristine due to its being like a 'cut off', it recorded the highest concentration levels of lead.

The reason for this phenomenon of high levels of lead as compared to the other bays could be its physical characteristics, which contribute to the retention of high levels of the metal. Since the bay is almost cut off, the pollutants that are advected there are probably retained and adhere to sediment particles, which settle to the bottom, hence the accumulation of the pollutant.

The other possible explanation could be that since Chituta Bay is an enclosure, this bay is shielded from the hydrodynamics of the main lake (e.g. the upwelling, turbulence, deep mixing etc.). Due to relative isolation, it is affected mainly by periodic local oscillations, which results in pollutants below to remain undisturbed for a long time (Plisnier, 1999). In fact, it is quite hazardous to have such a stable part of the lake polluted because natural self-purification is not possible.

6.7 Hypotheses testing

The extent to which objectives of the study were achieved is discussed below by looking at how the hypotheses were tested and decisions arrived. The first two hypotheses tested by interview responses, while the third was based on laboratory analysis.

Simple Pearson Correlation was used to establish the relationship between and among the variables using SPSS computer programme. All the correlations were significant at the level of 0.05 (2-tailed). Table 15 shows the correlation matrix for all variables related to water pollution on Lake Tanganyika in Mpulungu. The table illustrates the relationships of the variables investigated. This serves to assess whether certain factors have an effect or are dependent on one another or not.

Table 15 Correlation matrix for factors related to pollution on Lake Tanganyika

Variables	Physical aspect	Human activities	Diseases	Oil pollution	Biological contamination	Chemical poisonin.	Metal polluti.n	Water suitability
Diseases	0.953	0.992	1					
Oil pollution	0.456	0.955	0.098	1				
Biological Contamination	0.983	0.953	0.986	0.103	1			
Chemical poisoning	0.178	0.327	0.369	0.045	0.009	1		
Metal pollution	0.269	0.765	0.253	0.287	0.976	0.326	1	
Water suitability	0.134	0.834	0.958	0.960	0.894	0.157	0.298	1

6.7.1. Hypothesis one: Bacteriological, oil and heavy metal pollution is a function of anthropogenic activities and physical aspects of Mpulungu area.

A correlation was established for biological, oil and heavy metal pollution with the physical aspects of the area. The physical factors included hot weather through out the year, rocks which prevent digging of deep pits causing waste to go into the lake, slopping of land which made waste to easily drain in the lake and also lack of a drainage output for the lake around Mpulungu. The anthropogenic activities included doing laundry on the lake, washing pot, plates etc on the lake, disposal of solid wastes like batteries on the lake, which related to individual activities.

The results showed a correlation of (r = 0.456) between physical factors contributing to pollution and oil pollution while the relationship between oil pollution and human activities was (r = 0.992). As regards metal pollution in relation physical and human factor, the correlations were (r = 0.269) and (r = 0.765) respectively. The relationship between physical and anthropogenic factors, with oil, chemical and heavy metal pollution was found to be insignificant and it gives low likelihood that oil and heavy metal pollution could be a function of physical aspects of Mpulungu but that oil and heavy metal pollution is a function of anthropogenic activities in Mpulungu area.

The relationship between physical factors of Mpulungu and anthropogenic activities with biological contamination of water was (r = 0.983) and (r = 0.891) respectively. Going by these revelations, it could be seen that bacteriological factors are highly correlated with the anthropogenic activities and the physical factors of Mpulungu area.

This gives high likelihood that bacteriological factors are a function of anthropogenic activities and physical aspects of Mpulungu area.

Therefore, bacteriological pollution is a function of anthropogenic activities and physical aspects of Mpulungu area but oil and heavy metal pollution is not a function of the physical aspect of the area but is a function of anthropogenic activities. The hypothesis was accepted for the first part but rejected for the second part of the statement.

6.7.2 Hypothesis two: The magnitude of bacteriological, heavy metal and oil pollution is a function of the amount of biological, oil and chemical waste discharged into the lake.

The study did not quantify the magnitude of biological, oil and chemical waste discharged into the lake apart from identifying the sources of this pollution as well as quantifying the levels of pollution for these different pollutants on the lake. However, there was a significant relationship between what was seen to be the possible sources of pollution as shown in Figures 17, 22 and 23 and what was found to be the state of water in terms oil levels, coliform and lead in the water. Though not shown in the picture, just behind the storage facility of Figure 16 there were many leaking drums of oil, which were cited and photographed by Cohen et al, (1997).

Therefore basing on laboratory results with the highest value of coliform reaching as high as high 800 colonies/100 mls, oil levels as high as 0.4%/g and lead as high as

0.04g/l, this shows that these pollutants were found on the lake because in one way or the other they had moved from the place of discharge or storage on to the lake. As result, the hypothesis that 'The magnitude of bacteriological, heavy metal and oil pollution is a function of the amount of biological, oil and chemical waste discharged into the lake' is accepted.

6.7.3 Hypothesis three: There is a significant relationship between biological pollution status of the lake and patterns of water-borne diseases in Mpulungu area.

The findings indicated a high, significant relationship between pollution status of the lake and patterns of water -borne diseases in Mpulungu. Pearson correlation was used and it indicated a high relationship of 0.958 between common diseases outbreak in the area and suitability of water for drinking in Mpulungu. There was also a very strong relationship of (r = 0.986) between biological contamination and water-borne disease outbreaks in Mpulungu.

From the laboratory results, the status of bacteriological pollution on Lake Tanganyika was that, the mean values of both total and faecal coliform in all stations for all the months were well above the maximum permissible levels of WHO Guidelines for Drinking Water of 0 colonies/100 mls of water. This implied that the water was likely to cause diseases. (Tables 6a,b and c & 15) shows that the wet months, which had high levels of coliform bacteria, also recorded many cases of cholera.

The correlation between cholera cases and coliform levels during the months of October 1999 to March 2000 reveals a moderate correlation of ($r = - 0.407$). Though negative, the relationship between water status in terms of coliform and disease distribution was significant at 0.05 significant level (2 tailed) with the critical r-value of 0.729 and thus the hypothesis was accepted. This implies that there is a significant relationship between biological pollution of the lake and patterns of water-borne diseases in Mpulungu area.

The study did achieve its hypothesis/objectives in a sense that it established that there are many factors contributing to pollution on the lake apart from the physical aspect of the area. It also established sources of pollution on the lake and it determined the magnitude of bacteriological, oil and heavy metal pollution on Lake Tanganyika in Mpulungu through field observations, literature review and laboratory analysis.

