SHARED WATERS, SHARED OPPORTUNITIES AND SHARED THREATS; THE CASE OF CHUNGA RIVER, LUSAKA, ZAMBIA

BY

LEVY MUSETEKA

Submitted in partial fulfillment of the requirements for the Post-graduate diploma in Integrated Water Resources Management

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Declaration

I, Levy Museteka, hereby declare that this dissertation represents my own work, and that it has not been previously submitted for a Post-graduate Diploma or degree at this or any other University.

Full Name: Levy Museteka

Signature: ______________________

Date: 20th July 2010

Dedication

This dissertation is dedicated to Webster and Miriam Museteka (both late) for the courage and challenges they gave me through their existence

Approval

This Dissertation has been approved as partial fulfillment of the requirements for the award of the Post-Graduate Diploma in Integrated Water Resources Management.

Supervisor: Professor Imasiku A. Nyambe

Signature: ____________________

Date: 2/7/10

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ABSTRACT

Water is a scarce and a vulnerable resource. The use of water in an environmentally sustainable manner can help achieve global development. This is because an environment with poor water quality is bound to encounter catastrophic problems and subsequently derail global development. 'Shared water and shared opportunities' was the global theme of the World Water Day celebrations for 2009. This was the inspiration to doing this study. The study is premised on the fact that the water resources that are in the Chunga River, a local tributary of the Mwembeshi River in Lusaka District are important for human use while at the same time depend on waste water from Lusaka Water and Sewerage Chunga Treatment plant for much of the flow. The waters in this river are finite and under threat due to poor sewer handling. This study investigated and analyzed secondary and primary data in coming up with conclusions and recommendations. The methodology used in executing this study was first to analyze existing data on the Chunga River and the actual sampling in the field. The results obtained showed that Chunga River water is poor when analyzed from a point just after the discharge of effluent at the treatment plant. This shows that the water in many ways does not meet the recommended standard. Specifically, Biological Oxygen Demand, Chemical Oxygen Demand and Dissolved Oxygen and bacteria load (Total and Faecal coliforms) did not meet the statutory standard recommended for effluent. The average demand for BOD at Chunga LWSC discharge point was 185mg/l which is above the statutory ECZ limit of 50mg/l. Similarly, the average demand for COD for the period under review was 409mg/l, a figure which is about four times the ECZ statutory limit of 90mg/l. The dissolved oxygen levels remained below the 5mg/l statutory limit for most parts of the dry season while during the rainy season; the levels barely equaled the statutory limit. The microbiological quality was also found to be above statutory limits in both the LWSC and research results. The pH value however remained between 7 and 8 which is favourable condition for most aquatic life provided other conditions are also favourable. From the results, quality of the water is poor as indicated above at the discharge and improves at it flows down stream. It is important to improve the treatment capabilities of the Chunga Treatment plant and in the meantime cordon a considerable distance along the river immediately after the discharge to avoid sorption of concentrated contaminants right after discharge. The study also revealed that an average of 46 million cubic meters of water was discharged annually between 2007 and 2009 portraying the water potential of the Chunga River.

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LIST OF ABBREVIATIONS

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
ECZ	Environmental Council of Zambia
LWSC	Lusaka Water and Sewerage Company
NOAEL	No Adverse Effect Level
pH	Hydrogen Potential
Redox	Reduction Oxidation Potential
SAR	Sodium Adsorption Ratio
TSS	Total Suspended Solids
TC	Total Coliform
FC	Faecal Coliform

CHAPTER 1: INTRODUCTION

(1) Introduction

Chunga River is situated in the Northwest of Lusaka area and drains Lusaka in the North West direction. It is a major tributary of the Mwembeshi River which subsequently drains into the Kafue River. The source of the river is situated near the discharge area of the Lusaka Water and Sewerage Company Sewer Treatment plant. As it may substantial amount of water this treatment plant, the challenge of water quality, opportunities that emerge from this river are this going to be investigated and highlighted.

(2) Statement of the problem

The Chunga River presents many opportunities for the supply of perennial amount of water due to the discharge from the treatment plant. These opportunities however have not been explored to the full potential. The treatment plant according to some literature view has not been effective hence discharging water with sub-standard quality (LWSC, 2009). The same water is used for agro and fishing activities. The problem thus is that insufficiently treated waste could end up back in human food chain and affect human life. It is therefore important asses the opportunities and threats that are posed by Chunga River Catchment. To compound on the problem, many households resort to using Chunga River for their domestic purposes when their wells dry up in summer.

(3) Objective

I. To highlight the opportunities that are abound in the Chunga River for agricultural and fishing purposes

II. To investigate the quality of water along Chunga River and highlight the threats if any.

(4) Location of the study

The Chunga River catchment is located in the North-East side of the greater city of Lusaka. It is a major contributor of surface water to the Mwembeshi River. It drains streams from the Northeast of Lusaka and pours them into the Mwembeshi River. The Mwembeshi River subsequently empties into the Kafue River. The study is set on the Chunga catchment (Figure 1.1). In Figure 1.2, the treatment plant is depicted in a satellite (aerial) view courtesy of Google Earth (Eureka, 2010)

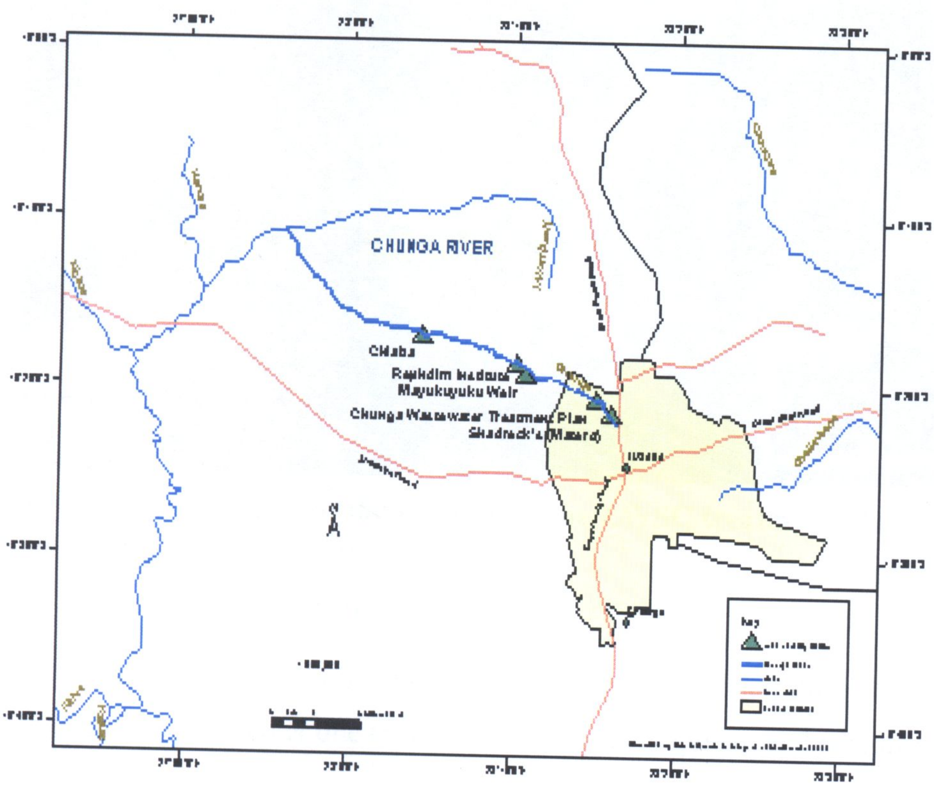

Figure 1- 1: Sketch map of the location of Chunga River catchment and selected sampling point in Lusaka and Kafue areas

Figure 1- 2: Aerial view of the location of the LWSC treatment plant and Chunga River in Lusaka, Zambia. (Source Google Earth)

(5) Limitation of the study

The study was limited in achieving the objective of analyzing the potential of setting up small dams on the Chunga River due to insufficient time, equipment and resources

(6) Hypothesis

I. What opportunities exist for setting up small dams for agricultural purposes in the Chunga River?

II. Does the effluent discharge and subsequent river flow present a danger to human life due to the water quality of the river?

(7) Rationale

The Millennium Goal number 7 commits countries to achieving environmental; sustainability therefore, it calls for efforts to treat effluent discharge as well as efficient use of discharge water in an environmentally sustainable manner. Water has many uses among its competing users. However the quality of water considerably influences the purpose for its use, thus the common connotation that waste water is not waste as the same waste water can be of good use for other purposes. Opportunities are abound for more efficient use of the water by way creating small dams. The water in the Chunga River is used by emerging farmers as well as fish farming (Nyambe and Feilberg, 2009). It is therefore important to investigate the quality of water as it is part of the food chain of the vegetables and fish products from the river.

CHAPTER 2: METHODOLOGY

The methodology used in generating data for analysis in this project is going to be covered in this chapter.

The method of data collection involved the use of existing information through review of literature available, data from the regulatory institutions and actual field sampling of the water from the Chunga River.

The first thing that was done is to review the existing information on the quality of water in Chunga River. Incidentally, there doesn't seem to be any published books and documents on the Chunga River. However, Secondary data exists at Lusaka Water and Sewerage Company in bi-annual returns found at the Environmental Council of Zambia and the Department of Water Affairs routine monitoring data.

