MANAGEMENT AND DISPOSAL OF MUNICIPAL WASTEWATER IN LUSAKA CITY, ZAMBIA

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By

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A Dissertation Submitted to the University of Zambia in Partial Fulfillment of the Requirements for the Postgraduate Diploma in Integrated Water Resources Management (IWRM)

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DECLARATION

I Chibwe Mary declare that this dissertation represents my own work, and that it has not previously been submitted for a degree, diploma or other qualification at this or another University.

Signature:.........................

CERTIFICATE OF APPROVAL

This dissertation of Chibwe Mary has been approved as fulfilling the partial fulfillment of the requirements for the award of the Postgraduate Diploma in Integrated Water Resources Management by the University of Zambia.

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ABSTRACT

Every form of water use results in production of wastewater. The wastewater is characterised by a number of substances which are usually added to it during the process of use. These substances must be removed from the water before returning it back to the environment. The pathogenic nature of wastewater demands that it should be adequately treated and disposed so that it does not become an environmental and public health hazard.

This study investigated how municipal wastewater is managed and disposed in Lusaka City. The city has been experiencing growth in size and population since independence. The population has increased from 2,433 in 1931 to 1,742,979 in 2010. This growth has however not been matched with significant improvements in the management of wastewater. The treatment plants are old and operating beyond their design capacities with some plants receiving sewage over twice their capacity. The total capacity for all the municipal wastewater treatment plants is 55,050m^3/day but these plants receive effluent which is over twice this capacity. The wastewater is inadequately treated and does not the standards. The BOD is often above 50mg/l for example. Wastewater management has been neglected as many policies are inclined towards water provision and solid waste management.

Population statistics show that the population of Lusaka is ever increasing indicating that wastewater generation is increasing. By 1980, all wastewater treatment plants had been constructed and were in goo condition. They were serving a population of 535,830. These plants have never been rehabilitated or expanded and are now (2010) serving a population of 1,742,979. While the population is increasing and increased water supply is being advocated for, the state of the wastewater treatment plants keeps on worsening because there is neither expansion nor rehabilitation of these existing plants. There has been no construction of new treatment plants. There is therefore urgent need to address this matter as this is not only a public health threat but it is also an environmental hazard.

DEDICATION

This work is dedicated to Violet Chikonoko Chibwe and Oliver Bwalya Chibwe for being wonderful parents. Given an opportunity to choose parents, I would still choose you!

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Special thanks to the Almighty God for affording me this opportunity of widening my knowledge and understanding on management of water and other resources. I also express my gratitude to Danida and the Danish Embassy for this scholarship which has enabled me to carry out these studies. Many thanks go to my Supervisor Professor I. Nyambe and to my lecturers Dr H.M. Sichingabula, Mr. J. Tembo, Dr W. Mafuleka, Professor Peter Bauer-Gottwein and Mr. J. Kabika. Thank you very much for your contribution to my success in these studies. I would like to express my gratitude to my fellow IWRM Masters and Postgraduate Diploma Students for the excellent team work we exhibited especially during the course work. Many thanks go to the staff at LWSC in the Department of Engineering, the staff at CSO and ZABS for assisting me with my data collection.

These studies would not have been successful without the encouragement, support, and prayers from my family (the Chibwe's and the Musonda's), my friends and my church mates at Praise Christian Centre.

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ABBREVIATIONS AND ACRONYMS

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CSO	Central Statistics Office
ECZ	Environmental Council of Zambia
GWP	Global Water Partnership
IWRM	Integrated Water Resources Management
LCC	Lusaka City Council
LWSC	Lusaka Water and Sewerage Company
MDGs	Millennium Development Goals
TSS	Total Suspended Solids
UNZA	University of Zambia
WWDR	World Water Development Report
WWTPs	Wastewater Treatment Plants
ZABS	Zambia Bureau of Standards
ZEMA	Zambia Environmental Management Agency

CHAPTER 1: INTRODUCTION

1.0 BACKGROUND

Water is the primary life supporting and sustaining natural resource. Its availability is essential for economic and social development and it has no substitute. Water use results in a change in the quality and characteristics of water. From time in memorial water has been used for cleaning purposes both at domestic and industrial level. There are three major uses of water and these are industrial, domestic and agricultural use. Another important use of water which has not received much attention is environmental use. This is simply the water required to sustain the living organisms in the environment. As the water is being used for industrial, domestic or agriculture purposes, a number of substances are added to it and these can be in suspension, colloidal or dissolved form. Water use is therefore followed by generation of wastewater. The characteristics of the wastewater depend on the use to which the water was put. Wastewater generated from each of the three major uses is therefore different. The characteristics of wastewater also depends on the population served, land uses and sanitary wastes (Guzzi, 1998).

Wastewater can either be domestic, trade or industrial. Domestic wastewater is generated from households and includes liquid wastes from kitchens, bathroom, toilets, laundry and anything that is poured down the drain in the home. Trade effluent is generated by commercial areas and institutions such as hospitals, schools, markets, shopping malls e.t.c. Industrial wastewater is the wastewater discharged by industries. Municipal wastewater is a mixture of trade effluent and domestic wastewater (Guzzi, 1998).

Most of the water used in the community ends up in the sewer system. Wastewater Treatment Plants (WWTP) treats wastewater so that the concentration of the various components is reduced to levels which nature can handle. This is because the treated effluent has to be returned to the environment or recycled. The solid components of wastewater are disposed off to the land while the liquid components are discharged into water bodies or recycled. Nature naturally takes care of minimal amounts of pollutants but the amounts of wastes produced daily in today's cities would overwhelm the natural purifying mechanisms of the local water bodies if the wastewater is directly discharged into them. WWTPs therefore need to adequately treat the wastewater in order to avoid the adverse effects that raw or inadequately treated effluent can cause on the environment and public health. Safe disposal of all human wastes is necessary to protect the health of humans and other living things. It is also necessary for disease prevention (GWP, environment and public health. Safe disposal of all human wastes is necessary to protect the health of humans and other living things. It is also necessary for disease prevention (GWP, 2009). All wastes especially human wastes must be disposed off in such a manner that they do not contaminate drinking water supplies or give rise to a public health hazard by being accessible to children, insects, rodents and other vectors that may come into contact with food or drinking water. The wastes must also not pollute receiving water bodies (water bodies into which the wastewater is disposed) (Cairncross and Feachem, 1993).

Water resources management involves the management of both the quality and quantity of water for human benefits without destroying its availability and purity. Wastewater management and disposal can affect both the quality and quantity of water in local water bodies. Wastewater significantly contributes to the volume of water in local streams and rivers in the dry parts of the year (Mackenzie et al, 2004). Wastewater management is therefore cardinal in Integrated Water Resources Management. In the interest of environmental sustainability as well as economic efficiency, wastewater must be viewed as an economic good that needs to be conserved. Wastewater also has an economic value as can be seen from the benefits of wastewater reuse and agricultural use of treated wastewater and digested sludge (UNESCO, 2006).

This study will investigate the management and disposal of municipal wastewater in Lusaka, the capital city of Zambia. Zambia is a country in southern Africa and has an average altitude of 1,000 to 1,400 m above sea level. It lies between 8° 20' and 18° S latitude and 22° 00' and 33° 45'E longitude and has an area of 752,614 km². According to the 2010 census Zambia's population is 13,046,508 and Lusaka City alone has a population of 1,742,979 (CSO, 2010). Being an administrative capital, Lusaka City`s main economic activities include manufacturing, transport, communication, hospitality, construction and many others. These services and administration account for most of the formal employment in the city. Many Lusaka residents earn their livelihood from informal economic activities such as trading, metal fabrication, wood processing and stone quarrying. Trading is the predominant activity (Mulenga, 2003).

Lusaka Water and Sewerage Company (LWSC) is the company that provides water and has the mandate of managing wastewater. This company treats sewage from all households, institutions and industries from parts of the city that are connected to sewer system. This study will investigate how municipal wastewater is managed and disposed in Lusaka City.

1.1 Study Area

The area of study is Lusaka city. In terms of sewerage services, the city is divided into six catchment areas and these are Manchinchi, Western, Chelston, Matero, Kaunda square and Ngwerere (Figure 1.1). Each catchment is serviced by a sewage treatment plant (Figure 1.1). This study will investigate the state of the treatment plants and the treatment methods being employed in each catchment. The service target area for LWSC is the area that is connected to the sewer line while the autonomic area consists of exclusive housing, governmental offices, university, golf course /park, city airport, which already have their own treatment, as well as areas where no public treatment is required. On-site treatment area use septic tanks or pit latrines.