6.8 Conclusion

Lake Tanganyika though currently appears to be pristine with acceptable standards for some important physical water qualities like pH and dissolved oxygen in surface water, not much is being done to avert further degradation of the lake. Pollution status of the lake in Mpulungu area is polluted with coliform bacteria, which can be linked to the prevalence of water-borne diseases in the area. Possibilities of lead pollution are there though this needs further and thorough investigation in order to conclusively say Lake Tanganyika in Mpulungu to be polluted with lead.

The next chapter summarises the findings of the study concludes and gives recommendations for future research on Lake Tanganyika in Mpulungu.

CHAPTER 7: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary

Total and faecal coliforms were found to be prevalent in all the stations sampled in Mpulungu. There was not a single station with coliform colony levels of 0/ 100 mls. The levels found in all stations were above the WHO Maximum Permissible Levels for coliform bacteria of 0 colonies/100 mls. Lunzua River Station recorded the highest mean colony levels of about 100 colonies/100 mls. For the stations on the lake itself, Mbete Bay recorded the highest levels. On the other hand, more total coliform colonies with a maximum value of 800 colonies/100mls and a mean value of 150 colonies/100 mls were recorded during the month of February. As regards faecal coliforms, maximum values of 250 with a mean value of 25 colonies/100mls were recorded during the month of December (Table 4).

There were more coliform colony levels at the water location of 100 m from the shore than at 232 m from the shore. More coliforms were found at a depth (point) of 5 m than on the surface and at 10 m, for all the stations, which were sampled. Despite the fact that for tap water samples, sodium thiosulphate was added in one sample (to inhibit the effect of chlorine), there was no significant difference in the levels of coliform bacteria in the two water samples. This implies that the chlorine added was not enough to kill the bacteria in drinking water.

Handling of petroleum products in Mpulungu has had a bearing on the presence of hydrocarbons in the surface sediments on Lake Tanganyika in Mpulungu. Out of the three bays sampled in Mpulungu, Musende Bay where the harbour and the oil storage facilities are situated, recorded as high as 0.4 %/g of oil in sediment. In Musende Bay, there was a significant relationship between depth of the lake, percentage of fine grains in sediment and the percentage of oil in sediment (Table 12).

The most prevalent metal on Lake Tanganyika in Mpulungu was found to be Lead with a maximum value of 0.0383 mg/l, above WHO Maximum Permissible Levels of 0.01mg/l. The station with the highest concentration levels was in the most enclosed Chituta Bay at the most southerly point of Lake Tanganyika. Copper and aluminum were far below the Maximum Permissible Levels (Table 14).

The most common water borne disease outbreaks found were cholera, dysentery and diarrhoea, which are prevalent in the wet season and mainly found in Mpulungu Township itself, in villages along the lakeshore and in the fishing camps.

7.2 Conclusions

Though Lake Tanganyika is one of the biggest inland fresh water lakes, water on Lake Tanganyika in Mpulungu is not safe to drink directly. According to the Environmental Council Of Zambia (1993) and WHO Guideline for Drinking Water (1985), water on the lake falls below recommended standards. People around Mpulungu have to take special precautions when utilising the water from the lake for domestic purposes. The presence of coliform bacteria particularly the faecal coliforms in water signals a health hazard and this justifies the endemicity of gastro- intestinal diseases in the area.

Regarding the number of coliforms, which were found during this study, the numbers were fewer than what was found by Garbrecht, (1971) on the same lake covering the same period of time of dry and rainy seasons. Some stations had mean levels as high as 1000 colony count/100 mls and maximun value of 1760 colony count/100mls. The reasons could be due to some improvement in waste management in Mpulungu from 1970 to 1999. Garbrecht (1971) alluded to some broken sewer pipes in Mpulungu at the time of his study which might have contributed to too much raw faecal matter draining into the lake, hence the high coliform counts.

Oil and heavy metal pollution at the moment may not seem to be a health hazard, but looking at the increment of cargo at the harbour and the lack of control on the part of Government regarding the number of fishing vessels allowed on the lake (which throw used oil on land and in the water), the ship wrecks left in the lake, oil and heavy metal pollution will soon be a hazard. People currently might not notice the effect of lead in the water but the effect could be there through food chain, though in minute concentrations this could later become fatal.

7.3 Recommendations

In order to ensure continued good health of people around Lake Tanganyika and the people of Zambia depending on Mpulungu fish, the biodiversity of Lake Tanganyika and the sustenance of the lake itself, the following recommendations are made:

i. The port in Mpulungu should expand to cater for increased number of cargo passing through. This expansion should take storage and sanitation facilities of the harbour into consideration.

ii. Mpulungu Council should improve its water purification system so that there is no coliform in drinking water above the Maximum Permissible Levels.

iii. The Council should formulate good wastewater and solid waste control strategies. Discharging raw sewage in the lake is quite dangerous for the lake's biodiversity and human beings.

iv. The Council needs to rehabilitate and improve on the current water system, which seem to be old and ineffective.

v. The Fisheries Department should strictly monitor the dumping of shipwrecks into the lake and the painting of boats by the fishing companies as there is a possibility of pollution from rusted metal.

vi. The council and other stakeholders need to educate and train people to safeguard the lake by reducing on pollutant loads. People to come to appreciate the lake and so become keen on preserving it.

vii. The Ministry of Environment needs to apply standards for discharge of pollutants and be strict in enforcing pollution control regulations. This can be done by local people themselves through neighborhood watch.

viii. Further research is required in the following areas:

- Assessment of the effect of lead on biodiversity, especially the possible presence of metals in fish.
- Assess the effect of pollution on surface water and the littoral zone on biodiversity, e.g. surface water fish and mollusks in terms of quantity and quality.

- Establish the relationship between water borne diseases and distribution of bacteria in the water. Different types of bacteria in water have to be singled out more especially the one likely to cause hepatitis A because this deadly disease can be confused with other ailments due to lack of proper diagnostic equipment. If the presence of the bacterium in water is ascertained, possible measures can be taken to prevent the disease and in case of illness, proper treatment could be given in good time.

REFERENCES

American Public Health Association, 1985, *Standard Methods for the Water and Wastewater*, Port City Press, Baltimore.

Anon, F.,1952, *Marine Fouling and Its Prevention*, Woods Hole Oceanography Institute, Annapolis.

Aro, E and Mannini, S, 1995, *Results of fish population biology studies on Lake Tanganyika during July 1993 – June 1994.* FAO/FINNIDA Research for the Management of the Fisheries in Lake Tanganyika.

Bannister, K., 1998, Morphology and sedimentation of Kigoma Bay and vicinity, Nyanza Project, Kigoma.