2.1 Literature Review

The study area is located in Lusaka province (Figure 2.0). According to the survey that was done in June 2003, the water quality results showed that water in this river comes from ground water aquifers. The sources are actually springs (DWA, 2007). The river originates from springs in George compound and Matero township of Lusaka. On its downstream the major contribution of water comes from the sewerage ponds in Chunga and further downstream is the effluent from Chunga treatment plant which is run by Lusaka Water and Sewerage Company (LWSC).

In the same survey it showed that there was more pollution in the upper reaches of the river than in the lower reaches. This is confirmed by higher levels of pollution in Chunga River just after the discharge point of around 1300μS/cm and dropping to around 1127μS/cm at Rephidim institute which is located about 20km downstream. This is an evidence of the self-purification capacity of the river. However , because of high conductivity (hence to a large extent total dissolved solids) as observed further downstream of the river, it is probable that the river could not purify itself to a level where the water quality can be acceptable for drinking or other uses before further treatment. Along the stretch on this river where the water quality monitoring points are one dam and one weir.

The Chunga River also lies on the periphery of the carbonate geological aquifer commonly known as the Lusaka Dolomite (Museteka and Bäumle, 2009). It is this geological setting that allow the groundwater to feed into the Chunga River thereby contributing to the purification effect that the river undergoes after injection sewer effluent at Chunga LWSC treatment plant. In analyzing the Literature review, the study drew its attention in reviewing the aspects of water quality test parameters which premised on analyzing physical-Chemical parameters, Principal cations and anions, Biological and Chemical Oxygen Demand (BOD and COD) the Sodium adsorption Ratio and selected heavy metals. The following section takes a detailed look into these parameters.

2.2 Physical chemical parameters

In the analysis of water quality, physical chemical parameters provide a preliminary perception on the quality of water. The major parameters under consideration are the Hydrogen Potential, Electrical Conductivity, Reduction-Oxidation Potential, the temperature of the media, Dissolved Oxygen and Turbidity.

(i) Hydrogen Potential (pH)

Water with a pH less than 7 is acidic while that which is greater than 7 is alkaline. The pH of water determines the solubility of chemical constituents such as carbon, nutrients (phosphorus, nitrogen, etc) and heavy metals (lead, copper, cadmium, etc). For instance, pH determines whether aquatic life can use dissolved constituents. In the case of metals, pH determines the degree to which the metals are soluble hence determining their toxicity. Metals generally tend to be more toxic at lower pH because they are more soluble. Low pH can also enhance corrosion of steel casing pipes. The statutory limit for pH set by the Environmental Council of Zambia (ECZ) on effluent discharges is 6.5 to 8.5. (See Figure 3.1and 3.4)

(ii) Electrical Conductivity (EC)

Electrical Conductivity (EC) estimates the amount of total dissolved solids or ions in the water. This is controlled by factors such as river geology and nature of the effluent discharge. The higher the Electrical Conductivity the more dissolved solutes are likely to be found in the water. This is indicative of pollution load in the water. (Figure 3.2)

(iii) Redox Potential

The Redox (or reduction-oxidation) potential works similar to the pH in influencing water quality. It indicates the presence of reducing (anaerobic) and oxidizing (oxic) conditions in the water source. A negative redox potential value (e.g., -300 mV when microbes are involved in the redox reactions) indicates reducing conditions while a positive value (e.g., +500 mV when in contact with air) indicates oxidizing conditions (Langmuir, 1997). Reducing (little or no oxygen) conditions are sometimes undesirable in surface water as they can lead to bad smell of water through the formation of hydrogen sulphide and ammonia.

(iv) Dissolved Oxygen (DO)

The presence of dissolved oxygen in river water is important for the survival of aquatic organisms that are aerobic in nature. Lack of oxygen can lead to suffocation of aquatic life and lead to the river acquiring the status of a dead river. Oxygen addition in the river is added through turbulence and aquatic plants growing in the river bed. The ECZ effluent standard for survival of aquatic life is 5mg/l of dissolved Oxygen (ECZ, 1993). If chemical constituents of the effluent are highly oxidative, they raise the Chemical Oxygen Demand (COD) and thus deplete the Oxygen. This may eventually lead to suffocation of aquatic life since the demand for this scarce supply of dissolved oxygen has increased.

The same scenario is encountered when organic constituents of the effluent use Oxygen for their continued breakdown. This is the same oxygen which sustains the aquatic life. The increased demand for oxygen therefore poses a threat to the existence of aquatic life in the river especially when treatment at Chunga is not to the required standard (ECZ, 1993).

Irrigation water quality refers to the kind and amount of salts present in the water and their effects on crop growth and development. Salts are present at variable concentrations in all waters, and the salt concentrations influence osmotic pressure of the soil solution: the higher the concentration, the greater the osmotic pressure. Osmotic pressure in turn affects the ability of plants to absorb water through their roots. Plants can absorb water readily when osmotic pressure is low, but absorption becomes more difficult as the pressure increases. Even if the soil is thoroughly wet, plant roots have difficulty absorbing water when the osmotic pressure is high. When the pressure is unusually high, it may even be impossible for plants to absorb sufficient water for normal plant growth. Under these conditions, plants may actually wilt when the roots are in water. When salts break down when they go into solution, various anions and cations produced in water and result in exerting considerably different effects on plants and humans. (Glover, 1996)

2.3 Principal Cations

There are four principle cations that are considered in water analysis. These are Calcium, Magnesium and Potassium. These are further discussed below:

(i) Calcium

Calcium (Ca) is an essential plant nutrient found extensively in Lusaka surface and groundwater. It occurs as limestone (Calcium carbonate) and gypsum (calcium sulphate). Calcium carbonate is considered slightly soluble, while calcium sulphate is moderately soluble. Waters high in calcium or magnesium are considered hard and are not desirable for domestic water supplies, but hard water is considered good for irrigation. Calcium helps keep soils in good physical condition, which favours good water penetration and easy tilling (Glover, 1996).

(ii) Magnesium

Magnesium (Mg) is another essential plant nutrient found in abundance in Lusaka surface and ground waters. Chemical reactions of magnesium in the water are similar to those of calcium. Magnesium normally occurs at about half the concentration of calcium. Cases exist however in Lusaka where magnesium has been found to be closer to the calcium values (Museteka and Bäumle, 2009).

(iii) Sodium

Sodium (Na), another cation, occurs in almost all Lusaka waters (Museteka and Bäumle, 2009). Although studies have considered it not to be an essential plant nutrient, it is the most injurious of the cations found in irrigation and drinking waters. Unlike calcium and magnesium waters, those high in sodium are considered "soft" and are generally undesirable for irrigation. Unfavourable conditions are likely to develop when the concentration of sodium exceeds that of calcium and magnesium (Apple and Postma, 2007).

Although concentrations of sodium in potable water are typically less than 20 mg/litre, they can greatly exceed this in some countries. The levels of sodium salts in air are normally low in relation to those in food or water. It should be noted that some water softeners can add significantly to the sodium content of drinking-water (WHO, 1989).

No firm conclusions can be drawn concerning the possible association between sodium in drinking-water and the occurrence of hypertension. Therefore, no health-based guideline value is proposed. However, concentrations in excess of 200 mg/litre may give rise to unacceptable taste (WHO, 1989).

(iv) Potassium

Potassium (K) is an essential plant nutrient commonly found in good supply in soils. Although rocks and minerals containing potassium are common in Lusaka, potassium is a minor element in irrigation waters; consequently, potassium determination is no longer a routine part of irrigation water analysis (Glover, 1996).

(v) Chromium

Although Chromium is not a principal cation, it was considered for the sake of determining the threat of heavy metal contamination in water. Chromium is widely distributed in the earth's crust. It can exist in valences of +2 to +6. Total chromium concentrations in drinking-water are usually less than 2 μg/litre, although concentrations as high as 120 μg/litre have been reported. In general, food appears to be the major source of intake. The absorption of chromium after oral exposure is relatively low and depends on the oxidation state. Chromium (VI) is more readily absorbed from the gastrointestinal tract than chromium (III) and is able to penetrate cellular membranes. There are no adequate toxicity studies available to provide a basis for a No adverse Effect Level (NOAEL) (WHO, 1989). In a long-term carcinogenicity study in rats given chromium (III) by the oral route, no increase in tumour incidence was observed. In rats, chromium (VI) is a carcinogen via the inhalation route, although the limited data available do not show evidence for carcinogenicity via the oral route. In Epidemiological studies, an association has been found between exposure to chromium (VI) by the inhalation route and lung cancer. IARC has classified chromium (VI) in Group 1 (human carcinogen) and chromium (III) in Group 3 (WHO, 1989).

Chromium (VI) compounds are active in a wide range of *in vitro* and *in vivo* genotoxicity tests, whereas chromium (III) compounds are not. The mutagenic activity of chromium (VI) can be decreased or abolished by reducing agents, such as human gastric juice. In principle, it was considered that different guideline values for chromium (III) and chromium (VI) should be derived. However, current analytical methods favour a guideline value for total chromium (WHO, 1989).

