EFFECTIVENESS OF NATURAL WETLAND IN WASTE WATER TREATMENT: A CASE STUDY OF TIBIA WETLAND, LIMURU MUNICIPALITY, KENYA.

BY

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DECLARATION

I hereby declare that this thesis is my original work and has not been presented for a degree in any other University or any other award.

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DEDICATION

To my Mum, Dad, Grandmother, Brothers, Sister, Aunts, Uncles and all my friends.

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ABBREVIATIONS AND ACRONYMS

COD	Chemical Oxygen Demand
BOD	Biochemical Oxygen Demand
BOD_5	Biochemical Oxygen Demand on the Fifth day
pH	Hydrogen ions
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TS	Total Solids
NO_3-N	Nitrate-Nitrogen
PO_4	Phosphate
Cr	Chromium
μScm^{-1}	Electrical Conductivity
LWSC	Limuru Water and Sewerage Company
BSC	Bata Shoes Company

ABSTRACT

Information on wetland function in waste water treatment is very important as the information can be used to detect undesirable qualities of water. The aim of the study was to assess the effectiveness of natural wetlands in the treatment of waste water. The study was carried out for a period of four months (November 2012 to February 2013). The objectives of the study was to find out the physico-chemical parameters of water from Limuru water and Sewerage Company and Bata Shoes Company before entering the wetland and after passing through the wetland, and whether there was a significant difference between the physico-chemical characteristics of water before and after passing through the wetland. Sampling was done during the day and samples analyzed within four hours after sample collection. The parameters whose concentrations were determined included pH, electrical conductivity, temperature, BOD, TDS, TS, TSS, DO, phosphate, chromium and nitrate. Data was analyzed using Anova, Microsoft excel program, T-Test (2 tailed). The study revealed that for most of the parameters understudy there was a decrease in their concentration after the water passed through the wetland except for DO and pH. From T-Test (2-tailed) analysis, it was noted that there was a significant difference between the levels of BOD, TSS, TS, TDS, conductivity, Nitrate-Nitrogen, phosphate and chromium before entering the wetland and after passing through the wetland. DO and pH improved after the water passed through the wetland. The study revealed that the wetland played a role in the removal of pollutants where the best performance was obtained at TSS removal efficiency of 97.67%. BOD, Chromium, Nitrate, Total Solids, and Phosphate ranged between 50-96% while conductivity and Total Dissolved Solids were less than 50%. DO increased by 23.4% and pH changed by -0.79% hence the effluent water was less acidic as compared with influent water. BOD failed to meet the required NEMA and General standards even after passing through the wetland. The study concluded that Tibia wetland was effective and had potential in treatment of the waste water from the discharging facilities. It is recommended that wetlands can be conserved and used as waste water treatment facility instead of regarding them as waste land. Measures should be put in place to improve the final effluent quality to ensure that the levels of the parameters in the effluent are within the permissible limits. For further research, the plants dominating the study site be studied so as to find out how they reduce the physico-chemical parameters in waste water and to see if they can be recommended for use in other treatment sites.

CHAPTER ONE: INTRODUCTION.

1.1 Background to the study

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres as well as human-made wetlands such as waste-water treatment ponds and reservoirs (Ramsar, 1971).

Wetlands are important to humans as they perform a variety of functions. They provide ecological, hydrological and Socio-economic functions (Dixon, 2003), source of rivers, storm water control, flow of water and acts as purification systems (World Conservation Monitoring Centre, 1995). Wetlands also acts as retention sink of nutrients from the catchment area, toxic waste and sediments (Enger and Smith, 2000). Wetlands are habitats and spawning and breeding grounds for many species of wildlife. Lake Tanganyika in Tanzania has 214 species of fish, four-fifth of which are endemic (World Conservation Monitoring Centre, 1995).

Wetland ecosystems though important, are among the most threatened of all environmental resources. The extent of wetlands and their species diversity has declined over the past years (Turner, 1990). The decline is due to population pressure, increased inflow of nutrients, encroachment for agricultural activities and new areas for development (Dixon, 2003, Okurut, 2000). The decline in wetland ecosystem is driven by public misperception of the benefits of wetlands (Hollis, 1990). Examples of wetlands which are under threat are Yala swamp, Tana River delta (Mwendwa, 2012).

The ability of wetlands to improve the quality of water has long been recognized and this had led to proliferation of wetlands as a means to treat diffuse and point source pollutants from a range of land uses. This is mainly done in the temperate climate, with paucity of information on the effectiveness of wetlands particularly natural wetlands in tropical regions, where the practice of discharging waste water into natural wetlands has been used as waste depository for hundreds of years (McEdlowhey *et al.*, 1993). The effectiveness of the wetland in treatment of the waste water is limited yet most Companies and human activities release their waste into the wetlands. Information on the effectiveness of wetland on removal of waste forms vital baseline for use of wetlands for waste water treatment and also their conservation.

In Kenya, wetlands are used for diverse purposes, including the treatment of waste water. Despite their widespread use and distribution, our understanding on their effectiveness in waste water treatment remains limited. To harness their function in waste water treatment, it is important to find out their effectiveness in the removal of contaminants from the waste water. Our limited understanding, especially of their function partly explains their under-utilization for waste water treatment.

Most wetlands in Kenya are small in size and located in areas of intense human activities. Tibia wetland in Limuru Municipality receives waste water from Limuru water and Sewerage Company and Bata Shoes Company. It is therefore likely that waste water from the two companies is treated as it passes through the Tibia Wetland.