Beadle, L.C, 1981, "The inland waters of tropical Africa. An introduction to tropical limnology". *2nd ed.* In: Plisneir, P.D, 1999, *Limnology Notes and Field Manual*, Nyanza Project, Kigoma.

Benton, A.H. and Wenner, W.E., 1958, *Field Biology and Ecology*, McGraw-Hill Company, Toronto.

Bridgewater, A.V. and Mumford, C.J., 1979, *Waster Recycling and Pollution Control Handbook*, The Pitman Press, Bath.

Briggs, D., 1977., *Sources and methods in Geography, Sediments*, Butterworths, London

Bollenbach, W.M., 1975, *Ground water and wells*, Johnson Division, UOP Inc, Minnesota.

Brock D.T., 1979, *Biology of Microorganisms*, Prentice-Hall, Inc, Jersey.

Brown C.W., and Lynch P.F, 1977, *Tanker Tragedies: Identifying the source and determining the fate of petroleum in the marine Environment, In: Environmental Pollutants, Detection and Measurement,* Toribara T.Y., Plenum Press, New York.

Bryan, C., 1994, *Health and the Environment*, Oxford University Press, Oxford.

Caincross, S. and Faechem, R.G., 1983, *Environmental Health and Engineering in the Tropics- An Introductory Test,* John Wiley and Sons, Singapore.

Cartledge, B., 1994, "*Health and the Environment*" the Linacre Lectures, Oxford University Press, Tokyo.

Ciacco, L.L.,1971, *Water and Water pollution Handbook*, Marcel Dekker, Inc,Newark.

Chapman, O., (1992), *Water quality assessment*, University Press, London.

Chikwama, P., 1998, *Mpulungu Port- Pollution Status Report*, Department of Maritime and inland Ways-paper presentation - Lusaka.

Coulter, G.W., 1981, *Lake Tanganyika and its life*. British Museum (Natural History) and Oxford University Press, London.

Cohen, A. Blundell, B and Reinthal, P., 1997, *The African Great Lakes*, CD-ROM, University of Arizona, Arizona.

Deelstra, H., Power, J.L., and Kenner, C.T., 1976, "Environmental contamination": In *Heavy Metals in tropical Lake Kariba, Zimbabwe*, Department of Systems Ecology, Stockholm. 28-32

Deming, H.G., 1975, *Water – The Foundation of Opportunity*, University Press, New York.

Dietrich, U., 1975, *Hydrobiology, A test for Engineers And Scientists*, John-Wiley, Toronto.

Environmental Council Of Zambia (ECZ), 1993, *Water Pollution Control Regulations of 1993*, Government Printers, Lusaka.

Fair, M.G., 1958, *Water and Waste Engineering, Vol.2 Water Purification and Wastewater Treatment and Disposal*, John Wiley & Sons, Sidney.

Farukwa-Tanaka, Mwape, L.M. and Shapola, R., 1995, *Distribution and abundance of Juvenile pamba (Lates angustifrons) around the cost of Mutondwe Island.* Ecology and Linnology of Tanganyika.

Frank, P. and Siever, 1994, *Understanding the earth*, W.H. Freeman and Company, New York.

Fryer, G., 1972, "Conservation of the Great Lakes of East Africa: a lesson and a warning". Biol. Conserv., 4, (4): In *Trends in Zambian fisheries: The Tanganyika and Mweru/ Luapula Fisheries as examples*. Proceedings of the \national Seminar on Environment and Development, Lusaka.

Garbrecht, G. 1971, *Mpulungu Water Supply – Example of water pollution in Zambia;* In: Pollution and Environment in Zambia, Governemnt Printers, Lusaka.

Giles, L. and Livingston, J., 1960, *Oil pollution of the seas*. American Wildlife Conference, New York.

Green, B.J., 1998, "A preliminary investigation of the vertical distribution of bacteria in the water column", In: *The Nyanza Project 1998 Annual Report*, University of Arizona, Arizona.

Hakan, B. Kiibus, M and Kautsky, N., 1995, *Heavy Metals in tropical Lake Kariba, Zimbabwe*, Department of Systems Ecology, Stockholm.

Hakizimana, G., 20th June 2000, *Pollution on Lake Tanganyika*, Times of Zambia, Lusaka.

Hecky, R.E., and Degens, E, 1993, *Late pleistoceine – Holocene chemical stratigraphy and paleolimnology in the Rift Valley lake of Africa*: Woods Hole Oceanographic Institution Technical Report 1-73-8.p. 1-144. In: Cohen A.S, et al, 1997, Lake level and paleoenvironmetal history of Lake Tanganyika, Africa, as inferred from late Holocene and modern stromatolites, GSA Bulletin; Arizona.

Huckabay, D., 1979, *Trends in Zambian Fisheries: The Lake Tanganyika and Mweru/Luapula as examples*. Proceedings of National Seminar on Environmental Development, Lusaka, ZGA.

Johnson, T.C. and Odada, E.O, 1996, *The limnology, climatology and paleoclimatology of the East African Lakes*, Gordon and Breach Publication, Amsterdam.

Kamona, F., 1990, *Stream processes and water-quality of the Ngwerere*, undergraduate dissertation, University of Zambia, Lusaka. (Unpublished)

Kimball, J.W., (1975), *Man and Nature, Principles of Human and Environmental Biology*, Addison-Wesley Publishing Company, Sidney.

Kings, S., 1996, *Water Pollution Management*. In: Water in Southern Africa, Print Holdings, Harare.

Kinoshita, I., 1997, "Early Histories of Pelagic Fishes". In: Kawanabe, M.Hori and M.Nagoshi (eds) *Fish Communities in Lake Tanganyika*. Kyoto University Press. page 259-273

Klen, L., (1985), River pollution, 1: Chemical Analysis, Butterworths, London.

Lezzar, K,E., 1999, *Part I – Limnogeology*, Nyanza Project, Kigoma.

Linsley, K.R., 1982, *Hydrology for Engineers*, McGraw-Hill, Inc, Toronto.

Lopi, B., 16th March 1996, *Only 25% percent of the total Zambian population enjoy clean water*, Zambia Daily Mail article, Lusaka.

Lukama, B.K., 1998, *Encroachment of Forest Reserves in the Lake Tanganyika Catchment*, Forest Department – Paper Presentation to Lake Tanganyika Biodiversity Project, Lusaka.

Lungu, O.I.M., 1998, *Adequacy of the Agricultural policy in supporting proposed actions for the sustainable management of Lake Tanganyika*, Paper presentation at Lake Tanganyika Biodiversity Project workshop, Lusaka.

Maitland, P.S., 1982, *Biology of Fresh Water*, Chapman & Hall, New York.