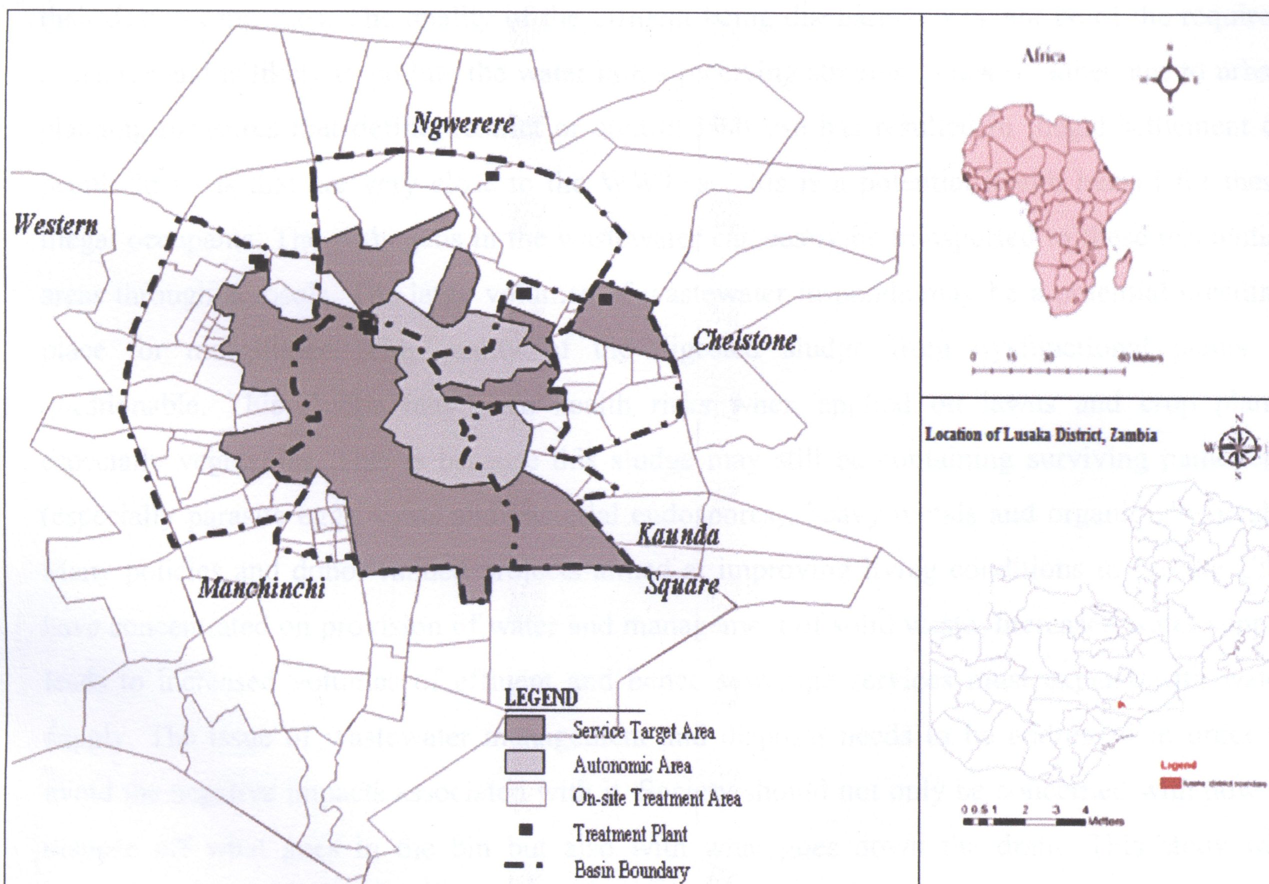

Figure 1.1: Map of Lusaka City showing the six catchment areas, Zambia (after: LWSC, 2009).

1.2 STATEMENT OF THE PROBLEM

Though wastewater is a resource from which economic benefits can be obtained, it is also a potential environmental and public health hazard if not properly handled. Humans and their activities are generators of waste and therefore have a responsibility of managing the waste in a manner that does not harm any living organisms. Wastewater must be managed in such a way that it does not pollute the environment or become a public health hazard. Wastewater management and sanitation services in Lusaka City have expanded much more slowly than the population growth the city has been experiencing since independence. Urbanisation, industrialisation and increase in the size of the city have not been matched with adequate waste treatment facilities. The city is still utilising the same old wastewater treatment plants which were designed for a smaller population. These treatment plants are likely to be operating beyond their design capacities. The quality of the effluent being discharged may not be of the required standards and is likely to pollute the water in the receiving streams. Lack of adherence to urban planning measures that define, restrict or control land use has resulted in illegal settlement of people in areas that are very close to the WWTPs. This is a potential health hazard for these illegal occupants. The pathogens in the wastewater can easily be transported to these residential areas through aerosols. The large volumes of wastewater in ponds may be a potential breeding place for mosquitoes. The quality of the digested sludge from dysfunctional plants is questionable. This sludge may pose health risks when applied on lawns and crop plants especially vegetables. This is because this sludge may still be containing surviving pathogens (especially parasite eggs, cysts and bacterial endospores), heavy metals and organic chemicals. Many policies and donor funded projects aimed at improving living conditions in Lusaka City have concentrated on provision of water and management of solid waste. Increased water supply leads to increased volumes of effluent and hence sewerage services must expand with water supply. The issue of wastewater management and disposal needs to be addressed in order to avoid the negative impacts associated with it. Society should not only be concerned with how to dispose off what goes in the bin but also with what goes down the drain. This study was therefore formulated to investigate how municipal wastewater is managed and to highlight the potential hazards associated with improper managed of wastewater.

1.3 AIM

- To investigate the management and disposal of municipal wastewater in Lusaka City.

1.3.1 Research Objectives

The objectives of this research are:

- To investigate the methods of municipal wastewater treatment in Lusaka City;
- To examine the efficiency and the state of the municipal wastewater treatment plants in Lusaka City; and
- To study how growth in size and population of Lusaka City has affected municipal wastewater management.

1.4 HYPOTHESIS

Population growth and expansion of Lusaka City has not been matched with construction of new wastewater treatment plants, rehabilitation or expansion of the existing WWTPs. Municipal wastewater is therefore not adequately treated and the effluent and sludge from these WWTPs does not meet the required standards.

1.5 SIGNFICANCE OF STUDY

Safe disposal of all human wastes is necessary for protecting the health of human beings and prevention of diseases especially in developing countries such as Zambia. Cities are facing challenges in ensuring that there is adequate provision of water and sanitation. Lusaka City is ever increasing in size and population and there is need to develop sustainable municipal wastewater management. Compared to water provision and solid waste management, waste water management is not a priority by government, NGO's and service providers. This is because the negative impacts of wastewater pollution have not been generally highlighted. The impacts are usually greatly felt when an epidemic of a water related disease arises. Wastewater management needs to be investigated because wastewater if not properly managed has the potential of transferring hidden costs to the health sector. It can also increase the cost of drinking water treatment for users downstream and deprive society of the goods and services provided by the ecosystem. Wastewater is a resource, and is an economic good. The quantity and quality of water used for human benefit must be managed without destroying its availability and purity. Wastewater must be managed in an integrated, sustainable and equitable manner. This study will highlight the environmental and health risks associated with improper management of wastewater. This will enable government, service providers and regulatory authorities to be accountable to its citizens and ensure that public health and protection of ecosystems is the first priority in wastewater management. This study is directly linked to water and sanitation related Millennium Development Goals (MDG's) and the MDG advocating for environmental sustainability. The study will also contribute to the efforts being made in ensuring that the Vision 2030 for Zambia is realized.

1.6 LIMITATIONS

This study was limited by time and resources. Due to these reasons, it was not possible to carry out independent analysis of samples as this was costly and needed to be carried out in the three seasons of the year. Another limitation was lack of readily available secondary data. The effluent quality data available was only for 2009 and 2010. It was also very difficult to obtain data from some institutions. The study was also delayed by the slow response from some institutions.

CHAPTER 2: LITERATURE REVIEW

The atmosphere, land and water resources, and the ecosystem they support play an important role in providing humans with shelter, food and safe water. They also have the capacity to recycle most wastes. However, the pressures exerted by urbanization, poverty and inequity, economic growth, technical and scientific developments for example, are in many instances increasing. Because of this air pollution, land degradation, deteriorating water quality and biodiversity loss are growing environmental threats. According to the United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2006), human settlements are the major polluters of water resources. During the 20th century, the world's urban population increased more than tenfold while rural population increased by twofold. These human impacts are asserting strong pressure on the water resources. The pressure is in form of warming temperature, rising sea levels, ecosystem damage and increased climatic variability. Major demographic changes are seriously affecting the quality and quantity of available freshwater on the planet. Although surface waters accounts for a smaller percentage of the total water, they are of critical importance. Surface water supports a number of activities and these include shipping, transport, irrigation, recreation, fishing, drinking water and hydropower. They also support ecosystems which provide a number of goods and services. Surface waters are more vulnerable to pollution than groundwater. Globally there is a trend towards more urbanized societies and the number of people living in large cities has increased. This trend has serious implications for freshwater use and wastewater management. In most rapidly growing urban centers, it is proving difficult to build infrastructure to deliver water and provide sanitation to the entire city. This has led to poor health, low quality of life and social unrest in many cases (UNESCO, 2006).

It has been noted that pollution of surface and groundwater resources and the atmosphere, as well as improper dumping of both solid and liquid wastes are becoming major environmental problems in the Zambezi Basin. Countries that lie in the basin have recorded high rates of urbanization and this is contributing to pollution, impacting human health and the environment (Chenge, 2000). The increase in the amount of discharge and types of pollutants in the Zambezi Basin has been attributed to population growth, intensive urbanization and increased industrial and agricultural activities. Sewage effluent is a major source of point pollution and nearly every town and city in the Zambezi Basin has some form of wastewater treatment plants. Urbanisation is considered to be probably the biggest threat in terms of pollution in this region. This is because of problems of sewage disposal but most cities tend to have localized pollution problems which hardly get as far as the Zambezi River (Chenge, 2000).

Common types of surface water pollution are organic matter, pathogen and microbial contaminants, nutrients, salinisation, acidification, heavy metals, toxic organic compounds, silt and suspended particles and thermal pollution (Marquita, 2004). Organic matter pollution originates from industrial wastewater and domestic sewage. It results in depletion of oxygen from the water column as it decomposes stresses or suffocates aquatic life. Organic matter increases the Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO). BOD is the amount of oxygen required to oxidize the organic matter present in water. High BOD indicates high human activity such as sewage or industrial discharge (Marquita, 2004). Raw sewage is categorized in terms of BOD as shown in Table 2.1

Table 2.1 BOD for raw sewage (after: Cairncross and Feachem, 1993).

STRENGTH	BOD mg/L
Weak	200 or less
Medium	350
Strong	500
Very Strong	750 or more

BOD values of 400-800 mg/L are common in many towns and cities in developing countries (Cairncross and Feachem, 1993).

Sewage is the primary source of pathogens, microbial contaminants and intestinal parasites. Examples of common water pathogens of bacteriological nature include *Shigella, Salmonella, Vibro cholera* etc. Raw domestic wastewater normally carries the full spectrum of pathogenic microbes- the causative agents of bacterial, virus, protozoan and helminthic diseases endemic in the population and excreted by the diseased and infected individuals (Shuval, 2003).

Many viruses are excreted by human and animals and these are present in wastewater. These include *Enteroviruses, Hepatitis A virus, rotaviruses, astro viruses, calciviruses, adenoviruses* and *corona viruses*. These can cause gastroenteritis and other diseases especially in infants.

Many of these viruses are frequently present in domestic wastewater and may be associated with plants if adequately or raw wastewater is used for irrigating crops (Oragni, 2003).