1.2 Statement of the Problem and Study Justification

Information on natural wetland as waste water treatment plants is missing/lacking or scanty. The information is important as it can be utilized in the conservation of wetlands at the same time being used as a waste water treatment system. Its usefulness to perform the function will bring some benefits and hence it will enhance the conservation of wetlands. Tibia wetland in Limuru is a small size natural wetland which might be faced with extinction due to land pressure and overloading with waste, and if made useful especially as a waste water treatment system, it can enhance its conservation and also reduced expenses involved in other methods of treating waste water. It is currently assumed that the Tibia wetland retains the nutrients, chemicals and pathogens carried with the wastewater, but there is no quantification of this function. Such information is necessary for the efficient planning of long-term sustainable use of the Tibia wetland. The purpose of this study was therefore to determine the effectiveness of Tibia wetland in treatment of the waste water flowing through it.

1.3 Research questions

1. What are the levels of physico-chemical parameters of waste water from Limuru Water and Sewerage Company and Bata Shoes Company before it entered the wetland?

2. What are the levels of physico-chemical parameters of waste water leaving the wetland?

3. Is there a difference between the levels of physico-chemical parameters of waste water from Limuru Water and Sewerage Company and Bata Shoes Company and the wetland leaving the wetland?

4. What is efficiency of the wetland in removal of pollutants from the water?

1.4 Hypotheses

1. The level of physico-chemical parameters of water from Limuru Water Sewerage Company and Bata Shoes Company before entering the wetland is the same as that leaving the wetland.

2. There is no significant reduction in the levels of physico-chemical parameters of water after passing through the wetland.

3. The wetland not efficient in the removal of pollutants from waste water.

1.5 Objectives

General Objective

The general objective of the study was to assess the effectiveness of natural wetland in waste water treatment**.**

Specific objectives

1. To determine the levels of physico-chemical parameters of water from Limuru water and Sewerage Company and Bata Shoes Company before it entered the wetland.
2. To determine the levels of Physico-chemical parameters of waste water after passing through the wetland and flowing into Ithanji River.
3. To determine the difference between the levels physico-chemical parameters of water before entering and after passing through the wetland.

4. To assess the wetland's efficiency in removing pollutants from the waste water.

1.6 Significance

The findings can be a reference for scholars, researchers and students. Wetland mangers can use the information to ensure sustainable use of wetlands as well as promoting recognition of wetlands as an integral part of the environment. The recommendations derived from this research can help in improving the effectiveness of the wetland in treatment of waste water.

1.7 Scope/limitation of the study/assumption

Research study covered Tibia wetland only and not any other wetland in the area due to logistics constraints and it highlighted the effectiveness of the Tibia natural wetland in waste water treatment.

1.8 Definition of terms

Composite sample- sample where individual samples are taken at various depths and deposited in the same collection bottle.

Physical parameters- for the purposes of this study physical parameters were those parameters that were measures insitu (pH, DO, Temperature, Conductivity).

Chemical parameters- for purpose of this study, chemical parameters were those parameters that were analyzed ex-situ (TDS, TSS, TS, BOD, Chromium, Nitrate and Phosphate).

In-situ– in-situ is at the study area.

Ex-situ- ex-situ is outside study area.

Effluent - effluent is what is getting out of a system.

Influent- influent is what is getting into the system.

CHAPTER TWO: LITERATURE REVIEW.

2.1 Introduction

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres as well as human-made wetlands such as waste-water treatment ponds and reservoirs (Ramsar, 1971).

2.2 Importance, Formation and Distribution of Wetlands

Wetlands support a rich diversity of wild life and fisheries by being stopping-off points and nesting areas for migratory birds and spawning grounds for fish and shellfish. Those along the coasts, riverbanks and lakeshores stabilize shorelines and protect them from erosion. Some wetlands may function as discharge areas for surfacing groundwater's, allowing stored groundwater to sustain base-flow streams during dry seasons. Above all, wetlands are 'natural purifiers of water. The functional role of natural wetlands in water quality improvements has offered a compelling argument for wetland preservation. Studies have shown that natural wetlands are able to provide high levels of wastewater treatment (Nichols, 1983; Kadlec & Knight, 1996; Mander *et al.,* 1997). Wetland systems reduce or remove contaminants including organic matter, inorganic matter, trace organics and pathogens from the water. Reduction is said to be accomplished by diverse treatment mechanisms including sedimentation, filtration, chemical precipitation and adsorption, microbial interactions and uptake by vegetation (Watson *et al*., 1989). However, these mechanisms are complex and not yet entirely understood.

Wetlands occupy only a small portion of most Countries, but they are extremely important sources of biodiversity, as well as key components of natural freshwater storage and purification systems (Cunningham *et al.*, 2003). Globally, wetlands occupy about 6% of the earth's surface (National Wetlands Conservation Management, April 2008). Of the 6 % of the earth's surface occupied by wetlands, 56% (4.8 million km^2) lie in tropical and sub-tropical regions. Kenya's wetlands occupy about 3% to 4%, which is approximately 14,000 km^2 of the land surface

and fluctuates up to 6% in the rainy season. According to Kenya National Environment Action Plan (NEAP), 1994, a substantial proportion of Kenya's water resources are found in wetlands. These wetlands are diverse in type and distribution.

2.3 Wetlands Functions and Services

Wetland performs a wide range of functions that are essential for supporting plant and animals' life for maintaining the quality of the environment (Finlayson & Moser, 1991). Wetlands perform a variety of ecological, hydrological and economic functions which according to Dixon (2003) are of benefit to human population particularly in many parts of the developing world where local communities are dependent on those functions for their very survival.