Mann, H.T. and Williamson, D, 1979, *Water Treatment and Sanitation – A handbook of simple methods for rural areas in developing countries*, Intermediate Technology Publications, Nittingham.

Masters, G.M., 1974, *Introduction to Environmental Science and Technology*, Toronto, John Wiley & Sons.

McKinney, R.E., 1962, *Microbiology of Sanitary Engineers*, McGraw-Hill Book Company, London.

Michel, E., 1999, *African Rift Lakes: Model system for studies of Evolution & Ecology*, Nyanza Project, Kigoma.

Menz, 20th June 2000, *Pollution on Lake Tanganyika*, Times of Zambia, Lusaka.

Muchelenganga, C.G., 1998, *Water Quality Monitoring - The Zambian Challenge* – A paper presented at the Water Africa 98 Conference, Nairobi, Kenya, 30th June – 2nd July 1998, NCSR, Lusaka.

Musonda, L.M., 1998, *Population and disease distribution in Mpulungu catchment*, unpublished records.

Mwape, L.M., 1998, *Pollution on Lake Tanganyika*, Paper Presentation at the Lake Tanganyika Biodiversity Project workshop, Lusaka

Mwilwa, J.K., 1998, *Pollution on Lake Tanganyika in Mpulungu*, Paper presentation at the Lake Tanganyika Biodiversity Project workshop, Lusaka.

Obrdlik, P., 1984, The Chongwe-Ngwerere river system in Zambia: Physico-chemical and bacteriological status, *Zambia Journal of Science and Technology*, Lusaka. Volume 7 ,1

O'Riodarn, T., 1995, *Environmental Science for environmental Management*, Longman Singapore.

Orem, H.W., 1999, *Procedure for analysing oil in sediments using Acetone*, U.S Geological Survey, Personal Communication.

Patterson, G., 1996, *Pollution control and other measures to protect Biodiversity in Lake Tanganyika, Baseline Review: Sediment Discharge and its consequences*, Kent.

Pearce, M.J., 1985, *A description and stock assessment of the pelagic fishery in the Southeast arm of the Zambian water of Lake Tanganyika*. Report of the Department of Fisheries, Zambia.

Plisnier, P.D., 1996, Limnological sampling during a second annual cycle (1994-1995) and some comparisons with year one on Lake Tanganyika: In *Limnology Notes and Field Manual*, The Nyanza Project, Kigoma.

Plisneir P,D., 1999, *Limnology Notes and Field Manual*, The Nyanza Project, Kigoma.

Phiri, H., 1993, *On gillnet surveys for benthic fishes in southern Lake Tanganyika*. Ecology and Limnology of Tanganyika.

Provincial Statistical Office, 1999, *Needs Assessment Survey Report, Mpulungu District*, P.P.U, Kasama.

Ralph, M., 1972, *Water Pollution Microbiology*, Wiley-Interscience, Toronto.

Salvato, J.A., 1958, *Environmental Engineering and Sanitation*, Wiley-Interscience, Toronto.

Sichilima, E., 2000, *Sediment Analysis for heavy metals*, Laboratory Results sheet University of Zambia, School of Mines, Lusaka.

Sichingabula, H. M., 1998, *Archival Review of available data for sediment study in Southern Lake Tanganyika basin, Zambia*, Third Quarterly Report. Lake Tanganyika Biodiversity Project, University of Zambia, Lusaka.

Sichingabula, H. M., 1999, *Analysis and results of discharge and sediment monitoring activities in the southern Lake Tanganyika basin, Zambia*. Report number 4. Lake Tanganyika Biodiversity Project. University of Zambia, Lusaka.

Southwick, C.H., 1976, *Ecology and quality of our environment*, D.Van Nostrand Company, Melborne.

Solomons, W. and Fouster, V., 1984, *Metal in the Hydrocycle*, University Press, Tokyo.

Turk, A., 1972, *Ecology, Pollution and Environment*, W.B Saunders Company, Toronto.

United Nations Environmental Program (UNEP), 1992, *Development issues for the 21st Century*, International Conference on Water and the Environment, The Dublin Statement and Report of the Conference, Dublin, 54 pp.

United Nations Environmental Program (UNEP), 1995, *Our Planet*, Magazine for sustainable Development, Nairobi.

U.S.A Environmental Protection Agency, (1976), *Water Quality Standards*, Univesity Press, New York.

White, R.E., 1987, *Introduction to the Principles and practice of soil Science*, Blackwell scientific Publications, Melbourne.

Wilber, C.G., 1969, *The Biological aspects of water pollution*, Charles C. Thomas Publisher, Illinois.

WHO, 1976, *Surveillance of drinking-water quality*, WHO Publications, Geneva.

Zambia Information Service, 23rd July,1998, *Man dies of cholera after eating fish*, Radio News Reel, Kasama.

Zulu A., 1998, *Wild Life in south Lake Tanganyika basin*, Paper presented at the Lake Tanganyika Biodiversity Project Workshop, Lusaka.

APPENDIX I

FREQUENCY OF DISEASE, WHICH COMMONLY CAUSE DEATH IN MPULUNGU BY WARD

NAME OF WARD	DISEASE	NO. OF VILLAGES REPORTING
CHILUMBA	Cholera	3
	Diarrhea	1
	Dysentery	3
	Malaria	13
CHISHA	Diarrhea	3
	Malaria	37
	Measles	2
	Pneumonia	2
ISOKO	Cholera	1
	Dysentery	2
	Malaria	29
	Malnutrition	2
ISUNGA	Cholera	1
	Cough	1
	Diarrhea	4
	Malaria	9
	Cough	2
	Dysentery	8
	Eye sores	1
	Headaches	1
CHITIMBWE	Malaria	13
	Malnutrition	2
	Measles	6
	Pneumonia	1
	Child birth complications	1
	Cholera	1
	Cholera	3
	Dysentery	7
YENDWE	Malaria	6
	Measles	3
	Meningitis	1
	Pneumonia	1
	Typhoid	1
	Anemia	1
	Child birth complications	1
KATWE	Diarrhea	3
	Dysentery	13

Appendix I continued

	Measles	1
	Typhoid	14
MPULUNGU	Cholera	2
	Diarrhea	9
	Dysentery	28
	Malaria	1
	Malnutrition	1
	Measles	13
	Cholera	5
	Cough	4
VYAMBA	Diarrhea	2
	Dysentery	1
	Eye sore	2
	Malaria	19
	Measles	4
Total		**284**

Source: D-WASHE - Needs Assessment for Mpulungu District – 1999.