2.4 Principal Anions

There are four major anions considered when conducting water quality analysis. These are;

(i) Sulphate

The most dominant anion in most well waters in the state is the sulphate (SO4) ion. The sulphate ion causes no particular harmful effects on soils or plants; however, it contributes to increased salinity in the soil solution (Glover 1996).

(ii) Chloride

The next most common anion is the chloride (Cl) ion. Unlike sulphate, the chloride ion has a direct toxic effect on some plants, while also contributing to the salinity of the soil solution when river water is used for irrigation (Glover 1996).

(iii) Carbonate and Bicarbonate

The carbonate (CO3) and bicarbonate (HCO3) ions are of major importance in surface water. They provide a higher buffering capacity of water especially under acid induced conditions (Langmuir, 1997).

(iv) Nitrates

Nitrates are important nutrients in the Agricultural sector, However for drinking purposes these can be fatal as they may induce blue eye syndrome in babies (WHO, 1989).

2.5 Sodium Adsorption Ratio (SAR)

The sodium adsorption ration (SAR) indicates the effect of relative cation concentration on sodium accumulation in the soil; thus, SAR is a more reliable method for determining this effect than sodium percentage. SAR is calculated using the following formula: Ions are expressed as milli-equivalents per litre (Meq/L). The potential for a sodium hazard increases in waters with higher SAR values (Glover, 1996).

2.6 Biological Oxygen Demand (BOD)

Biological Oxygen Demand (BOD) is one of the most common measures of pollutant organic material in water. BOD indicates the amount of putrescible organic matter present in water. Therefore, a low BOD is an indicator of good quality water, while a high BOD indicates polluted water. Dissolved Oxygen (DO) is consumed by bacteria when large amounts of organic matter from sewage or other discharges are present in the water. DO is the actual amount of oxygen available in dissolved form in the water. When the DO drops below a certain level, the life forms in that water are unable to continue at a normal rate. The decrease in the oxygen supply in the water has a negative effect on the fish and other aquatic life. Fish kills and an invasion and growth of certain types of weeds can cause dramatic changes in a stream or other body of water. Energy is derived from the oxidation process. BOD specifies the strength of sewage. In sewage treatment, to say that the BOD has been reduced from 500 to 50 indicates that there has been a 90 percent reduction (WHO, 1989).

The BOD test serves an important function in stream pollution-control activities. It is a bioassay procedure that measures the amount of oxygen consumed by living organisms while they are utilizing the organic matter present in waste, under conditions similar in nature (Trent and Nixon, 1990).

2.7 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes. Chemical Oxygen Demand is measured as a standardized laboratory assay in which a closed water sample is incubated with a strong chemical oxidant under specific conditions of temperature and for a particular period of time. A commonly used oxidant in COD assays is potassium dichromate ($K_2Cr_2O_7$) which is used in combination with boiling sulfuric acid (H_2SO_4). Because this chemical oxidant is not specific to oxygen-consuming chemicals that are organic or inorganic, both of these sources of oxygen demand are measured in a COD assay (Sawyer, McCarty and Parkin, 2003).

Chemical Oxygen Demand is related to biochemical oxygen demand (BOD), another standard test for assaying the oxygen-demanding strength of waste waters. However, biochemical oxygen demand only measures the amount of oxygen consumed by microbial oxidation and is most relevant to waters rich in organic matter. It is important to understand that COD and BOD do not necessarily measure the same types of oxygen consumption. For example, COD does not measure the oxygen-consuming potential associated with certain dissolved organic compounds such as acetate. However, acetate can be metabolized by microorganisms and would therefore be detected in an assay of BOD. In contrast, the oxygen-consuming potential of cellulose is not measured during a short-term BOD assay, but it is measured during a COD test (Sawyer, McCarty and Parkin, 2003).

2.8 Field Reconnaissance

A field reconnaissance visit was then set up in the month of December so as to select the sampling points so as to check the feasibility of sampling during the exercise. During the same period, interviews were conducted with the emerging farmers that line the river just beyond the LWSC Chunga Treatment Plant discharge point. The reconnaissance however for mapping potential sites for the set up of dams was however not done. This was due to lack of software (Digital Elevation model) and resources to map out ground-truthing events. A questionnaire was nevertheless prepared for collection of qualitative data on the types of farmers, crops grown and the extent of this practice.

Figure 2- 1: Agricultural activity on the banks of Chunga River at Rephidim institute in Lusaka

2.9 Equipment and Materials.

The following were pieces of equipment used in data collection:

i. A Geographic Positioning System (GPS for geo-referencing the data collection points;
ii. A Field multimeter for the collection of on-site physical chemical parameters such as Temperature, Hydrogen potential (pH), Electrical Conductivity and the Redox potential. The results from this campaign are tabulated in the results section;
iii. Stationery;
iv. Laboratory services for water Quality tests done at the University of Zambia Environmental Engineering Laboratory;
v. Protective clothing;
vi. Transport/ (vehicle and fuel);

vii. Software (Arc map) for projecting the spatial features of the study area and
viii. Sampling bottles

2.10 Data Collection

Primary and secondary data was collected for analysis. Primary data in this study comprised of physical chemical parameters collected on site. The results from this campaign are tabulated in the results section.

The water in Chunga River was mainly sampled on points; Chunga at treatment plant and Chunga River at Rephidim Institute. Before collecting a sample, physical chemical data was collected by inserting the probes of the water quality field multimeter in the flowing water and then taking the readings.

Samples were then collected and kept cool (<10°C) in a cool box until analysis at the Laboratory.

Secondary data was collected from Department of Water Affair's archives as well as annual returns from the Environmental Council of Zambia which monitor the Sewer effluent bi-annually from the Lusaka Water and Sewerage Company. The data has been included in the results and subsequent analysis.

CHAPTER 3: RESULTS

3.1 Results

In this chapter, secondary and tertiary results are presented and summarily discussed. In September 2007, the Department of Water Affairs conducted physical-chemical tests on the Chunga River just after the discharge of the LWSC. The results are presented in Table 3.1. In December 2009, a primary physical chemical data was collected for analysis and is presented in Table 3.2.

Table 3-1: Results from Chunga River after the LWSC discharge point in September 2007 (data courtesy of DWA 2007) Location (E 028°15'4", S15°20'38.4")

Station	Sampling Date Sept. 2007	pH	Electrical Conductivity (uS/cm)	Redox (Eh)	Dis. O2 (mg/l)	Temp. (°C)
Chunga River after discharge point	14	7.2	1578	-18	2.13	25.5
	17	7.4	1567	-10	1.32	25.6
	18	7.4	1732	-10	2.03	25.2
	19	7.3	1702	-10	1.6	26.2
	20	7.7	1662	-20	1.08	25.1
	21	7.2	222	3	1.94	25.4
	23	7.4	1730	-10	1.98	2.51
	26	7.5	885	-16	2.76	26.3
	27	7.5	292	-15	2.02	26.9
ECZ Standard		**6.0 – 9.0**	**4300**	-	**5**	-

During the Month of September 2007 (Table 3.1), precipitation was almost none as is usually the case in Zambia. Any dilution and river rejuvenation is most likely going to come from groundwater intrusion in where possible diluted effluent. The pH remained between 7 and 8 which are basically within ECZ effluent standards. The Electrical conductivity was also within statutory regulation values. However, the dissolved oxygen values well all below the ECZ standard for effluent discharge. The values collected were too low to support aquatic life such as fish. As a matter of fact, there were no observed fish species during the sampling in the September 2007 at the sampling point near Chunga discharge point.

Analyzing the pH values for September 2007 (Figure 3.1), it is observed that the values range between pH 7 and 8 which in a general sense ranges in the neutral figures. The ECZ effluent discharge standard is a range between 7 and 9.

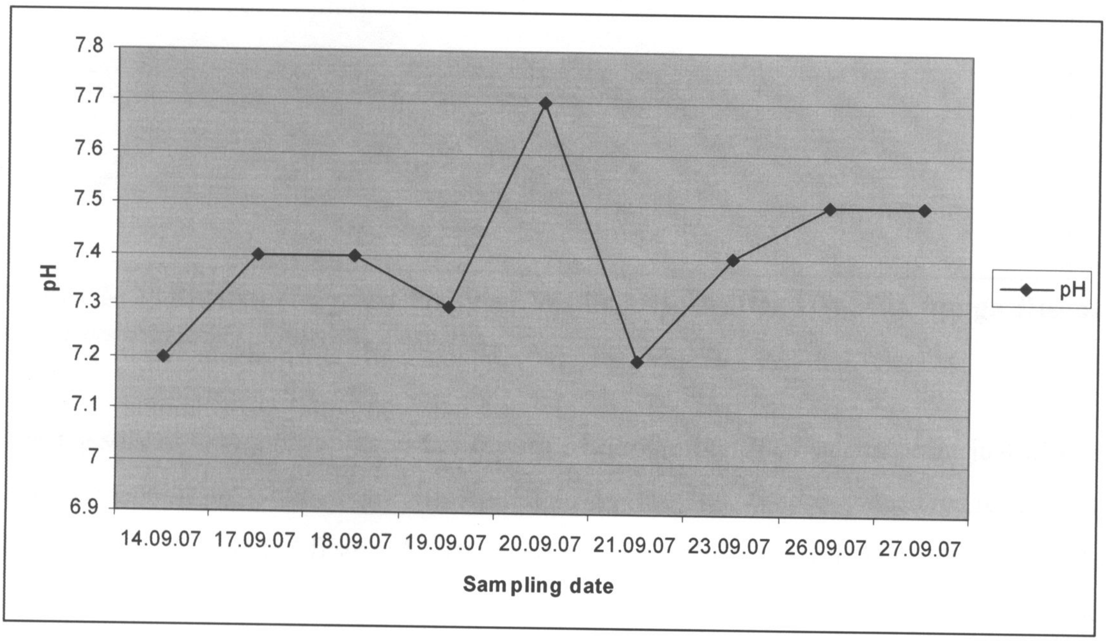

Figure 3- 1: pH values for Chunga River just after the discharge point in September 2007, Lusaka Zambia.