Many helminthic (i.e. the flatworms and roundworms) are intestinal parasites. Diseases caused by these parasites are often a principal cause of human morbidity. According to Stott, studies conducted in 1997 estimated that at least 50% of the world's population may be infected with one or more helminth species while prevalence rates of protozoan diseases in the tropics ranged from 15%-30% (Stott, 2003). Transmission of these diseases is usually due to lack of access to adequate water supply, lack of proper sanitation or disposal of raw or insufficiently treated wastewater. Water-associated pathogens are of great importance to public health. This is because of their environmentally persistent transmissive stages, low infective dose, limited or transcient acquired immunity and morbidity particularly in immuno- compromised hosts. Transmission can be directly through occupational exposure and consumption of wastewater or indirectly through ingestion of contaminated water or exposure to polluted recreation water. The performance of WWTP system in removing such parasites is rarely considered (Stott, 2003).

The type of parasites in wastewater depends on the source of the wastewater and the diseases present in the sewage contributing population. The principal groups of helminth parasites include nematodes, cestodes and trematodes while that of protozoa include *coccidian, flagellates, amoeba* and *ciliates*. Common helminthes includes *Ascaris lumbricoides, Trichuris trichiura, Ancylostoma duodenale, Taenia sp* and *Fasciola hepati*ca etc. These are usually present in larvae form. Protozoan parasites occur as cysts or oocysts depending on the species. Common protozoa include *Cryptosporidium spp, Giadia spp, Entamoeba histolytica, Balantidium coli* etc (Stott, 2003).

Raw wastewater in developing countries may contain concentrations of helminthes of 100-10000 eggs/L and protozoan concentration of 100-10000 cysts capable of causing infections. A high degree of parasite removal is required by WWTP's for public health protection. The WHO recommended quality is 0.1 to 1 egg/L per wastewater irrigation (Stott, 2003). Primary treatment combined with secondary treatment can significantly improve parasite removal efficiency especially for protozoa. Parasite removal increases with retention time. Trickling filters are less effective than activated sludge. Waste stabilisation ponds (WSP) can effectively remove parasites from wastewater. Removal mechanism is sedimentation facilitated by the long hydraulic retention times 1-5+days (anaerobic ponds), 5-40 days (facultative ponds) and 3-10 days (maturation ponds) (Stott, 2003).

The average urban resident with connections to water and sewerage services frequently uses many litres of water on a daily basis. A household of five produces about 750 litres of wastewater each day. A city of 1 million people will therefore discharge about 150,000m^3 of wastewater each day, representing a major hazard when directly discharged into the local rivers. Most of the water used in the community ends up in the sewer. Wastewater must be properly disposed off. It must not be easily accessible to people and must meet the required environmental standards before being disposed (Mackenzie, 2004).

Wastewater Stabilization ponds (WSP) are the most widely applicable and the most advantageous method of waste treatment in hot climates. Treatment occurs through natural physical, chemical and biological processes. No machinery or energy input is required. Though they are the simplest of all treatment technologies, they are capable of providing effluent of good standard. WSP can reduce pathogen levels much better than any other type of treatment. They are easy to maintain and require no routine operation. They are able to absorb both the hydraulic and organic shock loads and can treat a wide variety of domestic and industrial wastes. A complete set of WSP includes anaerobic ponds, facultative ponds and maturation ponds. In anaerobic ponds, anaerobic digestion and settlement occurs and a thick scum develops on the surface. Retention times are generally in the range 1-4 days and a depth of 2-4 m is preferred. Anaerobic ponds accumulate sludge at about 0.03 and 0.04m^3/capita.year and will require desludging every 3-5 years. Facultative ponds are usually the largest in the system. In the upper layers of the pond, oxidation of organic matter takes place with oxygen provided by photosynthesing algae. A symbiotic relationship between the algal and bacterial communities is built up. Sludge accumulates and digests anaerobically at the base of the pond so desludging is required only every 10-20 years. Maturation ponds are entirely aerobic and are responsible for the final improvement in chemical quality (BOD removal) and for most reduction in the numbers of feacal coliforms and viruses. In warm climate, each pond with a 5 day retention time removes at least 95% of the feacal coliforms.

Both the conventional and non-conventional methods produce sludge. Sludge is the biosolids that result from wastewater treatment process. Whilst sludge contains valuable organic matter and nutrients which may be beneficial to enrich the soils, they are also potential carriers of pathogens such as viruses, protozoan cysts and oocysts, bacteria, parasite eggs and heavy metals. Heavy metals are a group of metalloid elements with a high density and exhibit similar properties in the environment. These properties include high toxicity at low concentrations and long residence time in the soil. Some heavy metals are micronutrients required only in trace amounts for metabolic reactions. At high concentration they become toxic. However elements such as cadmium and mercury have no known metabolic functions and are toxic at all concentrations. Heavy metals cause non-infectious diseases in man and have significant impact when released into the environment. Pollution by heavy metals is serious and persistent in both aquatic and terrestrial ecosystems. Contamination of soil with heavy metals is a long term problem because estimation of the half lives of such elements in the soil ranges from 15-1100 years (cadmium) and 740-5900 years for lead. Heavy metals can be present in domestic, trade and industrial wastewater. They can be found in metal processing industries such as electroplating, chemical works, textile wet processing, tanneries, photographic industries and mining. In domestic wastewater, heavy metals may originate from metal piping, galvanic corrosion, cosmetics and household cleaning agents (Binkley and Simpson, 2003).

In Europe, North America and other developed countries, the disposal of sewage sludge is subject to strict controls designed to protect soil quality while encouraging its use in agriculture. Only treated sludge is permitted to be applied on any land type. Pathogen levels are reduced to those normally present in the soil. Activated sludge and anaerobic digestion are the most effective means of removing cysts and oocysts. In a properly working anaerobic digester, over 90% of cysts and oocysts can be destroyed in 24hrs (Binkley and Simpson, 2003).

Population statistics show that over 40% of Zambians are estimated to live in urban areas. Before 1964, movement of people from rural areas to urban areas was restricted. The free movement and prosperity which followed independence resulted in rapid urbanisation. Cities had good infrastructure which were built by colonial masters and good copper earnings provided for its support and maintenance.

Literature has revealed (Mulenga, 2003) that colonial masters conceived the city of Lusaka as an administrative centre only. Its original plan did not therefore for other economic activities other than government administration, domestic and menial services. Industrial activities and a large

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population of Africans were in particular not anticipated to form part of the city of Lusaka. Its initial total area was only 2.6 km^2 and by 1970 it increased to 360 km^2. In 1931 the total population was 2,433 and by 1946 it rose to 18,909. The population in the city grew most rapidly after 1948 after the passing of the African Housing Ordinance 1948 which granted the African population the right to reside in towns with their families. After Zambia gained its independence in 1964 the population of Lusaka drastically increased. Between 1963 and 1969 for example the city's population doubled (from 123,146 to 262,425). The population of Lusaka also doubled between 1969 and 1980, from 262,425 to 535,830. After 1980, the population growth rate declined. This was due to a reduction in rural-urban migration (Mulenga, 2003).

After the 1980, population growth was attributed to natural increase and the extension of the city boundary. Natural population increase was able to sustain the city's higher population growth rates, because those who immigrated to the city from the rural areas in the 1960s and 1970s were predominantly young people. According to the 2000 census, the population for Lusaka increased from 761,064 in 1990 to 1,084,703 in 2000 (CSO, 2003). The latest census shows that the population of Lusaka now stands at 1,742,979 (CSO, 2010).

The Government of the Republic of Zambia has adopted a water and sanitation sector strategy that requires the creation of commercially viable water and sanitation utilities. The Water Supply and Sanitation Act, No. 28 of 1997 established the National Water Supply and Sanitation Council. The Act provides for the establishment of commercial utilities to run water supply and sewerage services. Lusaka Water and Sewerage Company is one such commercial utility in the country and it provides services in Lusaka City, Chongwe, Chilanga and Kafue districts.

CHAPTER 3: METHODOLOGY

3.1 DATA COLLECTION

In order to achieve the objectives of this study two methods of data collection were utilized. These methods are primary and secondary data collection. Due to some limitations the methodology was however biased towards secondary data collection.

3.1.1 Primary Data Collection

Primary data was obtained from physical observations that were carried out at the WWTPs during field trips. Field trips were conducted in the month of March and April, 2011. A study of the current operations of the WWTPs, the type of methods employed in the treatment process, the state of the machinery and equipment was carried out. The field trips also included collection and analysis of samples with laboratory personnel at LWSC. Officials from institutions were interviewed and the list of the people is presented in Appendix 10.

3.1.2 Secondary Data Collection

This involved collection of data from already existing records. Results from experiments that have been carried out at LWSC on effluent were collected. Data collected was for 2009, 2010 and 2011(Appendices 1 to 9). The data collected was for the following parameters BOD (mg/L), COD (mg/L), Turbidity (measured in NTU), Total suspended solids (TSS) in mg/L, Feacal Coliforms (FC) counted as FC/100ml and Total Coliforms counted as TC/100ml. The coliform group of bacteria comprises mainly species of the genera *Citrobacter, Enterobacter, Escherichia* e.tc. The feacal coliform enumerated in this case is *Escherichia.*

The Biological Oxygen Demand (BOD) is measured by allowing a sample of effluent to stand at 20°C for five (5) days and calculating the amount of oxygen used up during the oxidation of the organic matter by bacteria. This measure is related to the amount of biodegradable organic matter contained in the effluent. The COD is measured by boiling the effluent with an acid dichromate solution which converts all organics and oxidisable matter to carbon dioxide and water. *COD is one and half times greater than BOD.*

Suspended Solids give rise to Turbidity of sewage and is determined by filtering a measured volume of the effluent. The solids are retained on a filter paper. The filer paper is oven-dried and *weighed. The Total Suspended Solids is the weight of the dried solids divided by the measured volume. This concentration is expressed in mg/L.*

Information on effluent standards was obtained from Zambian Bureau of Standards and Zambia Environmental Management Agency (ZEMA) formerly known as Environmental Council of Zambia (ECZ). Statistics on population were obtained from Central Statistics Office (CSO). Other sources of information included UNZA Library and National Water Supply and Sanitation Council (NWASCO).