APPENDIX II

MORBIDTY AND MORTALITY – WATERBORNE DISEASES IN MPULUNGU DISTRICT

DISEASES	OUT PATIENT			IN PATIENT			DEATHS		
1997									
	-5	+5	Total	-5	+5	Total	-5	+5	Total
Gastrol Enteritis	153	299	452	-	14	14	-	-	-
Diarrhea	2 529	1 543	4072	308	347	655	10	17	27
Dysentery	--	-	-	-	-	-	-	-	-
Cholera	5	105	110	5	105	110	2	7	9
Bilhazia	150	113	163	-	-	-	-	-	-
Hepatitis	--	-	-	-	-	-	-	-	-
Poliomyelitis	--	-	-	-	-	-	-	-	-
Typhoid	-	-	-	-	-	-	-	-	-
Conjunctivitis	1213	473	1686	6	4	-	-	-	-
1998									
Gastrol Enteritis	172	240	412	20	32	52	3	2	5
Diarrhea	2023	906	2929	325	537	862	13	11	24
Dysentery	-	-	-	-	-	-	-	-	-
Cholera	51	203	254	51	203	254	3	9	12
Bilhazia	28	53	81	-	1	1	-	-	-
Hepatitis	-	-	-	-	-	-	-	-	-
Poliomyelitis	-	-	-	-	-	-	-	-	-
Conjunctivitis	856	231	1087	-	1	1	-	-	-
Typhoid	-	-	-	-	-	-	-	-	-
1999									
Diarrhea none blood	1513	645	2158	298	107	405	2	1	3
Dysentery (sigellosis)	98	128	226	14	25	39	1	-	1
Cholera	-	-	-	29	110	139	4	13	17
Poliomyelitis	-	-	-	-	-	-	-	-	-
Bilhazia	1	35	36	-	-	-	-	-	-
Hepatitis	-	-	-	-	-	-	-	-	-
Typhoid	-	-	-	-	2	2	-	-	-
Conjunctivitis	538	260	798	6	3	9	-	-	-

Source MF47 - 1997-1998 (Disease Aggregation form HIA I for 1999)
Compiled by L. Musonda, District Health Information Officer.

-5 = children under five years of age, +5 = people above five years of age

APPENDIX IIIA

QUESTIONNAIRE FOR FISHING COMPANIES ON POLLUTION ON LAKE TANGANYIKA IN MPULUNGU.

Dear Respondent,

Sr. Christine Kabumbu is undertaking a research on the above-mentioned topic. This research is in partial fulfillment of the Degree of Master of Science in Geography at the University of Zambia.

You are kindly asked to answer the questions below. Please answer the questions to best of your knowledge. Be assured that all the answers you give will be treated with utmost confidentiality. Answer each of the questions in the spaces provided.

Section One: Identification

1. 1

Name of the company	

1.2

Year of establishment	

1.3

Number of employees	

1.4

Position in the company	

Section Two: View on pollution status of Lake Tanganyika

2.2

What is your view of pollution on Lake Tanganyika in Mpulungu area?	

2.3

What could be the source of this pollution on the lake?	

2.4

Could it be that your fishing	Yes	No

company is also contributing to any form of pollution on the lake?		

Section Three: Company solid waste disposal

3.1

Do you have wastes during your fish processing?		

3.2

How do you get rid of fish wastes after processing in your company?	

3.3

What other solid wastes are produced by your company?	

3.4

How do you get rid of this solid waste?	

Section Four: Use and disposal of petroleum by the company

4.1

Do you use petroleum products in your company?	**Yes**	**No**

4.2

What type of petroleum products do you use?	

4.3

Where do you normally use these petroleum products?	

4.4

How is used oil got rid of by your company?	

4.5

Do you think there is oil pollution on Lake Tanganyika in Mpulungu?	**Yes**	**No**

4.6

What is the source of oil pollution on the lake?	

Section Five: Evidence and possible sources of heavy metal pollution on Lake Tanganyika in Mpulungu.

5.1

Do you think there is evidence of heavy metal pollution on the lake?	**Yes**	**No**

5.2

In what ways is your company likely to contribute toward heavy metal pollution in the lake?	

5.3

How often do you repaint your company boats and fishing vessels?	

5.4

What kind of paint do you use to paint your vessels?	

5.5

Why do you have to paint your boats?	

Section Six: Suggestions for minimizing pollution on the lake

6.1

What is the best way of preventing any form of pollution by any company in Mpulungu?	

6.2

What measures can the Government take to safeguard pollution of the lake?	

APPENDIX IIIb

QUESTIONAIRE ON ATTITUDES OF THE COMMUNITY TOWARDS WATER POLLUTION ON LAKE TANGANYIKA IN MPULUNGU.

Dear Respondent,

Sr. Christine Kabumbu is undertaking a research on the above-mentioned topic. This research is in partial fulfilment of the Degree of Master of Science in Geography at the University of Zambia.

You are kindly asked to answer the questions below. Please answer the questions to best of your knowledge. Be assured that all the answers you give will be treated with utmost confidentiality. Answer each of the questions in the spaces provided.

Section One: Identification

1.1

Sex	i. Female	ii. Male

(Tick one)

1.2

Age	i. Below 15	ii. 16 - 25	iii. 26 - 36	iv. 36 and above

(Tick one)

1.3

Occupation	i. Civil servant	ii. Fisherman	iii. General trader	iv. Other

(Tick one)

1.4

Length of time lived in Mpulungu	i. 1 – 5 years	ii. 6 – 10 years	iii. 11 – 20 years	iv. 21 and above

1.5

Area of residence in Mpulungu	i. Township	ii. Village	iii. Island	iv. Non-resident

(Tick one)

Section Two: Source and status of drinking water in Mpulungu

2.1

How do you view the suitability of water for drinking in Mpulungu?	i. very suitable	ii. moderately suitable	iii. slightly suitable	iv. Not at all suitable

(Tick one)

2.2

How do you view the suitability of water for swimming in Mpulungu?	i. very suitable	ii. moderately suitable	iii. slightly suitable	iv. not at all suitable

(Tick one)

2.3

What is your source of drinking water?	i. Lake	ii. Well	iii. River	iv. Tap

(Tick one)

2.4

Do you regard boiling water a necessity in Mpulungu?	i. Yes	ii. No

2.5

Why do you regard or don't regard boiling water as a necessity?	

Section Three: Occurrence of waterborne diseases in Mpulungu

3.1

What waterborne disease outbreaks are common in Mpulungu?	

3.2

What do you think are the causes of these disease outbreaks?

3.3

When are these disease outbreaks common?	i. Cold and dry season	ii. Hot and dry season	iii. Wet season	iv. Throughout the year

(Tick one)

3.4

Which part of Mpulungu experiences major waterborne disease outbreaks?	