The Electrical Conductivity (EC) values in September 2007 as reflected in Table 3-2 are illustrated in Figure 3-2. Apart from the outliers on 21st and 27th September 2007, the EC ranges are above 1400µS/cm. The ECZ standard for is 4300µS/cm. These values are within the statutory limits.

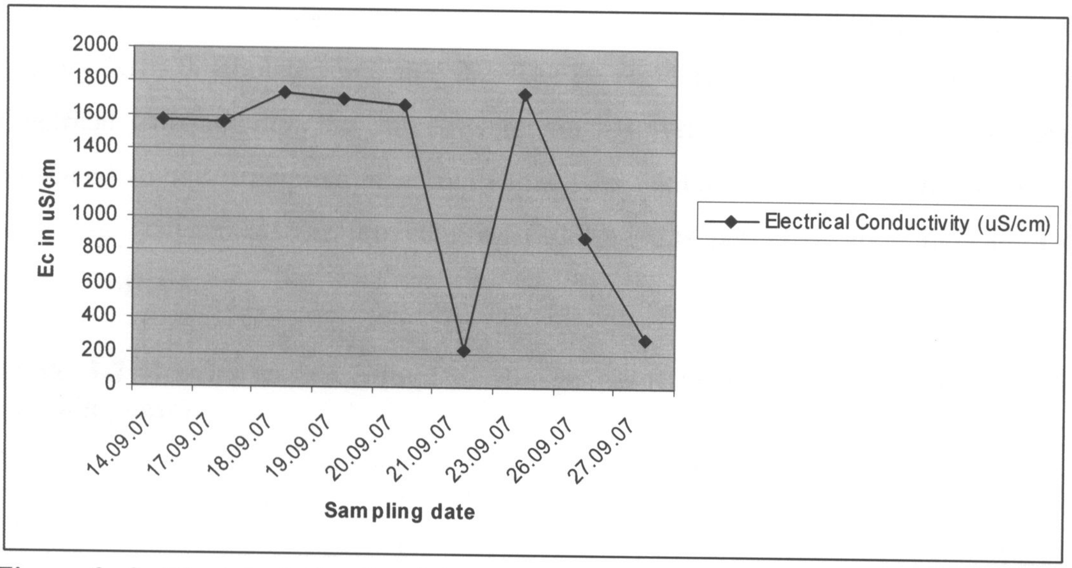

Figure 3- 2: Electrical Conductivity of Water at just after LWSC Chunga Discharge point in September 2007, Lusaka, Zambia.

The Dissolved Oxygen values in the month of September 2007 at the point just after the LWSC discharge point in Chunga are illustrated in Figure 3.3. These values were collected by the Department of Water Affairs. As is observed, the values are all below 3mg/l while the ECZ standard for effluent discharge is 5.0mg/l. These levels entail oxygen stress levels for aquatic life.

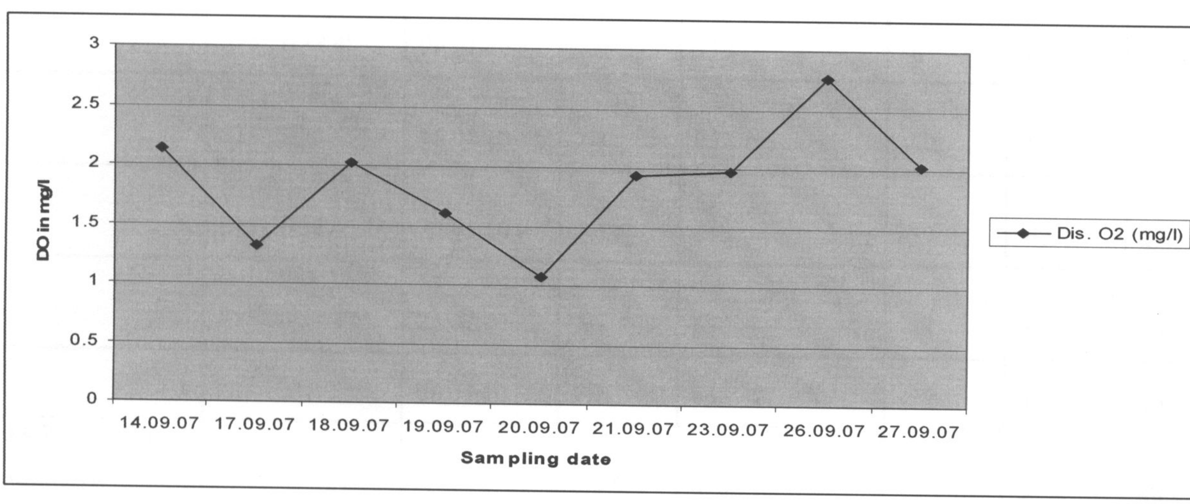

Figure 3- 3: Dissolved Oxygen (DO) in mg/l at Chunga Discharge point in September 2007. (Data – courtesy of DWA)

The physical chemical data collected just after the Chunga discharge site in December 2009 and January 2010 is tabulated in Table 3.2. The ph remained within a range of 7 and 8. As for the Electrical Conductivity, the values were much lower than results in the dry season. This is attributed to the precipitation activity that was taking place at the time of the season. The Dissolved Oxygen also improved greatly during this period; a good indication of the River channel's status.

Table 3-2 Results from Chunga discharge point in January/ December 2009/2010 (field sampling data)

Station	**Location**	**Sampling date**	**pH**	**Cond(uS/cm)**	**Redox (Eh)**	**Dis. O2**	**Temp**
Chunga Treatment Plant	E 028°15'4", S15°20'38.4"	12.12.09	7.5	425	-32	5.8	25.7
	E 028°15'4", S15°20'38.4"	19.12.09	7.7	512	-41	5.3	25.5
	E 028°15'4", S15°20'38.4"	26.12.09	7.6	501	-52	4.4	25.4
	E 028°15'4", S15°20'38.4"	02.01.10	7.4	610	-53	5	26
	E 028°15'4", S15°20'38.4"	09.01.10	7.6	712	-61	4.1	25.3
	E 028°15'4", S15°20'38.4"	16.01.10	7.4	752	-60	3.9	25.6
	E 028°15'4", S15°20'38.4"	22.01.10	7.6	613	-59	4.2	25.3
	E 028°15'4", S15°20'38.4"	23.01.10	7.5	650	-48	4.7	26.1
	" "	06.01.10	7.7	642	-55	3.2	26.2
ECZ Effluent standard			**6.0-9.0**	**4300**		**5**	**40**

The Figure in Figure 3.4 depicts pH values in the rainy season of December/January 2009/10 period. The pH values range between 7 and 8. This is reminiscent of the values obtained in September 2007 of which both were within recommneded statutory values.

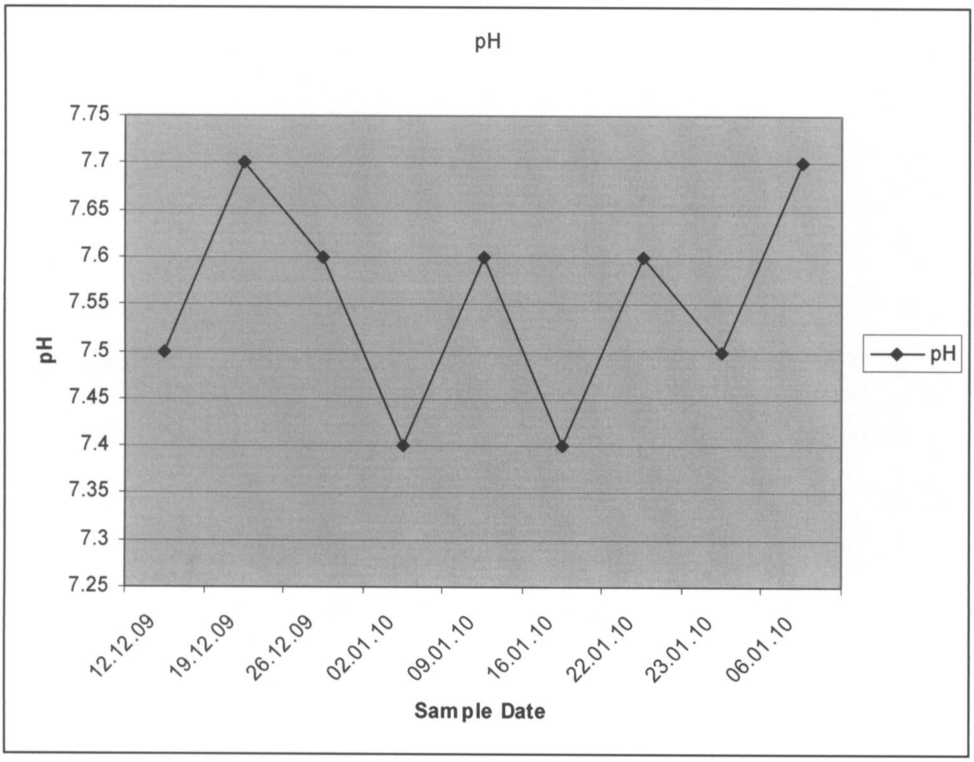

Figure 3-4: pH values for Dec/Jan 2010 rainy season just after the LWSC Chunga discharge point along Chunga River, Lusaka, Zambia

The Electrical Conductivity in the rainy season drastically reduced compared to the summer values (Figure 3.5). This is attributed to activity from precipitation which had a dilution effect on the riverwater and effluent.