3.2 DATA ANALYSIS

The collected data was analysed using Microsoft Excel Office 2007. Results were presented in form of tables and graphs. Digital photos were obtained using a digital camera.

CHAPTER 4: MUNICIPAL WASTEWATER MANAGEMENT IN LUSAKA, ZAMBIA

4.1 METHODS OF MUNICIPAL WASTEWATER TREATMENT IN LUSAKA, ZAMBIA

There are five municipal treatment plants in Lusaka City. These plants are the Matero, Kaunda Square, Chelston, Ngwerere and the Manchinchi-Garden WWTPs. The Matero WWTP consists of three independent systems (ponds) which are all non-conventional. Each of these systems consists of a primary pond, a secondary pond and a tertiary pond. The Kaunda Square WWTP is non-conventional and it consists of a primary pond, a secondary pond and a tertiary pond according to its design.

The Ngwerere WWTP treats effluent using the non-conventional method. It consists of two primary ponds, one secondary pond and one tertiary pond. The Chelston WWTP consists of anaerobic digestion process. The sewage is first digested anaerobically before discharging it into the primary pond. From the primary pond the effluent is discharged into the secondary pond and finally into the tertiary pond. This is the only plant with an anaerobic digestion process.

The Manchinchi WWTP is the only conventional municipal WWTP in Lusaka. The sewage is treated using mechanical methods. This plant consists of the preliminary stage, the primary treatment stage, the biological treatment stage, the secondary treatment stage and sludge digestion stage. The preliminary treatment stage consists of the screens, grit chambers and communitors while the primary treatment stage consists of four sedimentation tanks. The biological treatment stage consists of four trickling filters and the secondary treatment plant consists of four secondary sedimentation tanks. The treated effluent from the secondary sedimentation tanks is taken to the Garden ponds for further treatment. The settled material (sludge) is taken to the sludge digesters. This plant has two sludge digesters. The Garden ponds are maturation ponds and further treat the effluent before it is discharged into the stream. These ponds consist of two sets and each set has four ponds.

4.2 POPULATION GROWTH IN LUSAKA, ZAMBIA (1931-2010)

Population statistics show that population for Lusaka has been increasing. Figure 4.1 shows the population for Lusaka from 1931 to 2010. In 1931, Lusaka's population was only 2,433. The population increased to 18,909 in 1946. The population for Lusaka City in 1963 was 123,146 and by 1980 the population had increased to 535,830 (Mulenga, 2003). In 1990, there were 382,652 males and 378,412 females in Lusaka City giving a total population of 761,064. The population grew in the inter-censal period 1990-2000 (Figure 4.1). According to the 2000 census, the number of males increased to 549,020 while the number of females increased to 535,683 bringing the total population to 1,084,703. The total population for 2010 is 1,742,979 (CSO, 2010). Figure 4.1 shows the population for Lusaka City from 1931 to 2010.

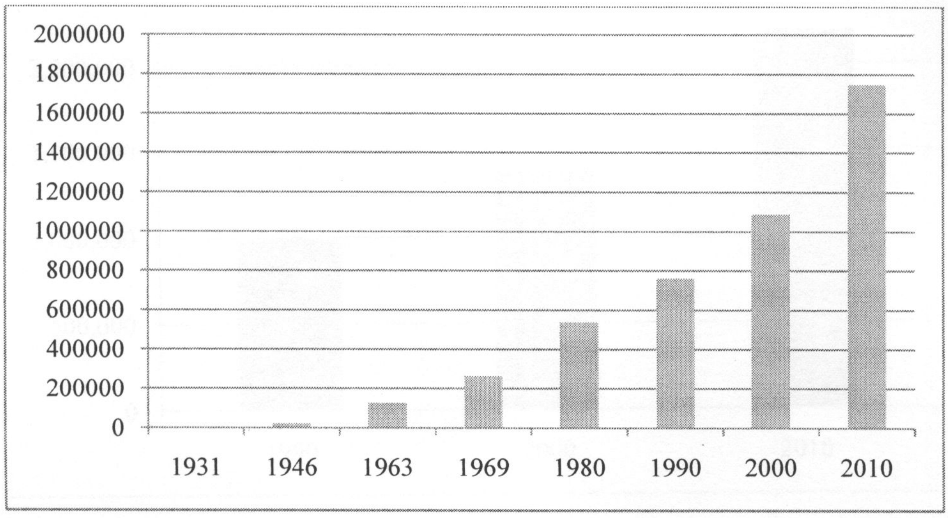

Figure 4.1: Population of Lusaka City from 1931 to 2010, Zambia.

Preliminary results for the 2010 census show that the population for Zambia in 2010 was 13,046,508. This is higher than the 9,885,591 for 2000. As shown in Figure 4.2, Zambia's population grew at an average annual rate of 2.8% during the 2000-2010 inter-censal period compared to an average growth rate of 2.4% in the 1990-2000 period.

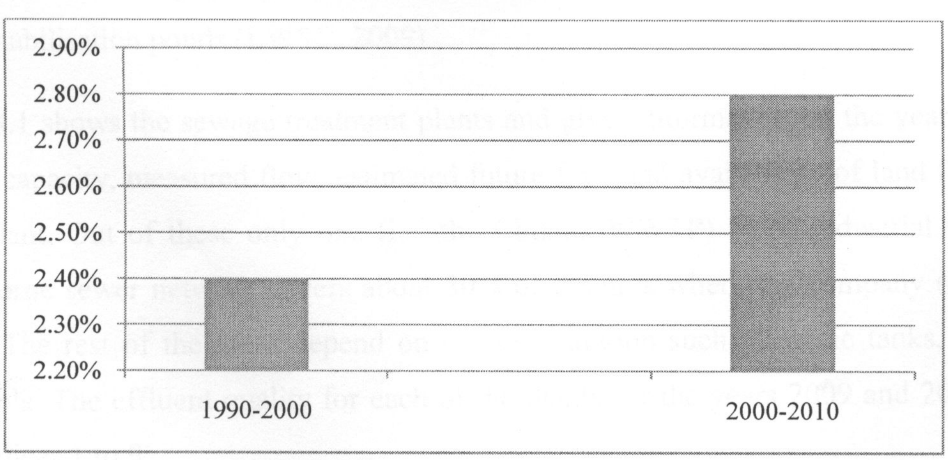

Figure 4.2: Population growth for Zambia during the periods 1990-2000 and 2000-2010.

Preliminary results show that Lusaka Province had the highest population (2,198,996) representing 16.9% of the total population. In the year 2000 Lusaka Province population represented 14% of Zambia's population. Figure 4.3 shows that there is uniform increase in population for Lusaka Province since 1990. Lusaka City constitutes the biggest percentage for Lusaka Province. In the 2000 statistics, Lusaka City's population was about 78% of Lusaka Province population while in 2010 it was 79%.

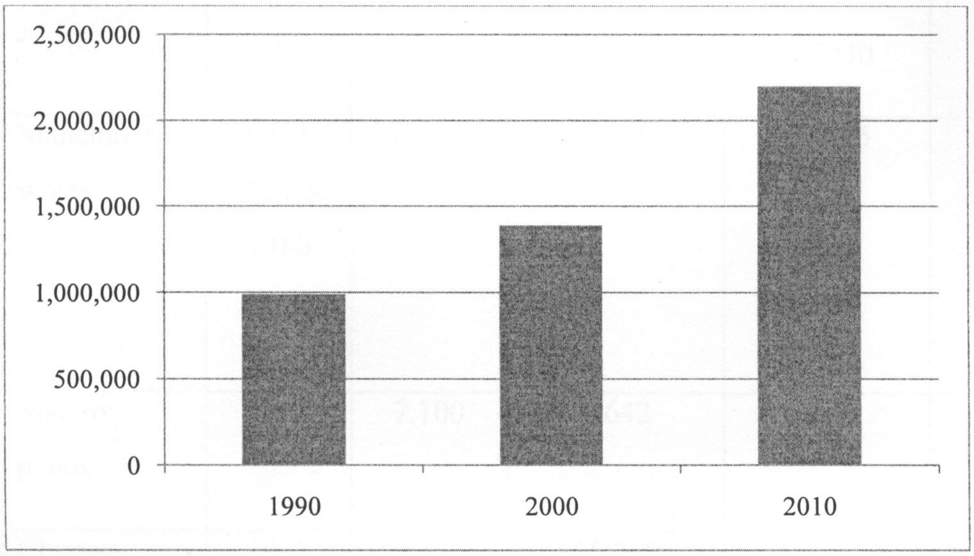

Figure 4.3: Population of Lusaka Province during the census years of 1990, 2000 and 2010, Zambia.

4.3 THE STATE AND EFFICIENCY OF MUNICIPAL WWTPS IN LUSAKA CITY, ZAMBIA

The sewerage system (Table 4.1) for the city comprises a sewer network of approximately 450km, seven sewage-pumping stations, two conventional sewage treatment plants and five waste stabilisation ponds (LWSC, 2009).

Table 4.1 shows the sewage treatment plants and gives information on the year of commission, design capacity, measured flow, estimated future flow and availability of land for expansion for each plant. Out of these only one (i.e. the Chunga WWTP) treats industrial wastewater. The waterborne sewer network covers about 30% of the area where the company (LWSC) supplies water. The rest of the areas depend on onsite sanitation such as septic tanks, pit latrines, and cesspools. The effluent quality for each of the plants for the years 2009 and 2010 are shown in Appendices 1 to 9.

Table 4.1. Sewage treatment facilities in Lusaka, Zambia (after: LWSC, 2009)

<table>
<tr><th>WWTP</th><th>Year Constructed</th><th>Design Capacity (m^3/day)</th><th>Measured Flow (m^3/day)</th><th>Estimated future Flow (m^3/day) Year 2030</th><th>Availability of land for Expansion</th></tr>
<tr><td>Manchinchi works</td><td>1959, 1969,& 1980</td><td>36,000</td><td>65,400</td><td>68,315</td><td>Yes</td></tr>
<tr><td>Matero ponds</td><td>1968</td><td>7,100</td><td>1,642</td><td rowspan="2">20,762</td><td>NIL</td></tr>
<tr><td>Chunga works</td><td>1973</td><td>9,100</td><td>15,750</td><td>Yes</td></tr>
<tr><td>Ngwerere ponds</td><td>1969</td><td>8,350</td><td>29,000</td><td>16,718</td><td>Nil</td></tr>
<tr><td>Kaunda Sq. ponds</td><td>1970</td><td>3600</td><td>Not Available</td><td>25,217</td><td>Nil</td></tr>
<tr><td>Chelston ponds</td><td>1972</td><td>2700</td><td>4370</td><td>6,563</td><td>Nil</td></tr>
</table>

The next sections describe each of these WWTPs in detail. The present condition of each WWTP is examined and their efficiency is determined by analysing the quality of the effluent.