Wetlands act as sponges, absorbing excess storm water from heavy rainfall, thereby ensuring flow regulation/ flood control and soil erosion prevention. Floodwater can be stored in the soils or retained as surface water, thereby reducing floodwater volumes downstream. Wetlands are recharge zones for ground water allowing rainfall to percolate into the ground and keeping wells full (Cunningham *et al.*, 2003). The retention ability of wetlands enables them to discharge and recharge both surface and ground water resources respectively. The impeded drainage allows the water to stay in one place long enough to maximize infiltration, enhancing recharge of groundwater aquifers.

According to (Cunningham *et al.*, 2003), wetlands improve water quality by acting as natural water purification systems, removing silts and absorbing nutrients and toxins. Wetlands are effective in removing and storing nutrients such as nitrogen

and phosphorous from water flowing through them. Wetland vegetation absorbs nutrients and toxic substances from inflowing water thereby improving the quality of water downstream.

Wetlands help in biosphere and micro-climate stabilization (Enger & Smith, 2000). The conditions of high humidity and evapo-transpiration found in many wetlands, may significantly affect local and regional climate (Dixon, 2003). The varied wetlands habitat is the home of many species of animals. In East Africa, Lake Tanganyika has 214 species of fish, of which four-fifth are found nowhere else. Wetlands are also important as feeding and drinking places for land animals. They therefore play a vital part in nature, supporting a vast amount of plant and animal life (World Conservation Monitoring Centre, 1995).

2.4 Convention on Wetlands and Wetland Conservation

The convention on wetlands of international importance, The Ramsar Convention is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. It's the only global environmental treaty that deals with a particular ecosystem. The treaty was adopted in the Iranian city of Ramsar in 1971 and convention's members' countries cover all geographic regions of the planet (Ramsar Convention, 1971). Wetlands were the first ecosystems to receive international attention through the 'convention on Wetlands of International Importance, especially as Habitat for waterfowl. Globally, wetlands losses are monitored by Ramsar Convention.

According to Cunningham *et al*., 2003, the main accomplishment of Ramsar Convention thus far has been to establish baseline information about wetland area and wetland losses. The convention also raises international awareness of the importance of the ecological services provided by wetlands. The 123 participating countries have compiled a list of 1,050 wetlands of international importance, adding up to more than 80 million ha of wetlands.

2.5 Wastewater Treatment in Developing Countries

In most developing countries, there are very few wastewater treatment facilities. This is mainly due to high costs of treatment processes and lack of effective environmental pollution control laws or law enforcement. A wide range of centralized sewage treatment methods are used instead in developing countries, including stabilization pond systems, septic tanks, activated sludges, trickling filters, anaerobic systems and land application systems (Canter *et al*., 1982; Von Sperling & Marcos, 1996).

The most widely used treatment systems are stabilization ponds. This is due to their low cost of installation and maintenance, and optimum climatic conditions found in tropical areas where many developing countries are located. The elimination of all pollutants (pathogens, organic, and inorganic chemicals) is the current wastewater treatment goal in developed countries. In contrast, the main wastewater treatment goal in developing countries is protection of public health through control of pathogens in order to prevent transmission of waterborne diseases and eutrophication of surface waters (Canter *et al*., 1982).

When the stabilization pond effluents are released without further treatment back into the environment, they can contaminate downstream ground and surface water making it unsafe for drinking and other uses. In combination with established stabilization ponds, wetland technology, which also employs a natural system, could be used to achieve a better removal of nutrients and pathogens from the wastewater prior to final release into the water supply. Watson *et al*., (1989) and Kadlec & Knight (1996) have discussed the advantages of using wetland technology for wastewater treatment. Compared to conventional treatment systems, wetland technology is cheaper, more easily operated and more efficient to maintain. Minimal fossil fuel is required and no chemicals are necessary.

An additional benefit gained by using wetlands for wastewater treatment is the multi-purpose sustainable utilization of the facility for uses such as swamp fisheries, biomass production, seasonal agriculture, water supply, public recreation, wild life conservation and scientific study (Knight, 1997). Being low-cost and low-technology systems, wetlands are potential alternative or supplementary systems for wastewater treatment in developing countries.

2.6 Wetland use in Developed Countries

According to Cunningham *et al.*, (2003), wetlands have been used for water purification in different parts of the World since the 1950s. Wetlands have been used successfully for advanced treatment of municipal and residential wastewater in the U.S and around the world for over three decades (Hammer, 1989; Kadlec & Knight, 1996). They are generally perceived as a technology that is relatively affordable and operationally simple. Compared to conventional systems, they have

less construction, operation, and energy cost plus more flexibility in pollutant loading. However, this is not done in the developing countries yet it is a relatively affordable technology (Kadlec & Knight, 1996).

There has been an environmental concern over insufficiently performing individual septic systems as well as high costs involved in the construction of sewer systems with centralized water purification. This has spurred investigations into the suitability of wetlands ecosystems for this purpose (Cunningham *et al.*, 2003). According to WSI, 2011 studies, through careful design, some natural wetlands can consistently and cost-effectively provide advanced treatment of wastewater and storm water constituents while retaining or enhancing their important ecological functions.

Wetland water treatment systems have been found to lower concentrations mass loads of biochemical oxygen demand (BOD), total suspended solids (TSS), and total nitrogen concentrations to 10 to 30 percent of the concentration entering the systems (70 to 90% reduction) (WSI, 2011). According to Cunningham *et al* 2003, the ocean ark organization proposes that small wetlands would be superior to household septic systems for rural sewerage disposal.