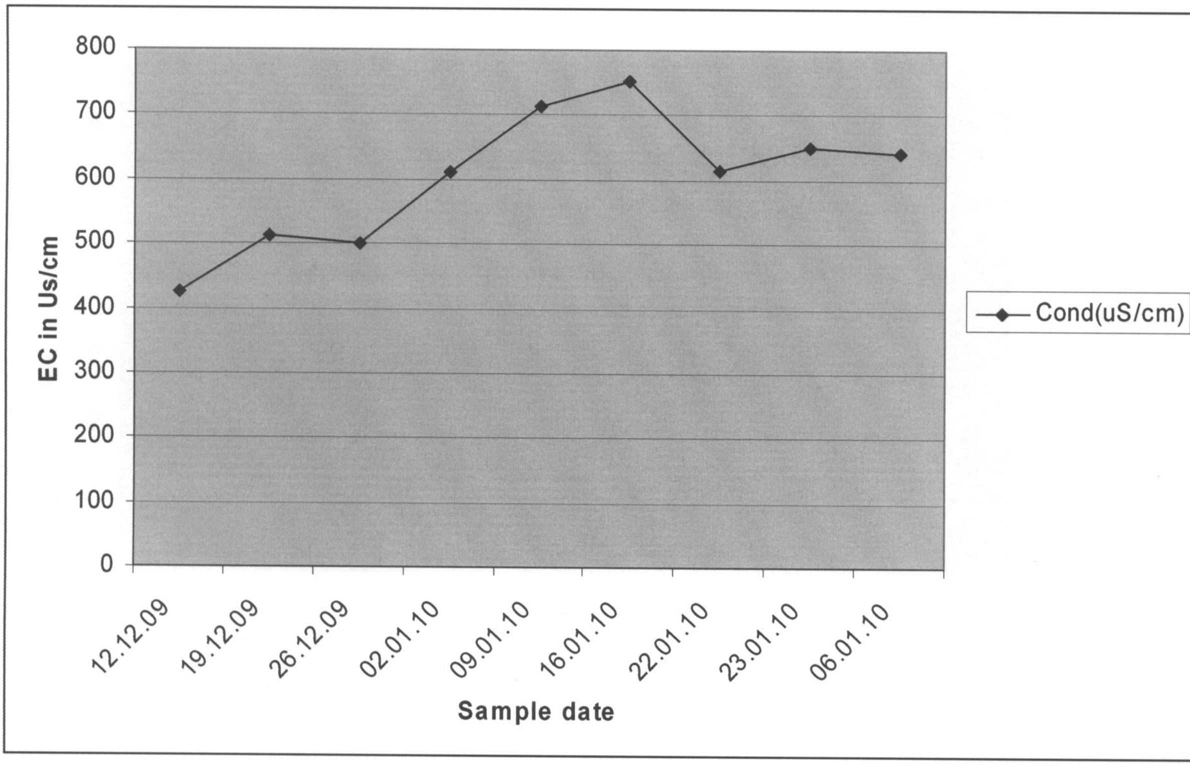

Figure 3- 5: Electrical Conductivity of water just after LWCS's Chunga discharge point in Dec/Jan 2009/2010, Lusaka, Zambia.

The Dissolved Oxygen values show a trend (Figure 3.6) that is higher than those in September 2007 sampling campaign (compare with Figure 3.3). Again this confirms the observation in Table 3.4 that precipitation during this period induces dilution of water in the rivers which in turn improves the Dissolved Oxygen in the surface water. However, it is observed that only three out of four readings met the standard for statutory regulation indicating that the quality of the water is poor at this point in the river channel.

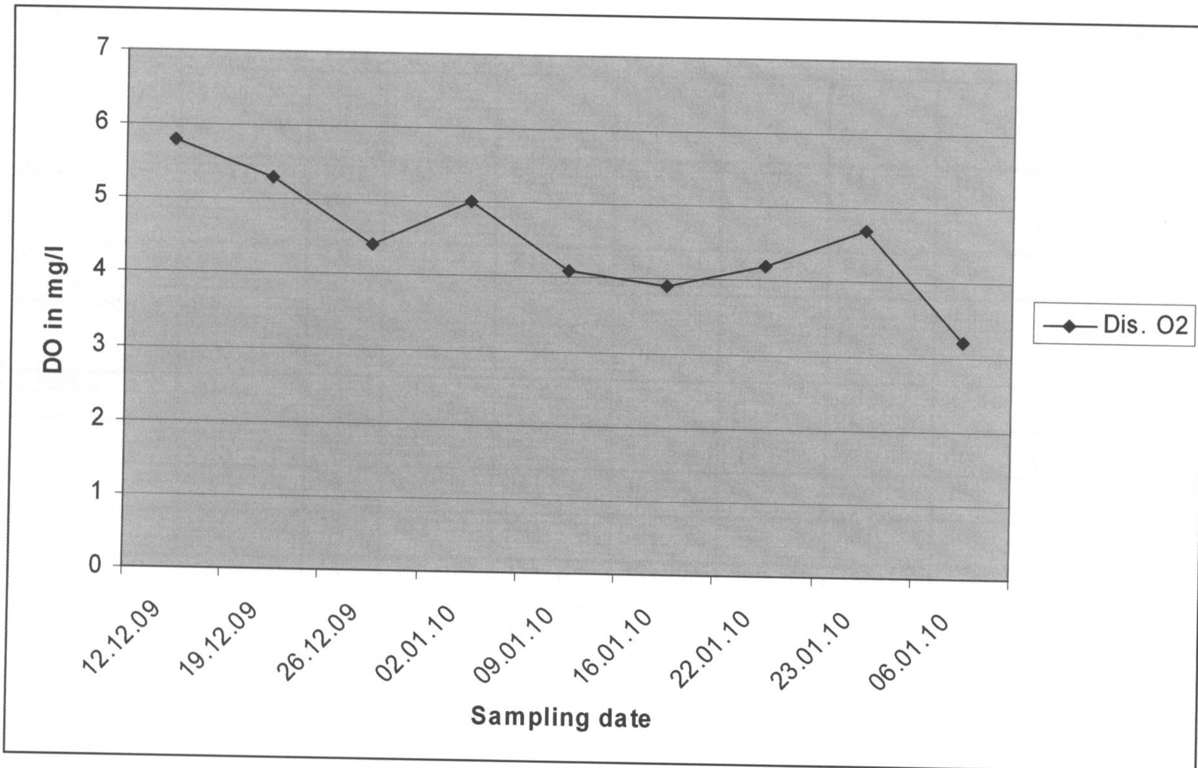

Figure 3- 6: Dissolved Oxygen values of water just after LWCS's Chunga discharge point in Dec/Jan 2009/2010

The results in Table 3.3 were collected from LWSC. These results show that Chunga River had unsatisfactory results from the performance indicators stipulated under the ECZ Pollution Control Act. Most notably, the discharge from the first part of the Year did not meet the standard for Total Suspended Solids, Biological Oxygen Demand, Chemical Oxygen Demand and the microbiological results. (Table 3.3)

Table 3-3: 2009 First half performance indicator results for the LWSC's Chunga discharge point, Lusaka, Zambia. (Data courtesy of LWSC)

					MON-TH				Average
Parameter	**UNIT**	**ECZ std**	JAN	**FEB**	**MAR**	**APRIL**	**MAY**	**JUN**	**Results**
pH		**6.9**	7.54	8.12	8.26	8.3	8.64	8.64	**8.25**
Settleability	0.5	**0.5**	1.2	1.2	1.5	2.1	2.5	0.8	**1.6***
Turbidity	NTU	**15**	88.4	33.6	25.3	27.6	66.7	49.4	**48.5***
TSS	mg/L	**100**	72	ND	66	146	231	123	**1288***
BOD	mg/L	**50**	278	312	166	82	136	136	**185***
COD	mg/L	**90**	618	ND	252	323	487	364	**409***
TC	Count/100	**25 000**	$170x10^6$	$132x10^6$	$158x10^6$	$208x10^6$	$152x10^6$	$54x10^6$	**$154x10^6$**
FC	Count/100	**5 000**	$36x10^6$	$34x10^6$	$22x10^6$	$6x10^6$	$43x10^6$	$20x10^6$	**$27x10^6$**

In Table 3.4, laboratory results from the University of Zambia Environmental Engineering Laboratory of samples collected from the Chunga River just after the point of discharge and Rephidim Institute which is about 20km from the LWSC Chunga discharge site are tabulated.