4.3.1 The Manchinchi Catchment Area

This catchment (Figure 1.1) is served by the Manchinchi WWTP and the Garden ponds. The Manchinchi WWTP is the largest plant in Lusaka with a capacity of 36,000 m^3/day. This plant receives sewage from Woodlands, Chilenje, Libala, Leopard Hill and part of central business district of Lusaka. Though this plant is a municipal WWTP, observations revealed that the plant also receives industrial effluent as tanker containing brewery effluent was seen off-loading its contents during one of the visits to this plant. The effluent from this plant undergoes further treatment at the Garden ponds. Currently, the plant is operating beyond its design capacity because the measured flow is almost twice its design capacity of 36,000m^3/day. Most of the units are old and nonfunctional. The trickling filters are nonfunctional and raw sewage from the bypass line is mixed with the inadequately treated sewage. The quality of the effluent is below the standards. The plant is characterised by bad odours due to the septic condition that prevail. The sludge digesters are also not fully functional and are often overloaded.

Although this plant is wall fenced with a lockable gate, houses have been constructed very close to the treatment plant. This plant still has sufficient land for further expansion.

The effluent from Manchinchi goes to the Garden maturation ponds. There are eight ponds, four in each line. Currently, one line has been closed for desludging (Figure 4.4). The other line has never been desludged and sludge accumulation has reduced the depth of the ponds (Figure 4.5).

Figure 4.4: Closed set of ponds at the Garden Ponds, Lusaka, Zambia.

Figure 4.5: Shallow Garden Maturation ponds, Lusaka, Zambia.

Figure 4.6 shows the Biological Oxygen Demand averages for the final effluent from the Garden ponds. In the graph for 2009, the highest value was in October and the lowest was in November. The high BOD could have been due to an increase in the strength of the sewage received and the low BOD indicates that the sewage had a very low concentration of organic material. In terms of BOD, the effluent quality for the Garden ponds in 2009 was good. This is because BOD was below the ZEMA standard of 50mg/l. In 2010, the highest value was above this standard. This could be due to an increase in the sewage strength or short retention time. The organic matter in the sewage was not adequately treated. The lowest values were observed in February and May. These low values indicate that the effluent was adequately treated because the concentration of organic matter was reduced to a level which the water body can handle.

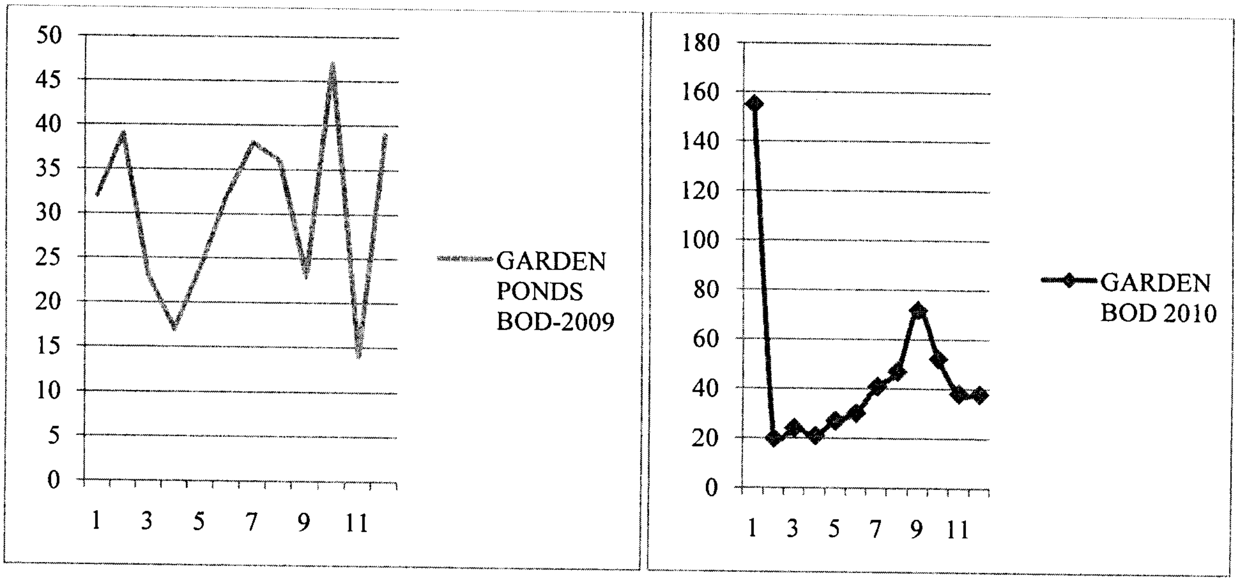

Figure 4.6: BOD for final effluent from Garden ponds 2009 and 2010

Generally the BOD results were good and were below the ZEMA standard of 90mg/l. The pH was within the ZEMA range (6-9). It was observed that the effluent is inadequately treated as it failed to meet the ZEMA standards for Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Turbidity, Total and Feacal coliforms (Appendices 1 and 2). The efficiency of the ponds is affected by the operations at Manchinchi. Most of the equipment at Manchinchi WWTP is old and broken down and the plant receives effluent (65,400m³/day) which is beyond its design capacity of 36,000m³/day as shown in Table 4.1. The effluent does not undergo the full biological process because of hydraulic overloading and reduced pond depth (due to excess sludge accumulation). The retention time is reduced to around six days from the originally designed retention time of 10-15 days.

Some residents of Garden Compound cultivate maize, sweet potatoes, vegetables and sugar cane in the area around the ponds (just a few meters away from the ponds). There is no fence around the ponds and houses have been constructed very close to the ponds.

4.3.2 The Ngwerere Catchment Area

This area is serviced by a nonconventional WWTP i.e. the Ngwerere ponds. These ponds were commissioned in 1969 and they have a design capacity of 8,350m³/day. From Table 4.1 it is

16718m³/day. The Ngwerere ponds consist of two primary ponds, one secondary and one tertiary. The ponds are odourless, well maintained with no overgrown grass or weeds or poorly disposed scum. It is located far away from settlements. Although the ponds are located far from the city, there is no land for expansion. There are however, a few huts around the ponds. The local people cultivate vegetables in gardens that are very near to the ponds (Figure 4.7).

Figure 4.7: A Vegetable garden next to the Ngwerere ponds, Lusaka, Zambia.

In Figure 4.8, there are two small gardens about 10 meters from the inlet channel apposite the sampler.

Figure 4.8: Vegetable gardens (opposite the sampler), Ngwerere ponds, Lusaka, Zambia.

Although this plant receives influent which is about 3 times beyond its capacity (8350m^3/day), the quality of the effluent is better than that obtained from the other treatment plants. Figure 4.9 shows the monthly averages for feacal coliforms. As presented in the graphs, the feacal coliforms per 100ml was within the ZEMA standard of 5000 per 100ml for most of the months.

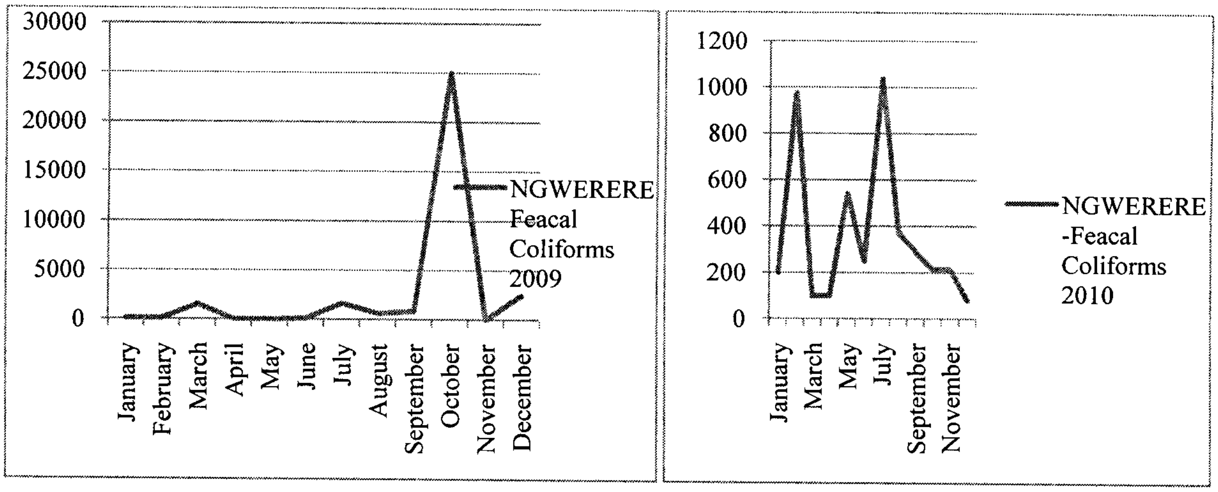

Figure 4.9: Feacal Coliforms for final effluent at Ngwerere ponds, Lusaka, Zambia (2009 and 2010).

The first graph in Figure 4.9 shows that the feacal coliforms were highest in the month of October. The total coliforms were also above the standard. This could be due to a reduction in the retention time or an increase in the strength of the raw sewage. These factors greatly affect the coliform removal efficiency. The data in Appendix 3 shows that effluent quality for pH, TSS and BOD were within the ZEMA standards. The effluent however failed to meet the standard for Turbidity and COD. The COD was above 90mg/l for all the months. This indicates that the effluent contained a large concentration of oxidisable inorganic compounds. This high concentration can cause depletion of oxygen in the receiving water body (the Ngwerere Stream in this case) stressing or suffocating aquatic life. On average all the parameters were within the ZEMA standards for both 2009 and 2010 (Appendices 3 and 4).