2.7 Contaminant Removal Processes in Wetlands

Wetlands are commonly known as biological filters, providing protection for water resources such as lakes, estuaries and ground water. The goal of wastewater treatment is the removal of contaminants from the water in order to decrease the possibility of detrimental impacts on humans and the rest of the ecosystem. The

term "contaminant" is used here to refer to an undesirable constituent in the wastewater that may directly or indirectly affect human or environmental health. Many contaminants, including a wide variety of organic compounds and metals, are toxic to humans and other organisms. Other types of contaminants are not toxic, but pose an indirect threat to our well-being. A number of physical, chemical and biological processes operate concurrently in constructed and natural wetlands to provide contaminant removal. Knowledge of the basic concepts of these processes is extremely helpful for assessing the potential applications, benefits and limitations of wetland treatment systems.

2.7.1 Physical Removal Processes

Wetlands are capable of providing highly efficient physical removal of contaminants associated with particulate matter in the water or waste stream. Surface water typically moves very slowly through wetlands due to the characteristic broad sheet flow and the resistance provided by rooted and floating plants. Sedimentation of suspended solids is promoted by the low flow velocity and by the fact that the flow is often laminar (not turbulent) in wetlands. Mats of plants in wetlands may serve, to a limited extent, as sediment traps, but their primary role in suspended solids removal is to limit re-suspension of settled particulate matter. Efficiency of suspended solids removal is proportional to the particle settling velocity and the length of the wetland. More commonly, re-suspension results from wind-driven turbulence, bio-perturbation (disturbance by animals and humans) and gas lift from decomposing organic matter (DeBusk & DeBusk, 2000).

2.7.2 Biological Removal Processes

Biological removal is perhaps the most important pathway for contaminant removal in wetlands. Probably the most widely recognized biological process for contaminant removal in wetlands is plant uptake. Contaminants that are also forms of essential plant nutrients, such as nitrate, ammonium and phosphate, are readily taken up by wetland plants (Metcalf & Edyy,1991).

The rate of contaminant removal by plants varies widely, depending on plant growth rate and concentration of the contaminant in plant tissue. Woody plants, i.e., trees and shrubs, provide relatively long-term storage of contaminants, compared with herbaceous plants. However, contaminant uptake rate per unit area of land is often much higher for herbaceous plants, or macrophytes, such as cattail. Algae may also provide a significant amount of nutrient uptake (Awuah, 2006).

In wetlands, as in many terrestrial ecosystems, dead plant material, known as detritus or litter, accumulates at the soil surface. Recycled contaminants may be flushed from the wetland in the surface water, or may be removed again from the water by biological uptake or other means. In most wetlands, there is a significant accumulation of plant detritus, because the rate of decomposition is substantially decreased under the anaerobic (oxygen depleted) conditions that generally prevail in wetland soil. If, over an extended period of time, the rate of organic matter decomposition is lower than the rate of organic matter deposition on the soil, formation of peat occurs in the wetland. In this manner, some of the contaminants originally taken up by plants can be trapped and stored as peat. Peat may accumulate to great depths in wetlands, and can provide long-term storage for

contaminants (www.wetland.com) However, peat is also susceptible to decomposition if the wetland is drained or otherwise dries up. When that happens, the contaminants incorporated in the peat may be released and either recycled or flushed from the wetland (DeBusk & DeBusk, 2000).

Microbial decomposers, primarily soil bacteria, utilize the carbon (C) in organic matter as a source of energy, converting it to carbon dioxide (CO_2) or methane (CH_4) gases. The efficiency and rate of organic C degradation by microorganisms is highly variable for different types of organic compounds. Microbial metabolism also affords removal of inorganic nitrogen, i.e., nitrate and ammonium, in wetlands. Specialized bacteria (*Pseudomonas* spp.) metabolically transform nitrate into nitrogen gas (N_2), a process known as denitrification. The N_2 is subsequently lost to the atmosphere, thus denitrification represents a means for permanent removal, rather than storage, of nitrogen by the wetland (DeBusk & DeBusk, 2000).

Removal of ammonium in wetlands can occur as a result of the sequential processes of nitrification and denitrification. Nitrification, the microbial (*Nitrosomonas* and *Nitrobacter* spp.) transformation of ammonium to nitrate, takes place in aerobic (oxygen-rich) regions of the soil and surface water. The newly-formed nitrate can then undergo denitrification when it diffuses into the deeper, anaerobic regions of the soil. The coupled processes of nitrification and denitrification are universally important in the cycling and bioavailability of nitrogen in wetlands and upland soils (DeBusk & DeBusk, 2000).

2.7.3 Chemical Removal Processes

A wide range of chemical processes are involved in the removal of contaminants in wetlands. The most important chemical removal process in wetland soils is sorption, which results in short-term retention or long-term immobilization of several classes of contaminants. Sorption is broadly defined as the transfer of ions (molecules with positive or negative charges) from the solution phase (water) to the solid phase (soil). Sorption actually describes a group of processes, which includes adsorption and precipitation reactions (Metcalf & Eddy,1991).

Adsorption refers to the attachment of ions to soil particles, by either cation or chemisorption. Cation exchange involves the physical attachment of cations (positively charged ions) to the surfaces of clay and organic matter particles in the soil. This is a much weaker attachment than chemical bonding, therefore the cations are not permanently immobilized in the soil. Many constituents of wastewater and runoff exist as cations, including ammonium (NH^{+}_{4}) and most trace metals, such as copper (Cu^{2+}) The capacity of soils for retention of cations, expressed as cation exchange capacity (CEC), generally increases with increasing clay and organic matter content of the soil.

Chemisorption represents a stronger and more permanent form of bonding than cation exchange. A number of metals and organic compounds can be immobilized in the soil via chemisorption with clays, iron (Fe) and aluminum (Al) oxides, and organic matter. Phosphate can also bind with clays and Fe and Al oxides through chemisorptions (Kadlec & Knight, 1996).