Preliminary analysis shows that BOD, DO and COD values did not meet the statutory regulation. This has an adverse effect to aquatic life in the River.

The chromium (III) levels also seem to have increased downstream of the discharge to about 0.2 at Rephidim Institute from 0.05mg/l at the discharge point in Chunga. The microbiological tests of Faecal and Total coliforms were way above the 5000 and 25000 cfu/100ml the statutory regulation levels respectively.

Table 3-4 :Laboratory results for samples taken from Chunga treatment plant and Rephidim institute in April 2010

Laboratory results for Chunga River and Rephidim						
	Chunga at LWSC discharge		**Chunga at Rephidim**		**FAO guidelines on water quality Standard**[1]	**ECZ Effluent Standard**
Date of sampling	12.04.2-10	19.04.2010	12.04.2-11	19.04. 2010		
Total Dissolved solids (mg/l)	885	915	762	770	**2000**	**3000**
Total suspended Solids (mg/l)	158	145	48	51		**100**
Electrical Conductivity (µS/cm)	1307	1360	1127	1133	**3000**	**4300**
Turbidity (NTU)	56	60	7.42	7.51	**15**	**15**
Total hardness (mg/l)	580	575	500	489	**850**	-
Temperature °C	24.8	25.1	24.8	24.9	-	**40**
Hydrogen Potential	7.3	7.4	7.54	7.46	**6.5-8**	**6.0-9.0**
Calcium (mg/l)	132.8	129	113.6	118.2	**180.5**	**500**
Magnesium (mg/l)	59.52	58.1	51.84	53.2	-	**500**
Sodium (mg/l)	66.78	64	49.1	46	**200**	-
Bicarbonate (mg/l)	422	415	426	429	**850**	-
Chloride (mg/l)	84	89	61	64	**800**	**800**
Sulphate (mg/l)	162	156	94.8	95.2	**1500**	**1500**
Phosphate (mg/l)	10.2	11	3.82	3.53	-	**6**
Nitrate (mg/l)	34	45	4.45	5.41	30	50
Chromium(III) (mg/l)	0.04	0.05	0.16	0.2	0.1	0.1
Manganese (mg/l)	0.04	0.04	0.08	0.07	**0.2**	**1.0**
SAR mel/l	0.86	0.82	0.63	0.59	**2.9**	**9**
BOD (mg O2/L)	135	98	68	86	-	**50**

[1] Food and Agriculture Organization, Guidelines for Irrigation Water paper 47

Table 3.4 continued	**Chunga at LWSC discharge**		**Chunga at Rephidim**		**FAO Irrigation water quality Standard**	**ECZ Effluent Standard**
COD (mg O2/L)	312	166	126	134	-	**90**
Total Coliform (cfu/100ml)	45,000	48100	21000	18500	-	**25,000 MF method**
Faecal Coliform (cfu/100ml)	34100	35500	9000	8500	-	**5000 MF method**
Dissolved Oxygen mg/l	1.8	2.5	3.1	3.7		**5**
Odor and taste	Strong pungent smell from the River atmosphere	Strong pungent smell from the River atmosphere	No strong smell	No strong smell		**no deterioration in taste or odor**

3.2 Results of farming survey

As mentioned earlier, a qualitative survey was undertaken with a view to appreciate the level and manner of farming practices practiced along the Chunga River banks after the discharge point.

The survey captured twenty respondents who are sparsely distributed along the banks. While there are commercial farmers lining the banks also, emphasis was put on the emerging farmers who supply their produce directly to the informal markets.

Most of the farmers fall within the group of emerging farmers (Nyambe and Feilberg, 2009). They use motorized pumps to draw water from the River and direct it into the furrows where they plant their agricultural produce (Table 3.5).

Table 3-5 : Results on the Farming practices by the farmers that line the Chunga River after the LWSC discharge point

Number of respondents	20
Type of farming	Emerging farming
Common method of irrigation	Farrow irrigation using motorized pumps

In the crop survey, five agricultural products were significantly prominent. (Table 3.5). It was also deduced from the respondents that there is common use of fertilizers and pesticides in the growing of these crops. Rape and maize were the crops grown by every respondent making it the most dominant crop.

Table 3-6 :: Results on the Farming practices and crops grown by the farmers that line the Chunga River after the LWSC discharge point

Farming Seasons	Types of crops grown	Percentage of respondents who grow crop	Application of fertilizers	Application of pesticides
Dry	Tomatoes	80%	Yes	Yes
Dry	Rape	100%	Yes	yes
Dry	Chinese Cabbages	75%	Yes	yes
Dry	Cabbages	40%	Yes	yes
Dry	Pumpkin leaves	50%	Yes	yes
Rainy	Maize	100%	Yes	Yes

CHAPTER 4: INTERPRETATION AND DISCUSSION

4.1 Interpretation

The physical chemical data collected by the Department of Water Affairs in September 2007 at the station just after the Chunga discharge point are tabulated in Table 3.1. The significance of this data is meant to compare with primary data collected in December 2009 and January 2010 which is the rainy season (Table 3.2) in Zambia.

The pH was observed to be between 7 and 8 in the Month of September 2007 (Table 3.1). The same was observed for pH values in the months December 2009 and January 2010. The pH values could be attributed to the fact that most of the water supply in Lusaka comes from groundwater resources which are rich in carbonates. These tend to increase the alkalinity of the soil and thus greater pH buffering capacity (Museteka and Bäumle, 2009). There was however a higher level of Electrical Conductivity (EC) in the dry season than in the rainy season. EC values of up to 1500µS/cm while those collected in the rainy season were all below 800µS/cm. The reason for this higher level of EC in the dry season is due to the lack of precipitation activity which normally impacts on the water by the dilution effect.

The Dissolved Oxygen levels in September 2007 were all below 3mg/l while those for December/January 2009/10 levels averaged around 4.5mg/l with the highest being 5.8mg/l. the effect of rainfall is the probable cause for this improvement at this time of the year.

Performance indicators from LWSC Chunga discharge plant between the first January 2009 and 30th June 2009 are shown in Table 3.3. The figures have been summed and averaged. The results point to the fact that the plant has not been meeting ECZ Effluent discharge standards on the performance indicators on Settleability, Turbidity, TSS, BOD, COD, Faecal and Total coliforms. The Settleability tends to be better in the rainy season while gradually declining in it quality towards the drier periods of the year. Again this is attributed to the rainfall activity which induces some dilution effect. The TSS and the BOD values though above the statutory limit on average, are heterogeneous in their distribution. This is because of the heterogeneous nature of sewer effluent. The failure to meet the standards when discharging effluents is due to broken down equipment especially the biological digester which are not working to the expected level. This means that the discharge then pollutes the Chunga River waters thereby degrading the quality of the water. The discharge however meets the standard for pH.

Primary data collected from the river and analyzed at the University of Zambia Environmental Engineering laboratory results by the Researcher are given in Table 3.4. The results show that the values are within recommended parameters for most of them including the Sodium Adsorption Ratio. However, the BOD, COD, Microbiological values did not meet the ECZ standard for effluent waters. Again these parameters fail the test due to broken down or underperforming equipment at the treatment plant.

The daily average discharges of sewer from Chunga discharge ponds are highlighted in Appendix C. between 2007 and 2009, the annual discharge has averaged around forty six million cubic meters of water discharged per year.

4.2 Discussion

The pH standard is 6.5-8.5 for effluent discharges. The pH of the water exhibited ranges that are close to neutral over the two different seasons. It is also noted that the pH was above seven but below 7.7. This presents a relatively good result on this particular parameter as most aquatic organisms will usually be comfortable at this pH. Between 2007 and 2010, the types of human activity for the study area has relatively remained constant hence the assumption that sewer discharge has remained the same in the general. It is noted that the pH remained between 7 and 8 regardless of the period of the year in the river channel (Figure 4.1).