3.5

What physical environmental factors contribute to disease development in Mpulungu?	

Section Four: Sources of biological pollution on Lake Tanganyika in Mpulungu

4.1

Do you think local people have a contribution toward pollution on the lake?	Yes	No

(Tick one)

4.2

If local people contribute toward pollution on the lake, how do they do this?	

4.3a

How would you describe settlement patterns in Mpulungu Township?	i. Spacious	ii. Moderate	iii. Crowded	iv. Very crowded

(Tick one)

4.5b

How would you describe the settlement patterns in Mpulungu villages?	i. Spacious	ii. Moderate	iii. Crowded	iv. Very crowded

(Tick one)

4.6

How do individuals and local authorities dispose of waste material in Mpulungu?	

Section Five: Evidence and sources of oil and heavy metal pollution in Mpulungu

5.1

Do you have evidence of heavy metal pollution on the lake?	i. Yes	ii. No

5.2

What do you think is the source of heavy metal pollution on the lake in Mpulungu?	

5.3

Do you have evidence of oil pollution on the lake?	i. Yes	ii. No

5.4

What do you think is the source of oil pollution on the lake in Mpulungu?	

Section Six: Preservation of Lake Tanganyika and Human life in Mpulungu

6.1

Do you value the conservation of Lake Tanganyika?	i. Yes	ii. No

6.2

Why do you value the preservation of Lake Tanganyika?	

6.3

Suggest measures the Government can take in order to conserve Lake Tanganyika?	

6.4

Suggest measures the local community can do in order to conserve Lake Tanganyika?	

6.5

Give helpful tips for this study.	

APPENDIX IV
WATER ANALYSIS RESULTS

MBETE BAY

GPS	DATE	DEPTH	TC	FC	TEMP.	DO	pH
08 48.046 31 03.384	06.10.99	S-5		0	26.2	85.3	8.9
08 48.046 31 03.461	06-10-99	B-5		1	26.3	86.3	9
08 47.891 31 03.461	06-10-99	S-10		0	26	80.4	8.9
08 47.891 31 03.384	06-10-99	M-10		0	26	80	8.8
08 47.891 31 03.384	06-10-99	B-10		0	27	90.5	8.4
08 47.891 31 03.384	05.11.99	S-5	9	0	27.1	97.3	8.7
08 48.046 31 03.461		B-5	10	4	27.2	96	8.7
08 48.046 31 03.461		M-5	4	0	26.9	92	8.6
08 47.891 31 03.384		M-10(5)	6	0	26.9	97.1	8.5
08 47.891 31 03.384		B-10	5	0	26.5	90.1	8.5
08 48.046 31 03.461	10.12.99	S-5	3	0	28.1	94.2	8.9
08 48.046 31 03.461		B-5	40	28	27.6	77.5	8.6
08 47.891 31 03.384		B-10	51	12	28	98.3	8.5
08 47.891 31 03.384		B-10(5)	3	0	27.8	78.5	8.4
08 47.891 31 03.384		B-10	250	180	27.3	96.1	8.5
08 48.046 31 03.461	25.01.00	S-5	30	10	26.7	88.9	8.4
08 48.046 31 03.461		B-5	4	1	26.5	88.9	8.7
08 47.891 31 03.384		S-10	25	0	26.4	86.6	8.8
08 47.891 31 03.384		M-10(5)	3	1	26.1	86.4	8.8
08 47.891 31 03.384		B-10	2	0	26.2	86.3	8.8
08 48.046 31 03.461	08.02.00	S-5	23	3	26.2	86.7	8.8
08 48.046 31 03.461		B-5	6	0	26.2	74.5	8.9
08 47.891		S-10	4	1	26.6	78.6	8.9

31 03.384							
08 47.891 31 03.384		M-10(5)	20	2	26.6	74.2	8.9
08 47.891 31 03.384		B-10	800	2	26.1	77.2	8.7
08 48.046 31 03.461	07.03.00	S-5	46	2	26	78.5	8.8
08 48.046 31 03.461		B-5	0	6	26	76.8	8.7
08 47.891 31 03.384		S-10	186	62	27.6	76.4	8.7
08 47.891 31 03.384		M-10(5)	5	0	26.1	74.2	8.8
08 47.891 31 03.384		B-10	25	18	26.7	77.2	8.8

MUSENDE BAY

08 46.114 31 06.451	''	S- 5		0	26	94.6	8.9
08 46.081 31 06.451	''	B- 5		2	26	93.3	8.8
08 46.165 31 06.270	''	S-10		2	26	92	8.9
08 46.265 31 06.270	''	B-10		0	26	91.8	8.8
08 46.081 31 06.451	05.11.99	S- 5	4	3	26.7	90.3	8.3
08 46.081 31 06.451	''	B -5	20	10	26.5	89.6	8.6
08 46.265 31 06.270	''	S-10	6	0	26.7	88.5	8.4
08 46.265 31 06.270	''	M-10(5)	7	3	26.4	87.9	8.6
08 46.265 31 06.270	''	B-10	6	2	26.3	73.8	8.5
08 46.081 31 06.451	10.12.99	S- 5	49	3	27.4	94.3	8.7
08 46.081 31 06.451	''	B- 5	56	0	27.2	79.6	8.7
08 46.265 31 06.270	''	S-10	3	0	27.9	97.5	8.7
08 46.265 31 06.270	''	M-10(5)	18	3	27.3	75.1	8.7
08 46.265 31 06.270	''	B-10	64	69	27.6	76.9	8.7
08 46.081 31 06.451	25.01.00	S- 5	1	0	26.4	91.4	8.7
08 46.081 31 06.451	''	B- 5	1	0	26.6	75.2	8.8
08 46.265 31 06.270	''	S-10	2	0	26.8	93.8	8.8

08 46.265 31 06.270	˝	M-10(5)	1	5	26.6	83.7	8.8
08 46.265 31 06.270	˝	B-10	3	0	26.4	80.5	8.8
08 46.081 31 06.451	08.02.00	S- 5	22	14	26.5	87.2	8.9
08 46.081 31 06.451	˝	B- 5	166	42	26.2	86	8.8
08 46.265 31 06.270	˝	S-10	17	5	26	86.7	8.8
08 46.265 31 06.270	˝	M-10(5)	32	9	26.2	86.6	8.8
08 46.265 31 06.270	˝	B-10	20	9	26.1	87	8.8
08 46.081 31 06.451	07.03.00	S- 5	0	1	26.1	80.3	8.6
08 46.081 31 06.451	˝	B- 5	3	4	26.7	69.8	8.7
08 46.265 31 06.270	˝	S-10	0	0	26.1	80.2	8.6
08 46.265 31 06.270	˝	M-10(5)	4	1	26.3	69.9	8.6
08 46.265 31 06.270	˝	B-10	13	2	26.7	66.5	8.6