Phosphate can also precipitate with iron and aluminum oxides to form new mineral compounds (Fe- and Al-phosphates), which are potentially very stable in the soil, affording long- term storage of phosphorus. Volatilization, which involves diffusion of a dissolved compound from the water into the atmosphere, is another potential means of contaminant removal in wetlands. Ammonia (NH_3) volatilization can result in significant removal of nitrogen, if the pH of the water is high (greater than about 8.5). However, at a pH lower than about 8.5, ammonia nitrogen exists almost exclusively in the ionized form (ammonium, NH_4^+), which is not volatile (DeBusk & DeBusk, 2000).

For effectiveness in the treatment of waste water, the pretreated waste water should be well distributed throughout the wetland for optimal treatment and to reduce localized impacts. Other factors which contributes to wetland filtering like nutrient loading, water level fluctuations, wetland soil oxygen status, presence of nutrient absorbing vegetation or vegetation that can store nutrients in their rhizomes, hydraulic loading (amount of water entering per unit area of wetland), residence time and management intervention such as biomass harvesting (McJannet, *et al.*, 2012) must be looked at to help in conservation of the wetland.

2.8 Waste Water and its Characteristics

Waste water is liquid waste water discharged by domestic residences, commercial properties, industry, agriculture which often contains some contaminants that result from the mixing of wastewater from different sources. Based on its origin waste water can be classed as sanitary, commercial, industrial, agricultural or surface runoff (Haluza, 2010). Waste water mostly consists of pure water (more than 95%)

and there are numerous processes that can be used to clean up waste waters depending on the type and extent of contamination. The treatment of waste water is not only important for our own health but also to keep our environment clean and healthy. Without the proper wastewater treatment many ecosystems would be severely damaged once the untreated water gets recharged back into the environment. Waste water treatment is a problem that has plagued man ever since he discovered that discharging his waste into surface waters can lead to additional environmental problems (United states Environmental Protection Agency, 1993).

According to Kansiime & Nalubega (1999), pollutants in wastewater include: organic substances which can be degraded by bacteria using dissolved oxygen in the water and rendering it unfit for human and animal use. The anoxic conditions created by depleting the dissolved oxygen in water may result in the death of higher forms of aquatic life like fish. Excessive concentration of nutrients (N and P) is another pollutant found in waste water, which may stimulate growing of plants and notably algae; when in excess, these nutrients result in eutrophication of water bodies. Another pollutant is pathogenic (disease causing) microorganisms from human and animal excreta and human wastewater and finally heavy metals and organic micro pollutants which may be toxic to plants, animals and humans.

2.8.2 Global Wastewater Problems

Water has been considered, since ancient times, as the most suitable medium to cleanse oneself and dispose of wastes. The wastes subsequently become distributed throughout the water body presenting a risk to downstream water users. This is more problematic if the water body is at the same time used as a source of drinking

water (Kansiime & Nalubega, 1999). The combination of rapid population growth, industrialization and associated urbanization resulted in increased wastewater generation. This necessitates treatment and disposal of the generated wastewater in a safe way in order to minimize environmental pollution and prevent transmission of water-borne diseases. Treatment is necessary to remove oxygen depleting substances, the major nutrients (nitrogen and phosphorus) as well as pathogenic bacteria (Bartram & Ballance, 1996).

2.9 Status, Challenges and Threats of Wetlands

The destruction and degradation of wetlands has been particularly commonplace throughout the industrialized world. The results can be seen all too vividly in an ever greater scarcity of wildlife and, for example, increased prices for wetland products such as fish and game, the need for water purification plants and concrete flood-protection structures (Finlayson & Moser, 1991). The practice of discharging waste water into natural wetlands has been used as means of waste disposal for hundreds of years (McEdlowney *et al*., 1993).

Wetlands have been considered disagreeable, dangerous and useless swamp and mires throughout our history (Cunningham *et al*., 2003). Until recent wetlands have been drained, and filled-up in order to create more land for development. Wetland ecosystems are considered by many authorities to be among the most threatened of all environmental resources. Both the physical extent of wetlands and their quality have decline greatly over the past years (Turner & Jones, 1990). Most of the physical losses have been due to conversion of wetlands to other land uses for example residential and agricultural.

Wetlands are highly sensitive to destruction by human activities. The scale of human impact on wetlands varies from transient or temporary to irreversible. Those actions which alter hydrology or substrate are generally more permanent than those which influence only the animal and plant life. Pressures for wetland alteration and loss are now increasing in the tropics and developing nations despite growing awareness of their important life and environmental functions (Finlayson & Moser, 1991).

High population densities linked with urban growth, expanding food needs in developing World especially in urban areas presents major threat to natural resources and biological diversity. The uncontrolled utilization of land in developing countries has led to considerable loss of prime agricultural land and the destruction or total destruction of fragile wetlands. Due to the urgent need to meet the food demand of rapidly growing urban population, the high rate of unemployment in most urban cities and the high poverty level, urban agriculture is presently taking over natural wetlands in and around urban cities (UNEP, 2005).

According to Dixon (2003) major threat of existence of wetlands has been their conversion to commercial, residential or industrial sites and their utilization for agriculture following intensive drainage. Economic growth, industrialization and population pressure have precipitated the increasing exploitation of wetland resources as new areas for development are sought. Public misperception of the benefits of wetlands has also aided these driving forces (Hollis, 1990.)