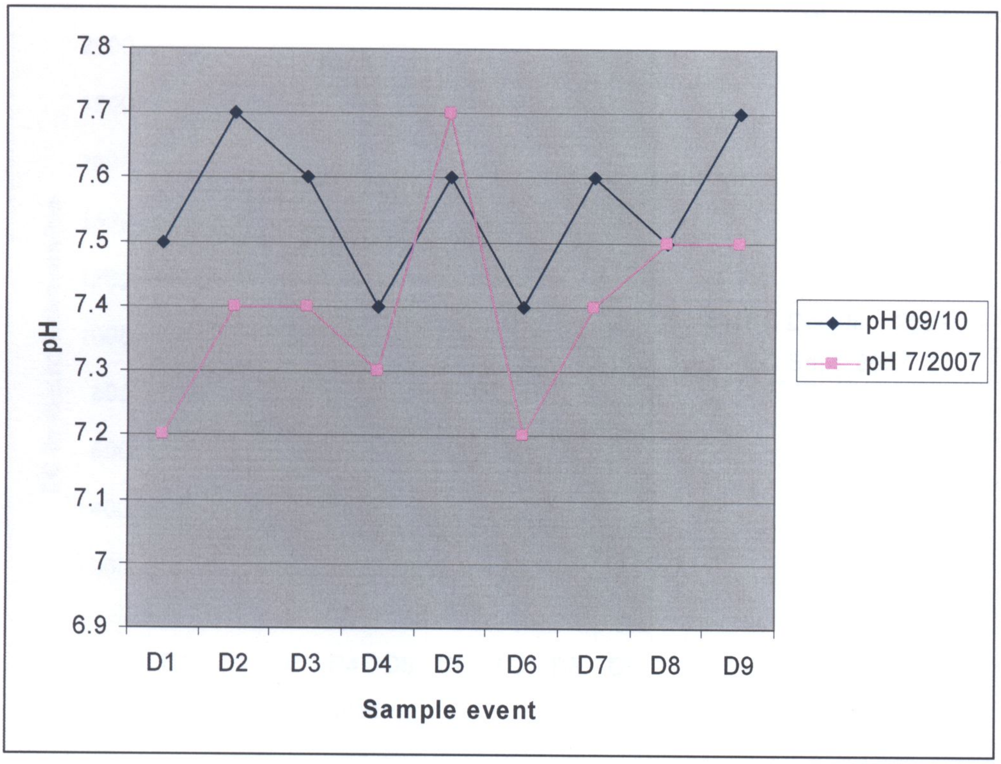

Figure 4- 1: Comparison of pH values for Chunga River just after the Discharge point for September 2007 and Dec/Jan 2009/10

The Electrical Conductivity however exhibited stark variations between the two reference points (Figure 4.2). Although it was within the ECZ effluent standard threshold, it was in the higher ranges in the in the dry than in the rainy season. Despite the two outliers (caused by instrument faults) in September 2007, the reason for this can be attributed to the dry weather where there is no precipitation to dilute the effluents. From this we can deduce that during the rainy season, effluent solute concentration is reduced due to the dilution effect of precipitation as well as groundwater intrusion from the ground. The Electrical Conductivity also showed a gradual drop as the river moved further downstream. For Example, the EC at Chunga in April averaged around 1133.5 μS/cm, while at Rephidim Institute (20km downstream) averaged around 1130 μS/cm (Table 3.4). This shows the river's self purification potential as the number of solutes dissolved in the water reduce the further you go from the discharge point. Groundwater intrusion is also a contributing factor in this self purification capacity.

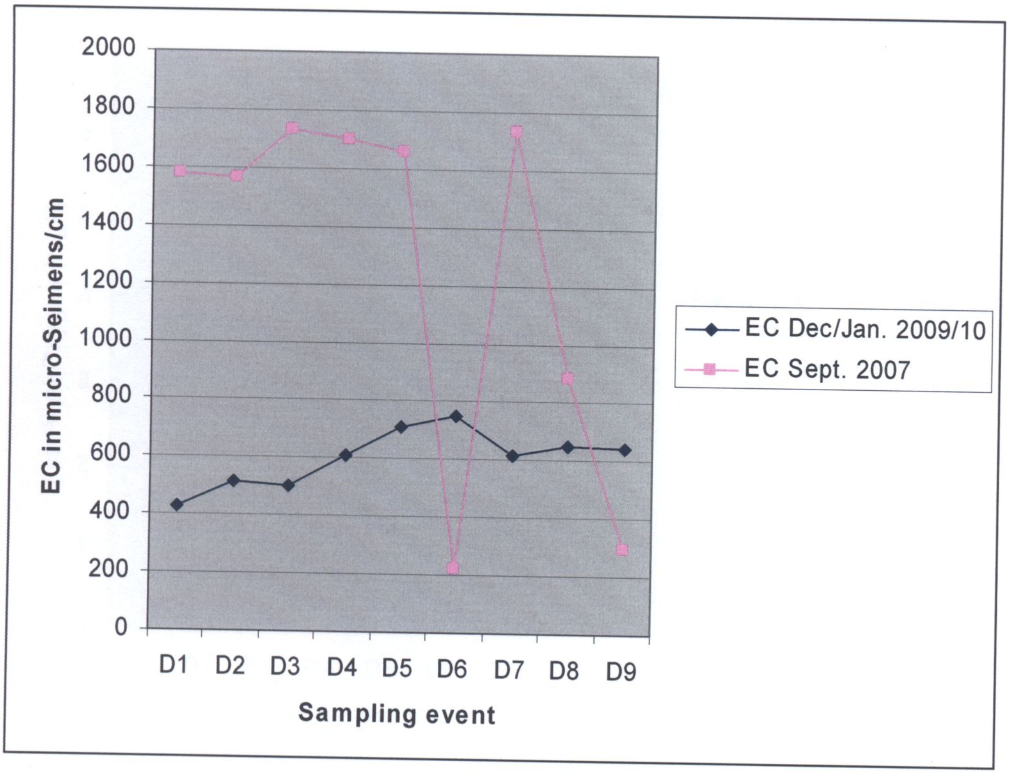

Figure 4- 2: Comparison of EC values for Chunga River just after the Discharge point for September 2007 and Dec/Jan 2009/10

The ECZ standard for effluent discharge for Dissolved Oxygen is 5.0 mg/l. The results from the physical-chemical tests revealed that the level of Dissolved Oxygen in dry season remained below 3.0mg/l. The result for the rainy season (Dec/Jan 2009/10) consistently exhibited a higher level of Dissolved Oxygen than the ones in summer 2007 (Figure 4.3). This poses a threat to aquatic life especially at the discharge site as it would suffocate out most aquatic organisms. Also this result denotes that within the effluent discharge, there exists a lot of oxidizing agents among them biological and chemical compounds.

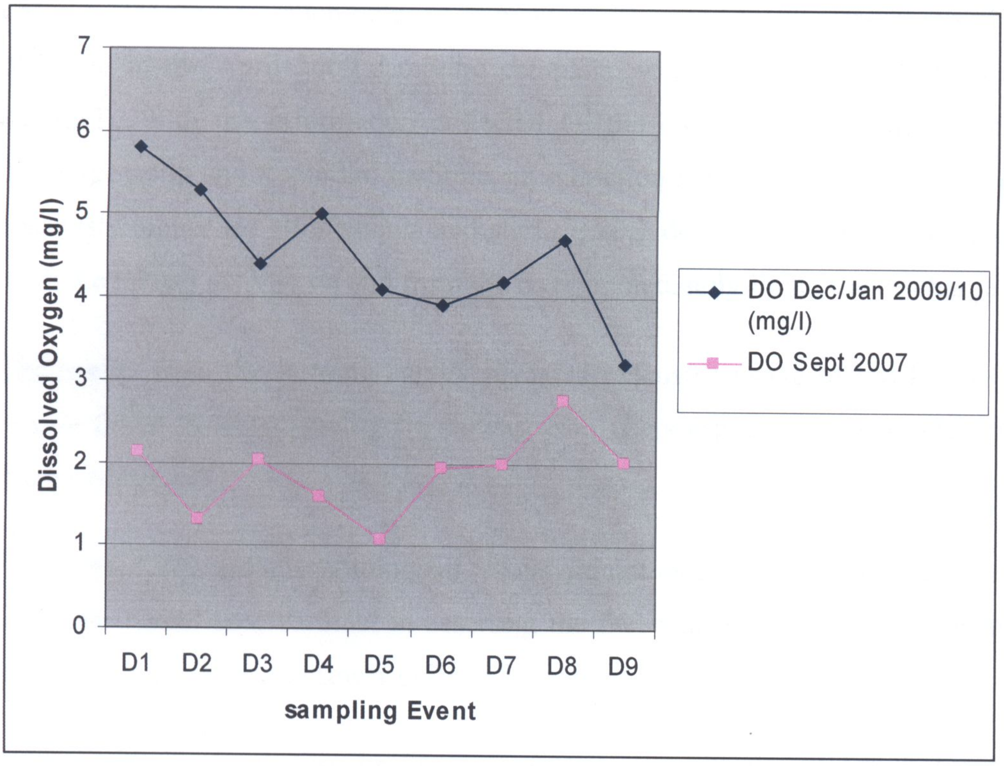

Figure 4- 3: Comparison of DO values for Chunga River just after the Discharge point for September 2007 and Dec/Jan 2009/10

The status report data (DWA, 2007), also points to the fact that the Chunga discharge in particular has high nutrient load. The nitrate levels had an average of 10mg/l at the discharge plant and drop to 3.3 at Rephidim Institute which is located about 15km downstream (Appendix B). In the April results (Table 3.4), the nitrate levels showed a similar trend dropping from an average of 39.5mg/l at the discharge point to about 5 at the Rephidim Institute. This confirms the fact that the river has a regeneration capacity even after polluted water is introduced. It means over the distance the river undergoes self purification partly due to groundwater intrusion (Mpamba, 2008) and oxygen dissolution due to turbulence and photosynthesis. There however exists a threat to the immediate water users at the discharge point as it is evident that the nutrient load is higher hence making the water of poor quality.