HARBOUR/NGWENYA

GPS	DATE	DEPTH	Total coliform	Faecal Coliform	T°	pH	DO
08 45.381 31 06.580	06.10.99	S-5		1	28.2	98.5	8.8
08 45.381 31 06.580		B-5		1	27.6	97.5	8.9
0845.107 31 06.453		S-10		0	26.4	96.2	8.8
0845.107 31 06.453		M-10		0	25	84.4	8.9
0845.107 31 06.453		B-10		0	26.5	98.7	8.9
08 45.381 31 06.580	5.11.99	S-5	10	4	26.7	90.6	8.4
08 45.381 31 06.580		B-5	31	36	26.2	80	8.9
0845.107 31 06.453		S-10	21	19	26	97.8	8.5
0845.107 31 06.453		M-10(5)	9	0	26	95.5	8.6
0845.107 31 06.453		B-10	8	2	26	94.7	8.7
08 45.381 31 06.580	10.12.00	S-5	0	0	27.8	75.9	8.8
08 45.381		B-5	42	18	27.5	71.1	8.7

31 06.580

0845.107 31 06.453		S-10	25	68	28.2	98.7	8.7
0845.107 31 06.453		M-(5)	31	20	27.5	80	8.7
0845.107 31 06.453		B-10	62	10	27.3	76.4	8.7
08 45.381 31 06.580	25.01.00	S-5	4	1	26.7	91.7	8.8
08 45.381 31 06.580		B-5	4	1	26.5	85.8	8.8
0845.107 31 06.453		S-10	10	0	26.6	93.5	8.7
0845.107 31 06.453		M-(5)	7	0	26.3	80.4	8.8
0845.107 31 06.453		B-10	2	0	26.2	78.3	8.8
08 45.381 31 06.580	08.02.00	S-5	12	3	26.2	86.6	8.8
08 45.381 31 06.580		B-5	600	110	26.2	87.5	8.8
0845.107 31 06.453		S-10	45	3	26.2	87.7	8.8
0845.107 31 06.453		M-(5)	7	1	26.4	86.8	8.8
0845.107 31 06.453		B-10	35	0	26	86.6	8.8
08 45.381 31 06.580	07.03.00	S-5	6	5	26.4	80.2	8.7
08 45.381 31 06.580		B-5	34	12	26.7	66.7	8.6
0845.107 31 06.453		S-10	0	0	26.6	87.5	8.3
0845.107 31 06.453		M-10(5)	2	0	26.5	85.3	8.4
0845.107 31 06.453		B-10	2	2	26.6	74.5	8.4

LUNZUA RIVER (Surface water samples)

06.10.99	**Total coli**	**Faecal coli**	**Temp.**	**DO**	**pH**
Point 1		0	26.5	98.1	8.8
Point 2		0	26.6	98.5	8.9
05.11.99					
Point 1	4	1	26.8	96.7	8.7
Point 2	2	0	26.7	96.9	8.6
10.12.99					
Point 1	9	3	26	98.3	8.9
Point 2	3	2	26.3	98.6	8.9
25.01.00					
Point 1	96	32	26	97.5	8.6
Point 2	84	45	26	97.9	8.6
08.02,00					
Point 1	67	32	26.2	95.7	8.7

Point 2	35	21	26.4	95.8	8.8
07.03.00					
Point 1	120	18	26.1	80	8.9
Point 2	57	22	26	80.3	8.9
07.03.00					
Point 1	120	18	26.1	89.4	8.9
Point 2	57	22	26	88.8	8.9

TAP WATER

06.10.99					
With		0	26.5	96.7	8.8
Without		0	26.6	96.9	8.9
05.11.99					
With	1	3	26.8	98.3	8.7
Without	13	10	26.7	98.6.	8.6
10.12.99					
With	5	0	26	97.5	8.9
Without	6	4	26.3	97.9	8.9
25.01.00					
With	97	43	26	95.7	8.6
Without	89	42	26	95.8	8.6
08.02.00					
With	22	6	26.2	80	8.7
Without	17	7	26.4	80.3	8.8
07.03.00					
With	45	10	26.1	89.4	8.9
Without	67	2	26	88.8	8.9

Note:
With = sample with Sodium Thiosulphate
Without = sample without Sodium Thiosulphate TC = Total coliform, FC = Faecal coliform,
ST = Sodium Thiosulphate

APPENDIX V

PREVALENT DISEASES REPORTED IN MPULUNGU

- **BACTERIOLOGICAL DISEASES**: Pneumonia, STD, Cholera, dysentery, Leprosy, mumps in the rainy season.

- **NERVOUS DISORDERS**: Sensation lost due to leprosy, but not common.

- **HEPATITIS**: Difficult to diagnose in Mpulungu because of lack of facilities. There are cases of jaundice, which are suspected to be hepatitis because of inadequate diagnostic facilities.

- **BLOOD DISODERS**: Inadequate platelletes, leucocytes and iron. There are cases of puss in the blood called septicemia.

Source: Mr. Silavwe (Mpulungu District Health Office) – Unpublished data.

APPENDIX VIA

MPULUNGU HARBOUR CORPORATION LIMITED
ANNUAL CARGO ANALYSIS DATA (TONNES)

YEAR	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99
ZAMBIAN EXPORT								
Cement	47 025.35	35 506.12	25 369.55	13 236.75	31 563.95	15 963.15	21 148.78	33 126.70
Sugar	1 035.90	-	5 593.55	14 458.35	16 306.35	9 429.30	9 478.85	7 149.45
Lime	119.08	622.00	693.50	305.65	181.28	30.00	-	194.94
Gypsum	-	-	-	135	-	-	-	389.30
Coal	-	-	-	-	-	-	-	671.00
Match splints	102.10	184.72	119.50	-	8.00	-	-	-
Calcium carbide	10.60	21.00	40.00	-	20.00	-	-	-
Maize	-	-	142.72	471.00	10.00	-	955.29	-
Steel pipes	-	-	-	-	29.84	-	26.23	-
Match paper	-	-	-	-	4.00	-	-	14.00
Explosives ♦	-	23.05	-	-	9.24	20.75	-	14.92
Gas oil	-	-	-	-	12.00	-	-	45.50
Soya beans	-	-	-	-	60.00	-	-	-
Blankets	-	-	-	79.98	-	-	-	-
Zambian bitumen	572.00	38	-	-	-	37.98	-	-
Tea leaves	19.24	-	-	-	-	-	-	-
Salt	-	-	-	-	-	400.00	-	-
Rice	-	-	-	-	-	-	149.85	-
Others	-	-	-	-	-	-	639.73	
SUB TOTAL	**48 884.27**	**36 394.89**	**31 958.85**	**28 686.73**	**48 204.41**	**25 881.18**	**32 198.73**	**41 605.81**