Wetlands in many parts of developing world, which are in close proximity to urban centres, are threatened with increased inflow of nutrients and extensive

encroachment for agricultural activities and high settlement densities which have altered wetland ecosystems (Okurut, 2000). Wetlands are prime targets for reclamation, exploitation, modification and destruction by human activities (IUCN *et al*, 1980). Some of the threats facing the wetlands include;

2.9.1 Pollution, Eutrophication and Salinization of Wetlands

Wetlands have always been used as a convenient place to dispose of waste and many are now becoming severely polluted. Many factories and mines get rid of poisonous substances by pouring into rivers and lakes and pesticides used on farmland are washed into wetlands (World Conservation Monitoring Centre, 1995). The quality of many water sources in Kenya is declining as a result of municipal, agricultural and industrial wastes/ discharges. These have negatively impacted water quality and biodiversity within the wetland ecosystems thereby reducing their values. Increased nutrient loads have led to eutrophication and episodes of algal blooms in wetlands near major settlements. In certain areas excessive abstraction of fresh waters, diversions, and catchment degradation, have led to increased salinity.

2.9.2 Reclamation and Conversion of Wetlands

Drainage and reclamation of wetlands for agricultural development, human settlement and industrial development is one of the biggest threats to wetland conservation and management. In the past, wetlands have been regarded as "wastelands", which harbour disease vectors. This has led to large-scale drainage

and conversion for alternative uses without regard to ecological and socio-economic values. (National Wetlands Conservation Management April, 2008).

2.9.3 Over-exploitation of Wetland Goods and Services

Increasing human populations and change from subsistence to commercial exploitation of wetland resources continue to exert increasing pressures on limited wetland resources, resulting in a decline of services and quality as well as quantity of products derived from wetlands (Kenya Wetland Forum, 2010).

2.9.4 Alien Invasive Species

Wetlands are highly vulnerable to alien and potentially invasive species. Many wetlands have in the past been affected by the introduction of alien invasive species that have altered the biodiversity characteristics and diminished the services provided by wetlands. For example, the introduction of Nile perch nearly eliminated the indigenous fish species of Lake Victoria while water hyacinth, Salvinia sp, and Typha sp. have affected numerous (Kenya Wetland Forum, 2010).

2.10 Wetland user Rights and Livelihoods

The government recognizes the important role that these benefits play in the livelihoods of wetland adjacent communities. People living adjacent to wetlands have been deriving benefits from them for many years. These benefits may include ecological, hydrological, socio-economic benefits associated with wetlands some of

which are goods like trees products, reeds, water supply, fishing and grazing (Dixon, 2003). Any change of use of a wetland must allow those traditional uses to continue without loss or hindrance of any other user.

CHAPTER THREE: STUDY AREA, MATERIALS AND METHODS .

3.1 Introduction

In this chapter, the study area, data collection procedure, sources of data and data analysis are described. The collected data were the physico-chemical characteristics of waste water before and after passing through the wetland. Research design, sampling process and sample analysis are also presented.

3.2 Study Area

3.2.1 Location of the Study Area.

The study was carried out at Tibia wetland, which is located at the outskirts of Limuru town, Limuru District, in Kiambu County, Kenya. The swamp is located along Kiambu-Tigoni road next to Limuru milk processing factory. Limuru District borders Lari to the West, Kikuyu to the East and is connected to Nairobi by Nairobi-Nakuru highway. Limuru is located at 1˚06´26″S and 36˚37´53″E (www.limurumunicipal.go.ke).

3.2.2 Climate/Relief/Soils

Temperature ranges from a minimum of 12.8˚C to a maximum of 24.6˚C with an average temperature of 18.7˚C. The hottest months are January through March (24.6˚C), while the coldest are July and August (12.8˚C). The average rainfall is 989mm per annum. The rainfall is bimodal with long rains occurring between April and June and short rains falling from October to November (www.limurumunicipal.go.ke). It is situated at an altitude of 2272 meters above sea level. The soils of the area are rich acidic soil. Limuru is characterized by

undulating topography with land generally sloping towards the East. Consequently, drainage is in the same direction with the slope (www.limurumunicipal.go.ke)