Another aspect is the high chloride values observed at the Chunga River discharge point (Appendix B). This chloride is evidence that the effluent is highly influenced by anthropogenic activity from within the city limits. However, the chloride levels drastically reduce from about 440 at discharge to 105 at Rephidim Institute about 20km downstream. This trend was also observed for nitrates which reduced from about 39mg/l to 5mg/l respectively. The chloride values observed in the April 2009 sampling campaign were all within ECZ statutory limits. (Below 800mg/l). With the information collected on the concentration in the river between Chunga discharge point and Rephidim Institute, an induction is made to the effect that concentrations are obviously higher for all elements and start diluting downstream. Therefore the greatest threat is upon the human activity on and from the river immediately lining the discharge point.

The results from the farming survey revealed extensive usage of fertilizers (Table 3.6). These pose a threat to water quality for downstream users especially during the rainy season due to increased run-off.

The BOD, COD and microbiological results did not meet the recommended standards (Tables 3.3 and 3.4). These were cardinal in asserting the fact that the water quality in the river is of poor quality largely due to the sewer effluent it receives.

On a positive note, the results for Sodium Adsorption Ration (SAR) indicate that the water is suitable for irrigation on all sampling points. The maximum value for this ratio is 9 while the maximum value recorded in this study is 4 and is at the discharge point. This means that there exists an opportunity to use the water from Chunga River for agricultural purposes by among other reasons having a SAR that is less than 9. Moreover, the river is perennial largely due to the contribution of the sewer effluent.

With reference to Appendix C, there obviously appears an opportunity to exploit the massive water resource that is discharged per year. This water can be turned into value for money when put to good agricultural use and thereby benefit the people.

CHAPTER 5: CONCLUSION AND RECOMMNDATIONS

5.1 Conclusion

The study was undertaken in order to see what opportunities and threats abound in sharing the waters of Chunga River. The LWSC Chunga Discharge Plant has been overwhelmed by effluent since the city continues to expand while the plant capacity has remained the same. This is due to continuous breakdown of machinery too. This has caused the discharge of the water to be of poor quality. For instance the nitrates at Chunga River discharge are above 10mg/l and the chloride values above 400mg/l. Similarly, Electrical Conductivity results at this point are also higher than values downstream although they are all within recommended threshold of effluent discharges (See Table 3.1, 3.2 and 3.4). The differences between the two points range between 300μS/cm and 500μS/cm. The pH of the river oscillates between 7 and 8 regardless of the time of the year.

It is concluded that the water quality at the LWSC Chunga discharge point in Lusaka is generally poor and poses a threat to the agricultural produce and the water users (farmers) that line the immediate discharge point. This is confirmed by poor BOD, COD and microbiological results.

There is also good opportunity for agricultural activity owing to the perennial discharge (averaging around 46 million cubic meters between 2007 and 2009) from the LWSC's Chunga discharge point.

5.2 Recommendations

The following are the recommendations;

1. The area immediately adjacent to the Chunga River Discharge along the river bank should be cordoned off for a distance so as to allow river re-generation using natural processes. As for how long this cordoned should be, it is recommended that a further detailed research is carried out to profile the river from the discharge point until the point where the quality becomes reasonably acceptable.

2. There is need to recapitalize the Chunga Treatment plant so as to improve the quality of the discharge as well as improve the quality of the water for the water user.

3. The relevant municipal authorities should plan for expansion of the plant as Lusaka's population growth rate of 1.4% will result in higher population from the current population of 1.5 million people. This would ultimately impact negatively on the quality of water in the river.

4. The performance indicators for effluent discharge should be expanded from the current eight (pH, Settleability, Turbidity, TSS, BOD, COD, TC, and FC) to include other parameters such as Electrical Conductivity, SAR and Dissolved Oxygen. This will provide a straight forward perception on the ability of the effluent to support aquatic life and agriculture.

5. On the opportunity for Agricultural development, there should be farmer sensitization campaigns that are going to educate the farmers on the exact status of the water of the Chunga River. This would pave way for ensuring farmers grow appropriate crops for that kind of water a method commonly known as Crop Restriction. In this aspect, crops that need little or no cooking before consumption (e.g. tomatoes, cucumbers) would be restricted from being produced.

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Appendix A - Questionnaire

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

POST GRADUATE DIPLOMA IN INTEGRATED WATER RESOURCES MANAGEMENT

Survey on farming practices in Lusaka along Chunga River just after the Lusaka Water and Sewerage Treatment Plant

Name:..

Interviewed Person & Position: ....

Location: ....

Date: ....   [Catchment Area: ....]

Survey No.: ....

1.) What is your total farm, plot size?

....

1.1) What is the size of the area only used for cultivation?

....

1.2) For how long has this farm been existing? ....

2 What type of crop do you grow?

Type of crop	Size	Rainy season	Dry season	From..... - ......
Maize				
Potatoes				
Mixed Beans				
Groundnuts				
Cassava				
Cabbage, Lettuce				

Rape				
Rice				
Tomatoes				
Onion				
Green beans				
Carrot				
Pepper				
Citrus fruits				
Banana				
Butternut				
Pumpkin				
Peas				

3.) Do you follow any crop cycle?

- □ NO ⇨ *Question 5.)*
- □ YES
  - ↳ **Rotating every.......... years with the following order of crops:**

Type of crop	From..... - .....

5.) Do you apply any fertilizer?

- □ NO⇨ *Question 8.)*
- □ YES
  - ↳ **5.1) Type of fertilizer?**
    - □ Mineral
      - ↳ □ Nitrate
      - □ Phosphate
      - □ Potassium
    - □ Organic
      - ↳ □ Animal manure
      - □ Compost

Continues next page!!!

↳ **5.2) Frequency of application?**

- □ Once per growing period
- □ Split application
  - └► □ 2 times per period
  - □ 3 times per period
  - □......................

└► **5.3) Kg of fertilizer per application?**...............................kg/ha

└► **5.4) The exact name of the fertilizer used?**...

Compound D	MOP	Amm. Nitrate		
Urea	Calc. Nitrate	Potas. Sulphate		
Amm. Sulphate	Potassium	Amm. Phosphate		

6. Do you use any pesticides?

□ NO ⇨ *Question 9.)*
□ YES

└► **6.1) Frequency of application?**

- □ Once per growing period
- □ Once per month
- □ More than once per month

└► **6.2) Date of application?** ....

└► **6.3) Average amount per application in kg/ha?** ....

└► **6.4) The exact name(s) of the product(s) used:** ....

Dursban	Alsystem	Azoxy-strobin	Chlorothalonil	
Cypermethrin	Pyrethroide	Tebuconazole		
Endo-sulphide	Diphenhydramine	Trimangol		

Thank you very much for your cooperation.

Please place any additional information and comments here:

Appendix B Status report results on Chunga River

Status Report data of Chunga River in Lusaka, courtesy of Department of Water affairs (September 2007)

S/N	Station	NO_3	Cl	SO_4	PO_4	HCO3	TH	K	Na	Ca	Mg	Iron	Mn	Cd	Co	Zinc
		mg/l	mg/l	mg/l	mg/l	as mg/l $CaCO_3$	as mg/l $CaCO_3$	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	Matero Lilanda bridge	4.61	55	81.6		328	247	9.43	40.33	64	21.12	0.15		<0.002	<0.005	<0.001
		14.16	68	5.6	2.32	446	324	7.62	68.2	38	55.68	<0.01	<0.01	<0.002	<0.005	<0.001
2	Wastewater treatment plant	9.32	440	192		390	168	13.23	134.33	10.32	34.56	0.33				
		13.86	203	35	7.88	688	235	10.33	98.96	62.4	19.2	0.97	<0.01	<0.002	<0.005	<0.001
3	Mayukwayukwa Weir	2.13	20	3.1		330	296	3.76	10.68	70.4	29.28	0.01				
4	Rephidim	3.31	105	152		336	376	10.42	75.31	88	37.92	0.15				
		14.61	180	18.7	3.86	760	338	9.81	136	72	38.4	0.44	<0.01			

S/N	Station	SAR	Qualified
1	Matero Lilanda bridge	1	Less than 9
		2	
2	Wastewater treatment plant	4	
		3	
3	Mayukwayukwa Weir	0	
4	Rephidim	2	

Appendix C: Monthly average daily discharges from Chunga Treatment plant

Average daily discharges by month for Chunga River treatment plant in m^3/day

year	Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2004	Chunga	10,661	11,218	12,478	8,648	8,256	8,224	7,768	7,465	7,396	7,590	8,543	12,288
2005	Chunga	15,758	13,311	13,649	10,309	9,853	9,829	9,286	9,228	7,959	9,655	8,602	12,949
2006	Chunga	9,655	12,471	9,655	12,290	9,655	12,762	13,179	13,179	10,361	8,759		
2007	Chunga	13,452	14,652	11,390	10,590	11,091	9,641	9,025	8,584	8,892	9,298	9,202	12,711
2008	Chunga	20,335	19,313	16,515	15,450	13,952	12,110	12,806	11,236	11,213	11,118	12,445	14,944
2009	Chunga	15,698	12,047	10,761	8,065	8,202	6,755	6,417	5,135	5,272	2,828	2,828	4,483