4.3.3 The Western Catchment Area

This catchment area is serviced by two WWTPs. One is the conventional type (Chunga WWTP) and handles industrial wastewater whereas the other one is non-conventional (Matero ponds) and treats municipal wastewater. The Matero ponds (Figure 4.10) consist of three independent systems and have a total capacity of 7,100 m^3/day. According to the information obtained from LWSC, the system's condition and capacity are relatively good. A field visit to the ponds revealed that these ponds are the most poorly maintained. They have overgrown with weed and algae (Figure 4.10).

Figure 4.10: Matero 3 secondary pond, Lusaka, Zambia.

The water is stagnant and has become a breeding place for mosquitoes. Swarms of mosquitoes were observed as early as midday making it difficult to carry out observations. The final effluent being discharged into the stream was characterized by a deep green colour. There are no gardens around pond 3 but houses have been constructed very close to the ponds. Some were being constructed on the day of the visit.

The ponds in this catchment have no available land for expansion. Figure 4.11 shows the final effluent being discharged into the stream. Next to the outlet is a house which is still under construction. This final effluent is characterised by a deep green colour.

Figure 4.11: Final effluent being discharged in the stream at Matero ponds, Lusaka, Zambia.

In the year 2009, the annual averages for turbidity, TSS, COD, BOD, total and feacal coliforms were above the ZEMA standards (Appendix 5). Figure 4.12 show the graph for the monthly averages for total coliforms. The lowest concentration was 40,000 coliforms/100ml (January) which was above the 25,000/100ml standard.

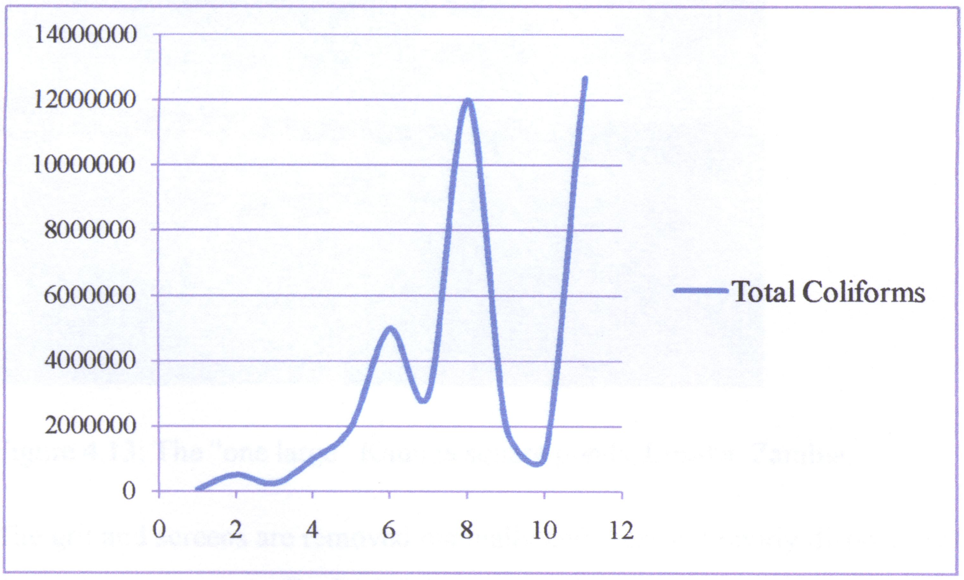

Figure 4.12: Total Coliforms for 2009- Matero ponds, Lusaka, Zambia.

The results were highest in August and December. These results show that the ponds are nonfunctional and are discharging effluent which is polluting the receiving stream. This untreated effluent is likely to pose health risks to the people living around the ponds. The final poorly treated effluent (Figure 4.11 above) is a public health hazard as it can be easily accessed by children, rodents and domestic animals. The mosquitoes in the stagnant water can also be potential carriers of pathogens causing diseases such as Malaria, Filariasis, Encephalitis etc. This highly pathogenic effluent can also be easily transported to the houses through aerosols.

4.3.4 The Kaunda Square Catchment Area

This area is serviced by the Kaunda Square stabilisation ponds situated in Chamba Valley, Lusaka north. Originally, the system consisted of three ponds, one primary, one secondary and one tertiary pond. The dam between the secondary and the tertiary ponds was made of stones and embankments with no slab. Currently, the system consists of only one segment because of the collapse of the banks. There is only one large pond (Figure 4.13) and hence the wastewater does not undergo the different stages required for biological reactions to completely digest the sewage.

Figure 4.13: The "one large" Kaunda square ponds, Lusaka, Zambia.

The grit and screens are removed manually and these are poorly disposed off. Figure 4.14 shows the preliminary stage. To the left is a heap of scum lying next to a pumpkin leaves and maize garden. The entire ponds are surrounded by maize fields and the plant is not fenced.

Figure 4.14: The preliminary treatment stage- Kaunda Square, Lusaka, Zambia.

Figure 4.15 shows the results for COD from samples collected at these ponds in 2009 and 2010. The ZEMA standard is 90mg/l but what can be observed from the graphs is that the results are above the standard for most months of the year. The BOD was also above the standards for most months (Appendices 6 and 7). This shows that the effluent contained a high concentration of organic and inorganic matter. On average the effluent quality in 2009 and 2010 failed to meet the standards for Turbidity, COD, Total and Feacal coliforms. This is because of the reduced retention time and the hydraulic overloading. The sewage is also not completely digested because it does not go through the complete stages because of the collapsed banks. The high COD between July and December 2009 can be attributed to high raw sewage strength experienced in drier months of the year (due to low dilution). This may also be true for August 2010. The high COD in January is due to the high organic content resulting from decaying aquatic plants and algae.

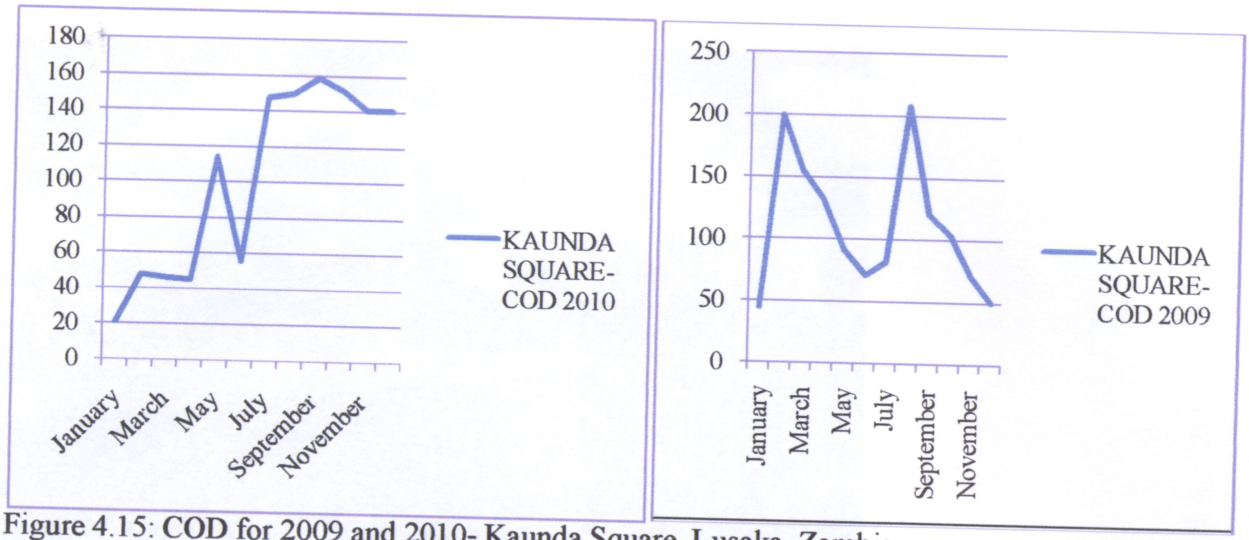

Figure 4.15: COD for 2009 and 2010- Kaunda Square, Lusaka, Zambia.

4.3.5 The Chelston Catchment Area

This area is serviced by the Chelston stabilisation ponds. This is the smallest set of ponds and the only system which has an anaerobic process. Constructed in 1972, the plant has a design capacity of 2700m³/day but it is currently receiving about 4370m³/day. The ponds are located in the middle of a residential area. Some houses have been built very close to the ponds (Figures 4.16 and 4.17)

Figure 4.16: Secondary pond-Chelston, Lusaka, Zambia.

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Figure 4.17: Tertiary ponds-Chelston, Lusaka, Zambia.

There is no land available for expansion. Monthly averages for turbidity are shown in Figure 4.18 and they are above the ECZ standards. The highest values where observed in November and December. The turbidity (clearness) of the water is affected by the number of particles that are in the water. These high values could be to short retention times which could not allow the particles to settle at the bottom. Except for turbidity, the effluent met the ECZ standards for all other parameter (pH, TSS, BOD, COD, Total and Feacal coliforms) (Appendices 8 and 9). These ponds perform well because the sewage influent is digested in the two anaerobic digesters before discharging it into the stream.

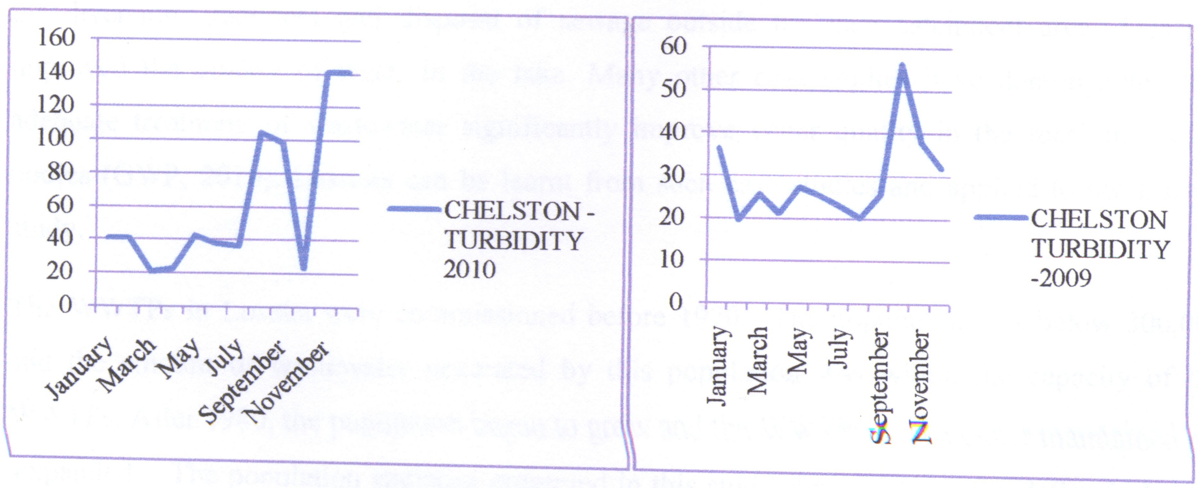

Figure 4.18: Monthly averages for Turbidity-Chelston ponds, Lusaka, Zambia.