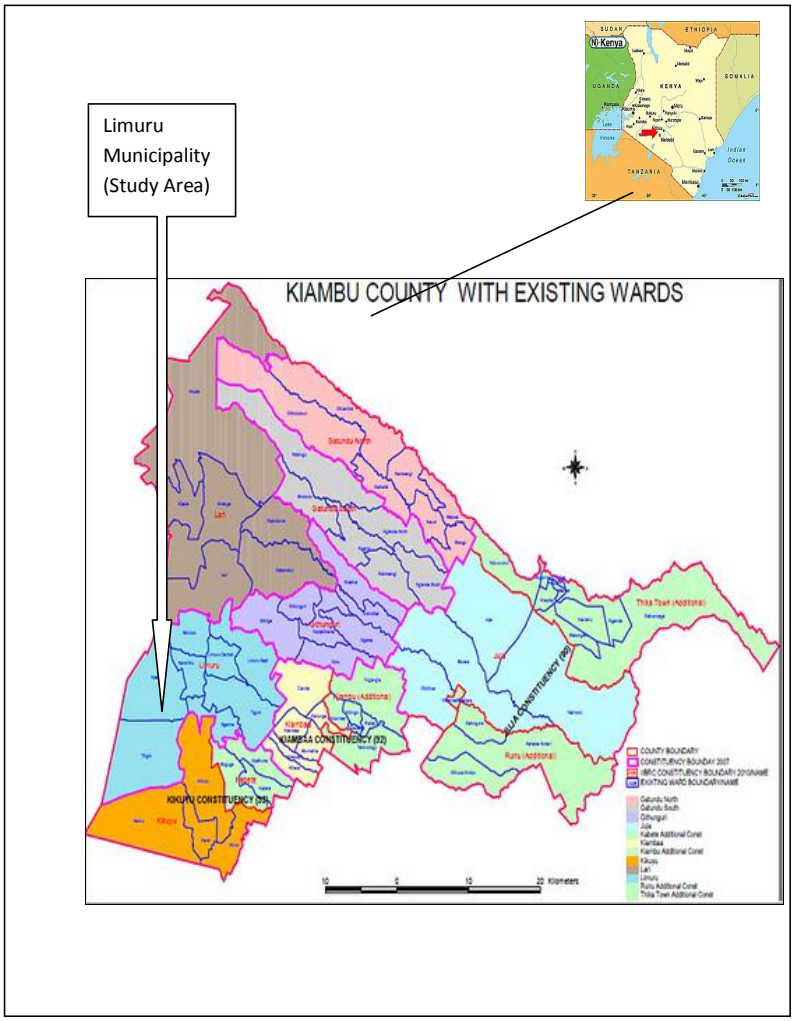

Fig. 3.1: Map of Kiambu County showing Tibia Wetland the Study Area.
(Source: Flickriver.com)

3.2.3 Economic Activities

The main economic activity is agriculture which is mainly carried out in small scale. The main crops are tea, cut flowers and keeping of dairy animals. (www.limurumunicipal.go.ke). The main industries in the area are the Bata Shoes Company, Limuru milk processing company and the small scale industries found in the area are posho mills, furniture making and slaughter houses.

3.3 Research Design

3.3.1 Selection /Choice of the Study Area

The actual study was preceded by a preliminary survey. The aim of the survey was to assess the accessibility of Tibia wetland, collect background information about the wetland, and services provided by the wetland to the people who live around the wetland. It was also to find out the conservation measures in place to conserve the wetland and to test the instruments which were to be used in the actual study.

The preliminary study found out that the wetland provides many services to the locals. It provides water for domestic use and the water is also used for irrigation purposes downstream. The wetland is a source of fodder for domestic animals. It is also used as a waste water treatment plant for water from Limuru Water and Sewerage Company and Bata Shoes Company.

3.3.2 Sampling Points and Frequency

Water was collected from Bata Shoes company inlet into the wetland (BSC) and Limuru Water and Sewerage Company inlet into the wetland (LWSC) and in the

wetland. Another sampling point was at the point where the water was leaving the wetland (outlet). At each of the sites water samples were collected using a water scooper with a 3m extendible handle. Sampling was carried out once after every two weeks for a period of 4 Months. Three composite water samples were collected from each sampling point per visit.

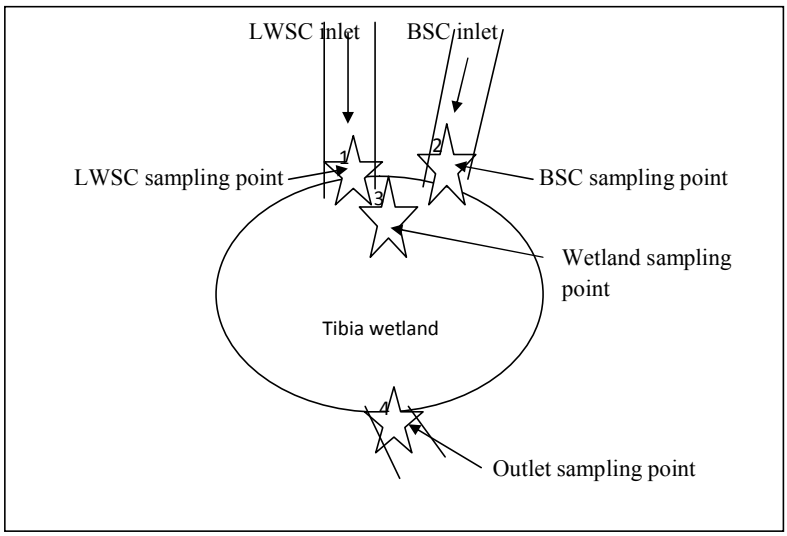

Fig. 3. 2: Schematic diagram showing the sampling points at Tibia wetland

3.3.3 Sample Processing and Storage

One litre plastic bottles were washed thoroughly and rinsed with the sample water to be collected. Using a water scooper, water samples for laboratory analysis were collected into a collection bucket and transferred into I litre plastic bottles and capped. Water samples were collected from each sampling point at different depth and pulled together to form a composite sample. Rainfall amount data during the study period was obtained from Kenya Metrological department. Samples analyses commenced within a period of four hours, sample preservation was in most

occasions not necessary, and when not possible to analyze the sample within four hours they were deep frozen stored at 4°C.

3.3.4 Sample Labeling

The sample bottles were each labeled to prevent sample misidentification. Gummed paper labels were used and affixed on the containers at the time and point of sample collection (APHA, 2005). On the labels, the following information was included: a unique sample number, sample type, date, and time of collection (APHA, 2005).

3.4 Analytical Procedures

3.4.1 Field Analysis

3.4.1.1 pH

Water pH was measured using a SensION 1 pH meter: (HACH model) with temperature compensation up to 19.9°C. The pH meter was immersed into the water, allowed to equilibrate and the pH values on the meter read directly and recorded.

3.4.1.2 Temperature (°C)

Water Temperature was determined with a temperature sensor of SensION 1 pH meter: (HACH model with a Range: -2.00 to 19.99 and temperature: -10 to 100°C). The probe was immersed in water allowed to equilibrate before temperature readings was taken and recorded in °C.