Appendix VIA continued

Secondhand cloth	-	-	-	-	-	-	1 387.35	-
Blankets	-	-	70.00	753.39	-	-	254.01	-
Sugar rollers	28.10	88.80	-	32.00	-	-	-	-
Acid & chloride	-	-	-	38.30	-	-	-	-
Kango enamal	-	-	27.30	567.05	-	-	-	96.23
Milk	74.75	-	-	16.00	-	-	-	-
Grinding balls	-	-	58.00	-	-	-	-	-
Cement	533.07	-	100.00	-	-	-	-	209.85
Roofing sheets	100.57	26.00	36.00	-	-	-	-	-
Tin plates		433.00	-	-	-	—	-	-
Alcohol	7.63	50.81	-	-	-	-	-	-
Floor tiles	-	26.86	-	-	-		-	-
Lime	-	-	-	-	-	-	-	-
Paint	247.55	65.23	-	-	-	-	199.96	-
Salt	32.39	-	-	-	-	594.96	-	1 000.75
Gardion baskets	-	-	-	-	-	-	-	-
Tea	-	-	-	-	-	12.57	-	5 040.62
Coffee	-	-	-	-	—	200.00	2 498.94	20 848.15
Primus	-	-	-	-	-	310.32	1 828.59	-

Indian rice	-	-	-	-	-	415.50	-	2 043.34
Petrol	-	-	-	-	-	-	-	-
Diesel	-	-	-	-	-	-	4 580.02	3 448.04
Chemicals	-	-	-	-	-	-	1 966.39	-
Asbestos fibre	28.00	168.56	-	-	168.00	514.72	-	
Wire	-	256.38	59.38	45.95	120.00	-	-	
SUB TOTALS	**14 113.30**	**7 215.01**	**11 911.47**	**24 767.42**	**11 767.42**	**6 633.37**	**52 073.54**	**63 701.46**
GRAND TOTAL	**62 996.96**	**43 609.90**	**43 870.32**	**53 454.15**	**54 454.15**	**32 514.55**	**84 272.27**	**105 307.27**

Source: Department of Marine and waterways, Mpulungu Harbour.

APPENDIX VIB

MPULUNGU HARBOUR CORPORATION LIITED
VESSEL CALLS FOR THE PERIOD OF JANUARY TO DECEMBER 1999

VESSELS	STATUS	CAP mt	REG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Mv Liemba	C/passanger	250	Tanz	5	3	4	4	1	0	0	0	0	0	0	0	3
Mv Muongozo	C/passenger	120	Tanz	0	0	4	1	3	4	5	4	4	4	4	5	17
Mv Tora	Gen-cargo	1150	Bur	1	1	1	2	0	1	1		2	0	0	0	38
Mv Rwegura	Gen-cargo	500	Bur	0	0	1	1	1	1	2	2	1	2	1	1	8
Mv Mbaza	Gen-cargo	450	Bur	1	1	2	1	1	1	1	1	1	1	1	2	13
Mv Camus	Tug-boat	-	Bur	2	2	0	0	0	0	0	1	0	2	1	1	14
B Murumbi	Gen-cargo	500	Bur	1	2	0	0	0	1	0	0	0	2	0	1	11
B Albertville	Gen-cargo	860	Bur	1	1	1	1	0	0	01	2	0	0	0	0	8
B Warega	Gen-cargo	1200	Bur	2	1	1	0	0	0	0	0	0	1	1	0	5
B Lubaya	F/tanker	420 c/m	Bur	0	0	0	1	2	0	0	1	1	1	0	0	8
Mv Kabambara	Gen-cargo	450	DRC	0	0	1	1	2	2	0	0	0	0	0	1	3
Mv Fizi	Gen-cargo	450	DRC	0	0	0	0	2	0	1	0	1	2	1	1	7
Mv Lengwe	Gen-cargo	350	DRC	0	0	0	0	1	1	1	0	0	0	1	1	8
Mv Mpala	Gen-cargo	120	DRC	0	0	0	0	1	1	0	1	0	0	0	0	8
Mv	Gen-cargo	80	DRC	0	0	0	0	0	0	0	0	1	0	0	0	3

Kasenga																
Mv rafiki	C/passenger	80	DRC	0	0	0	0	0	0	0	1	0	0	0	0	1
Mv Baraka	Gen-cargo	800	DRC	0	0	0	0	0	0	0	0	1	0	1	0	12
B Nyanza	Gen-cargo	300	DRC	0	0	0	0	0	0	0	0	0	0	0	1	1
Mv Raya	Gen-cargo	150	DRC	0	0	0	0	0	0	0	0	0	0	0	1	1
B Mugandja	Gen-cargo	600	Bur	0	1	1	1	1	1	0	1	0	0	0	0	4
TOTAL				14	11	16	14	14	13	12	12	12	15	12	15	160

Tanz. – Tanzania, Bur.- Burundi, DRC – Democratic Republic of Congo

Average loading time per ship

1. Loading from trucks, gang/shift = Two days for 500 mt capacity ships
Six days for 1200 mt capacity ships.

Appendix IIb continued

2. Loading from warehouses, gang/shift = Three days for 500 mt capacity ships
= Eight days for 1200 mt capacity ship

FACTORS AFFECTING LOADING AND OFFLOADING SHIPS

1.Availability of cargo and ships
2.Weather conditions e.g. rain
3.Cargo handling equipment availability
4.Regional security i.e. civil wars etc.

FREQUENCY OF SHIPS

1.Once or twice per month for Burundi vessels

2.Once per week for Tanzanian vessels
3.Congolese vessels available only on charter

Key to abbreviated countries:

Bur. – Burundi
D.R.C. – Democratic Republic of Congo
Tanz. - Tanzania

APPENDIX VIC

TRUCKING REPORT FOR JANUARY TO DECEMBER 1999

PERIOD	NO OF TRUCKS	AVERAGE DAYS/TRUCK
January	74	1 to 3
February	160	1 to 2
March	100	1 to 2
April	135	1 to 3
May	99	1 to 2
June	115	1 to 2
July	79	1 to 4
August	113	1 to 3
September	157	1 to 3
October	104	1 to 2
November	135	1 to 3
December	130	1 to 5
TOTAL	**1401**	-

Average trucks/month = 11

Source: Department of Marine and Waterways, Mpulungu Harbour.