4.4 DISCUSSION

The results for all the WWTPs show that all of these plants are operating beyond their design capacities. This is because these facilities are serving a population that is far much higher than they were designed for. The population of the area from which the wastewater is generated plays an important role in the performance of a WWTP. This is because wastewater is generated by humans and through human activities. The more people in a community, the more wastewater generated. The design of any WWTP always carefully takes into consideration the population which will be served by that WWTP. Demographic changes therefore have an effect on the performance of a WWTP. Management and disposal of wastewater must evolve with change in population but this has not been the case in Lusaka City.

Many studies around the world (GWP, 2010) have demonstrated that demographic changes in an area significantly affect the quality of water in that area. In the city of Bhopal in Madhya Pradesh, India, about 40% of the water supply comes from Upper Lake. Before 1947, the water quality of Upper Lake was so good that it required no treatment before supply to the public. However, due to the tremendous population growth of the city (from 70,000 in 1951 to 1.4 million in 2001) and rapid urban development, the lake has been subject to various environmental problems. Sewage is one of the major factors that have contributed to reduction of the quality of the water in this lake. The Government of Madhya Pradesh implemented an integrated lake conservation programme (1995-2004) that included a sewerage scheme based on the diversion, treatment and disposal of sewage outside the lake catchment area. This has improved the quality of water in the lake. Many other case studies have demonstrated that adequate treatment of wastewater significantly improve water quality in the receiving water bodies (GWP, 2010). Lessons can be learnt from such case studies and applied to the Lusaka study.

The WWTPs in Lusaka were commissioned before 1970. The population was below 300,000 and the amount of wastewater generated by this population was within the capacity of the WWTPs. After 1980, the population began to grow and the WWTPs were neither maintained nor expanded. The population statistics presented in this study show that the population in Lusaka City has been constantly increasing. The increase in population has resulted in an increase in human settlements and activities. These factors affect the management of water resources because there is increased demand for water and an increase in the amount of wastewater generated. The WWTPs are overwhelmed and receive wastewater beyond their capacities. Therefore, the quality of the effluent from these plants does not meet the required standards.

Zambian Bureau of Standards (ZABS) has set the standards on the quality of effluent discharged into in-land surface waters in the standard ZS 323:2006, ICS 13:060.01. Effluent conforms to the requirements of the relevant parts of this standard if it passes all tests and all the requirements as prescribed in this standard and tested according to the methods given in the standard. The characteristics of the effluent in this standard are in six categories i.e. physical, bacteriological, chemicals, metals, organics and radioactive material characteristics. ZABS has no specific method for detecting mercury and many other metals. The only specified methods are for arsenic and barium. The only pathogens included in this standard are the bacteria indicators i.e. the coliforms. Wastewater also contains many other pathogens which are not of bacterial origin and their presence cannot be indicated by coliforms. The helminthic parasites and virus are examples. Their virulence has been clearly outlined in literature (Stott, 2003) and must therefore be included in this standard.

ZABS also lacks well defined standards for Industrial effluent, trade effluent or municipal effluent. This standard (ZS 323:2006, ICS 13:060.01) is a general standard and does not pay particular attention to the nature and characteristics of each of the three kinds of effluent. There is need to clearly define the quality of industrial, domestic and trade effluent being discharged into the water bodies. According to Chenge (2003), the quality of effluent discharged, directly or indirectly must be strictly controlled by regulations, which prescribe a comparatively high standard of purity.

Studies have shown (Hutton, 2002), that population groups residing near wastewater treatment plants are at greater risk from diseases caused by pathogens in aerosolized wastewater resulting from aeration processes or sprinklers. Matero, Garden and Chelstone residents near the WWTP are therefore at great risk.

Though morbidity and serological studies on wastewater treatment plant workers occupationally exposed to wastewater directly and to wastewater aerosols have not been able to demonstrate excess prevalence of viral, bacterial and helminthic diseases; there is need of protecting these workers from such risks.

Indian studies, reported by Shuval and Badri. (2003), have shown that sewage workers exposed to raw wastewater in areas where *Ancylostoma* (hookworm) and *Ascaris* (nematode) infections are endemic have significantly excess levels of infection with these two parasites compared with other workers in similar occupations. Further more, Godfree (2003) has demonstrated that municipal wastewater also contains a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc, etc. Even if toxic materials are not present in concentrations likely to affect humans, they might well be at phytotoxic levels, which would limit their agricultural use.

The effluent may also contain pathogen which are viable or in form of spores. Therefore cultivating of crops (especially vegetables) near the ponds should be discouraged. Cases of water borne diseases associated with raw vegetables have already been experienced in Lusaka (Sinkala, 2004).

The Environmental Protection and Pollution Control act No.12 of 1990 gives Zambia Environmental Management Agency (ZEMA) the mandate to control all kinds of pollution and enforce legislation against pollution. ZEMA adopts and enforces the standards set by ZABS ensuring that the effluent discharged does not pollute the environment. In order to carryout its mandate effectively, ZEMA needs to be equipped with the state of art monitoring equipment and facilities such as its own laboratories. Compared to the cost of rehabilitating or expanding WWTPs, ZEMA disincentives for pollution are very low. This has made it cheaper for sewerage service providers to pollute and pay than rehabilitate their infrastructure. Pollution must be made more expensive. Pollution is both preventable and controllable. Though pollution control is expensive, the benefits outweigh the costs.

A case study for Robertson Town in South Africa shows direct relation between water quality, water efficiency, capacity building and planning. The reduction of the quantity and improvement of the quality of the water could be achieved by the integration of these components (GWP, 2010). ZEMA needs to increase its monitoring capacity and ensure that water quality in the receiving streams is maintained. Lusaka City Council (LCC) needs to enforce the existing regulations that restrict, control or define land use. In its planning for the expansion of the city, LCC should allocate land for WWTPs and ensure that there are no illegal settlements in such areas or near such areas.

Expansion of urban populations and increased coverage of domestic water supply and sewerage give rise to greater quantities of municipal wastewater. With the current emphasis on environmental health and water pollution issues, there is an increasing awareness of the need to dispose of these wastewaters safely and beneficially. The water related Millennium Development Goals (MDG's) cannot be achieved without improving the management and disposal of wastewater.

The Ngwerere stream is one of the water bodies that receive from the WWTPs in Lusaka City. It is a small, seasonal tributary to the Chongwe River. The Chongwe River is the water source for the water system in the town of Chongwe. Chongwe is a small rural town located about 40km east of Lusaka with a population of 19,000 people (LWSC, 2009).

The inadequately treated effluent from the Manchinchi and Kaunda Square treatment plants is the major sources of pollution for the river especially during the dry season. Currently, the only treatment provided for the water taken from the Chongwe River and piped into Chongwe is disinfection with Calcium Hypochlorite tablets. As a result, most of the residents of Chongwe do not use the water from the distribution system for drinking or washing. Instead, the residents of Chongwe use water from wells for these purposes (LWSC, 2009). Water users upstream must also consider the users down stream. The sewage generated in Lusaka is adversely affecting and posing serious health hazards to the people in Chongwe.

Improvements in the management and disposal of municipal wastewater in Lusaka City will utimately improve public health, promote environmental sustainability and reduce government expenditure on treating water borne diseases associated with wastewater. This can be done by effective removal of sewage from living areas and prevention of sewage entering drains, streams, water supply pipelines and groundwater. The collected sewage must also be properly disposed and adequately treated. This will result in more pleasant surroundings (e.g. Garden compound) through a reduction in odour and an improvement in the aesthetic quality of streams and rivers.

CHAPTER 5: CONCLUSION AND RECOMMEDATIONS

5.1. CONCLUSION

This study has revealed that the current Wastewater Treatment Plants (WWTPs) are operating beyond their design capacities. The total capacity of all the municipal WWTPs in Lusaka is 55,050m^3/day but the actual amount of effluent received per day is over twice this amount. This is because the WWTPs were designed for a smaller population. Increase in population has not been matched with expansion of sewerage services. The population has been increasing over the years and the WWTPs have been dilapidating. Based on these findings the following conclusions have been drawn:

1. Municipal wastewater in Lusaka city is not adequately treated. The treated effluent does not meet the required standards and hence water bodies that receive effluent from the WWTPs are being polluted.
2. Most of the equipment at the Manchinchi WWTP has broken down and hence the sludge is not adequately treated. This sludge is not suitable for application on crops and on lawns as it may still be containing pathogens and heavy metals.
3. Sewage facilities in Lusaka City have not attained the stage at which their end products can be used in agriculture or recycled. Treated effluent from Lusaka's WWTPs is not suitable for irrigation.
4. Population in Lusaka City will continue to grow and the increased water supply which is emphasized will naturally increase the amount of sewage generated in the city, which has to be disposed off. The sewerage system in Lusaka City needs to be improved urgently.
5. Pollution penalty fees are low and Water and Sewerage companies find it cheaper to pollute and pay than improve on their effluent quality. Zambia Environmental Management Agency (ZEMA) needs to review the disincentives for pollution, update their standards, acquire infrastructure and increase their capacity.
6. Compared to water supply and solid waste management, management and disposal of wastewater has not received much attention.

5.2. RECOMMENDATIONS

From the findings of this study, the following are recommended:

- The government should assist Lusaka Water and Sewerage Company (LWSC) to obtain funds for rehabilitation and expansion of the existing WWTPs;
- Zambian Beurea of Standards (ZABS) should include standards for parasitic worms and protozoan cysts in their ZS323:2006 standard;
- LWSC should increase the number of parameters that they test for. They should include parasitic worms, heavy metals and organic compounds. Quality assessment of digested sludge should also be carried out;
- Zambia Environmental Management Agency (ZEMA) should be more stringent on Water and Sewerage Companies by increasing the penalty fees and make it very expensive to pollute;
- Lusaka Water and Sewerage Company (LWSC) should ensure that cultivation of crops around the WWTPs is prohibited and discourage their general workers from doing so;
- In addition to provision of Personal Protective Equipment (PPE), LWSC should protect the health of their worker (especially general workers) providing immunisation against helminthic worms, health education and washing facilities;
- Lusaka Water and Sewerage Company (LWSC) needs to build fences around the ponds and prohibit people from loitering in these areas. LWSC should also improve on the maintainance of the ponds especially Garden and Matero ponds;
- Lusaka City Council (LCC) should prevent illegal construction of houses near the ponds; and
- The government should give more attention to the management and disposal wastewater as it can be an economic good if properly managed and an environmental and public health hazard if not properly managed.

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APPENDICES

APPENDIX 1: GARDEN PONDS EFFLUENT QUALITY- 2009, LUSAKA, ZAMBIA

	pH	Turbidity	TSS	COD	BOD	TC/100ml	FC/100ml
January	7.98	22.5	25	65	32	105600	32000
February	7.85	12.7	43	243	39	832000	64000
March	7.99	13.1	48	132	23	3.36x10^6	1.1x10^6
April	7.87	17.2	6	113	17	70x10^6	500000
May	8.32	17.4	165	75	24	15x10^6	3x10^6
June		18.2	108	67	32	10x10^6	4x10^6
July		27.7	33	102	38	16x10^6	5x10^6
August		51.2	37	841	36	131x10^6	54x10^6
Sept		53.3	22	308	23	31x10^6	4x10^6
October		79	58	146	47	3.8x10^6	4.2x10^6
Nov		38	8	73	14	1.5x10^6	1.1x10^6
December		66	42	117	39	32x10^6	3x10^6
ZEMA standard	6-9	15	100	50	90	25000	5000

APPENDIX 2: GARDEN PONDS EFFLUENT QUALITY- 2010, LUSAKA, ZAMBIA

	pH	Turbidity	TSS	BOD	COD	TC/100mL	FC/100ML
January		164	172	155	234	33X10^6	8X10^6
February		22	27	20	60	4.3X10^6	608000
March	7.39	16.6	15	24	63	7X10^6	440000
April	7.29	31	37	21	95	7X10^6	440000
May	7.12	24	34	27	84	70X10^6	26X10^6
June	7.18	42.5	32	30	62	16.7X10^6	1.7X10^6
July	7.19	42.5	99	41	154	16X10^6	1.9X10^6
August	7.13	43	79	47	135	21X10^6	2.6X10^6
September	7.11	37.1	79	72	157	25X10^6	375000
October	7.32	118	90	52	122	26X10^6	3X10^6
November	7.22	83.5	62	38	133	9X10^6	500000
December	7.22	83.5	62	38	133	9X10^6	500000
ZEMA Standard	6-9	15	100	50	90	25000	5000

APPENDIX 3: NGWERERE PONDS EFFLUENT QUALITY-2009, LUSAKA, ZAMBIA

	pH	Turbidity	TSS	COD	BOD	TC/100ml	FC/100ml
Jan	10.53	39.9	41	32	12	1600	100
Feb	9.25	24	120	276	21	1200	100
March	10.29	27.8	112	34	9	10700	1550
April	10.52	9.9	76	75	9	1000	50
May	11.32	17.7	59	70	13	150	50
June	10.43	19.7	157	71	17	460	150
July		18.9	61	66	18	2700	1650
Aug		17.9	190	380	14	2700	650
Sept		48.2	76	111	23	2100	879
Oct		53.4	80	148	19	410000	25000
Nov		54	50	111	18	3.7X10^6	2.2X10^6
Dec		21	16	30	10	20000	2500
ZEMA standard	6-9	15	100	50	90	25000	5000

APPENDIX 4: NGWERERE PONDS EFFLUENT QUALITY-2010, LUSAKA, ZAMBIA

	pH	Turbidity	TSS	BOD	COD	TC/100mL	FC/100ML
January		33	33	12	18	1000	200
February		23	48	8	25	3400	975
March	8.59	18	25	12	74	400	100
April	8.96	20	40	9	66	400	100
May	8.84	26	50	13	74	1400	540
June	8.82	19.1	42	15	33	600	250
July	8.52	19.1	24	15	84	2475	1037
August	8.85	23	53	15	87	1500	375
September	9.85	26.8	78	18	128	1475	288
October	8.17	144	96	20	88	950	215
November	8.17	144	96	20	88	950	215
December	8.56	88	62	17	68	720	80
ZEMA Standard	6-9	15	100	50	90	25000	5000

APPENDIX 5: MATERO PONDS EFFLUENT QUALITY- 2009, LUSAKA, ZAMBIA

	pH	Turbidity	TSS	COD	BOD	TC/100ml	FC/100ml
January	8.57	51.1	17	180	96	76800	40000
February	9.1	27.6	80	304	111	512000	56000
March	9.81	16.2	66	187	29	240000	40000
April	8.06	49.9	22	220	50	1000000	125000
May	8.57	99.9	17	171	80	2000000	690000
June	8.19	47.4	44	124	55	5000000	1X10^6
July		87.4	37	138	55	3000000	562500
August		87.4	31	781	39	12000000	2X10^6
September		153	108	95	60	2000000	1X10^6
October		151	104	272	80	1100000	812300
November		237	98	404	28	12700000	3.25X10^6
December		112	89	144	48	12800000	725000
ZEMA Standard	6-9	15	100	50	90	25000	5000

APPENDIX 6: KAUNDA SQUARE PONDS EFFLUENT QUALITY- 2009, LUSAKA, ZAMBIA

	pH	Turbidity	TSS	COD	BOD	TC/100ml	FC/100ml
January	8.26	36.3	51	45	35	1.32X10^6	120000
February	7.88	19.6	90	200	36	1.2X10^6	220000
March	7.89	25.8	69	155	47	4.2X10^6	1.4X10^6
April	7.93	21.2	16	132	20	5.6X10^6	120000
May	8.23	27.3	80	92	26	4X10^6	2X10^6
June	7.77	25.5	91	72	26	2X10^6	760000
July				83		5X10^6	2X10^6
August		20.2	14	208	32	4X10^6	2.7X10^6
September		25.8	26	121	30	42X10^6	88000
October		56.4	33	105	25	1.1X10^6	1.5X10^6
November		38	8	73	14	1.5X10^6	1.1X10^6
December		32	9	51	17	23X10^6	
ZEMA Standard	6-9	15	100	50	90	25000	5000

APPENDIX 7: KAUNDA SQUARE PONDS EFFLUENT QUALITY-2010, LUSAKA, ZAMBIA

	pH	Turbidity	TSS	BOD	COD	TC/100Ml	FC/100ML
January		53	41	14	21	4.6X10^6	590000
February		25	28	16	48	4.9X10^6	1.2X10^6
March	7.24	19.7	5	13	46	5.9X10^6	2X10^6
April	6.96	28	7	12	45	5.9X10^6	2X10^6
May	7	33	55	32	114	9.4X10^6	1.9X10^6
June	6.93	41	86	26	56	7.75X10^6	2.8X10^6
July	7	41	65	38	148	11X10^6	2.3X10^6
August	6.98	49	75	37	150	18X10^6	4.8X10^6
September	7.12	35.9	80	52	159	11X10^6	1.3X10^6
October	7.12	96	81	42	152	14X10^6	2X10^6
November	7.15	69	114	51	141	7X10^6	250000
December	7.15	69	114	51	141	7X10^6	250000
ZEMA Standard	6-9	15	100	50	90	25000	5000

APPENDIX 8: CHELSTON PONDS EFFLUENT QUALITY- 2009, LUSAKA, ZAMBIA

	pH	Turbidity	TSS	COD	BOD	TC/100ml	FC/100ml
January	9.26	20.6	41	28	15	2900	100
February	9.83	44.6	113	390	13	2200	150
March	9.94	46.7	112	44	9	10700	1550
April	9.75	77.8	51	98	9	16200	1000
May	10.23	66.6	107	74	11	3300	1900
June	9.52	19.9	99	46	17	7600	3800
July		61.2	29	31	10	3200	700
August		20.3	8	44	16	1200	400
September		24.8	44	112	20	4200	1400
October		39.6	28	62	14	1.25X10^6	12000
November		20.2	66	113	19	1X10^6	10400
December		28	6	27	9	10000	2500
ZEMA Standard	6-9	15	100	50	90	25000	5000

APPENDIX 9: CHELSTON PONDS EFFLUENT QUALITY- 2010, LUSAKA, ZAMBIA

	pH	Turbidity	TSS	BOD	COD	TC/100mL	FC/100ML
January		41	9	9	14	3850	1875
February		41	7	7	21	6800	1300
March	7.92	21	6	6	53	1400	300
April	7.36	23	3	3	30	1400	300
May	7.53	43	9	9	55	2950	1153
June	7.61	38	11	11	24	6150	975
July	8.21	36.5	12	12	50	19000	1750
August	9.05	105	11	11	73	18400	3000
September	7.05	98.6	18	18	126	6100	400
October	7.91	23.6	23	23	85	54100	10750
November	7.36	141	18	18	89	85000	2500
December	7.36	141	18	18	89	85000	2500
ZEMA Standard	6-9	15	100	50	90	25000	5000

APPENDIX 10: LIST OF OFFICIALS INTERVIEWED, LUSAKA, ZAMBIA

1. Mr. Osbert Musongo, Senior Chemist, Lusaka Water and Sewerage Company.
2. Mrs. Mary Bbukali, Senior Engineer, Lusaka Water and Sewerage Company.
3. Mr. Frank Chimpukutu, Senior Laboratory Technician, Lusaka Water and Sewerage Company
4. Mr. Brian Mweemba, Communications and Information Officer, Zambian Bureau of Standards.