3.4.1.3 Electrical Conductivity

Electrical conductivity of the water was measured using a portable SensION 5 Conductivity meter, (HACH-USA with Range: 0 to 50000mg/l and conductivity

range: 20 to 199.9 μScm^{-1}). The probe was immersed in the water allowed to equilibrate before the electrical conductivity was read and recorded in μScm^{-1}.

3.4.1.4 Dissolved Oxygen

Dissolved Oxygen in the water was measured using SensION 15b Dissolved Oxygen meter (HACH model with Range: 0-20 mg/l (ppm), (temperature: 0-50˚c and accuracy: 1% full scale). The Dissolved Oxygen probe was immersed in the water after being calibrated according to manufactures guide and allowed to equilibrate before the readings of the dissolved Oxygen of the water sample was read and recorded in mgL^{-1}.

3.4.2 Laboratory Analysis

3.4.2.1. Nitrogen-Nitrate (No_3-N).

Nitrate-nitrogen concentration was determined by the modified Sodium salicaylate procedure (Scheiner 1974). Nitrate-nitrogen reacts with sodium salcylate in an acidic condition to form nitro salicylic acid. The salicylic acid turns yellow under alkaline conditions (APAH, 1998). Colour intensity was measured calorimetrically using a digital spectrophotometer (HACH MODEL). An amount of 5ml of filtered sample was put into a clean 50ml Nessler tube and 2ml sodium salicylate added and evaporated to complete dryness at 98^0C in an oven. An amount of 1.0ml concentrated sulphuric acid was then added and allowed to dissolve for 10 minutes, 25 ml distilled water was added followed by 5ml Rochell salt solution. Absorbance was read at 420nm. Standard of known NO_3-N concentration was subjected to the same treatment as water sample and readings used to determine the actual concentration of nitrate in the sample.

3.4.2.2 Total Phosphate

Total phosphate concentration was determined using the ascorbic acid reduction procedure (APAH 1998). Unfiltered water was oxidized to Po_4-P by autoclaving the samples at 120^0C for 40 minutes using Ammonium persulfate oxidizing agent. Phosphate ions combine with ammonium molybdate to form a molybdophophate complex. The complex is readily reduced by ascorbic acid to an intensely blue phophomolydenium complex. Colour intensity was measured calorimetrically at a wavelength of 690 nm using a digital spectrophotomer **(**HACH Model**).**

3.4.2.3 Biological Oxygen Demand (BOD)

BOD was determined using BOD bottle and aerated water samples. Dilution water (aeration water) was first prepared. A sample was pipette into a BOD bottle containing aerated dilution water. The DO content was determined and recorded and the bottle was incubated in the dark for five days at 20°C. At the end of the five days, the final DO content was determined and the difference between the final DO reading and the initial DO reading was calculated. The decrease in DO was corrected for sample dilution, and represents the Biochemical oxygen demand of the sample.

3.4.2.4 Total Solids

The amount of Total solids in water was determined gravimetrically; 100ml of well mixed sample was put into a special dish of known weight and then evaporated over a water bath to dryness. The residue was dried to a constant weight at temperature between 103 - 105°C. The residue was cooled in a dessicator, weighed and results computed. The difference between the weight of the dish after and

before the experiment gave the weight of the total amount of solids present in the sample.

3.4.2.5 Total Dissolved Solids

The amount of total dissolved solids in water was determined gravimetrically. Using filtered water samples, 100ml of the filtered sample was transferred to a weighted conical beaker and evaporated to dryness on a hot plate. The conical beaker plus the residual was cooled in a desiccator and then weighed. The difference between the weight of weighted beaker after and before the experiment gave the total amount of dissolved solids present in 100ml water sample.

3.4.2.6 Total Suspended Solids

The amount of Total suspended solids in the water sample was determined gravimetrically. A pre-weighed filter paper was used to filter 100ml of the water sample. The filter paper plus the precipitate were dried in an oven to a constant weight. The change in weight of the filter paper was the weight of the Total suspended solids in 100ml of the water sample.

3.4.2.7 Chromium (Cr_3)

The concentration of chromium in the water samples was determined using a Shimadzu type Atomic Absorption Spectrophotometer (AAS) 6800 model with Air-C2H2 flame type of an average fuel flow rate of between 0.8-4.0 L min-1 and the support gas flow rate between 13.5-17.5 l/min was used for sample analysis.

3.6 Data Analysis and Presentation

The data obtained from the field was analyzed using Anova, T-test and Microsoft excel program and $p<0.05$ was considered as minimum value for statistical significance. The data was presented inform of tables and bar charts. This was done in order to draw an intellectual conclusion from the research to be done. The resultant data were compared with NEMA's and General Standards permissible limits for discharge of effluent into the environment.

3.7 Percentage Removal Efficiency

The percentage removal efficiency is in most cases simply defined as:

(Cin - Cout) / Cin x 100, where Cin and Cout are the inflow and outflow pollutant concentrations respectively. The negative values denote negative efficiencies (Ellis, J. B. *et al*, 2003).

CHAPTER FOUR: RESULTS AND DISCUSSION.

4.1 Introduction

In this chapter the physico-chemical characteristics of waste water from Limuru Water and Sewerage Company (LWSC), Bata Shoes Company (BSC), the wetland and the wetland outlet are discussed. The chapter also discusses the findings of the study and finally conclusions and recommendations of the study are given.

4. 2 Physico-chemical characteristics of Water.

Table 4.1: The Mean Values of the Physical Parameters of water from LWSC, BSC, Wetland and Outlet of Tibia wetland.

PARAMETERS	LWSC	BSC	WETLAND	WETLAND OUTLET	T-test P value
pH	7.1	8.1	7.6	7.8	0.714
Temp°C	18.4	16.6	17.5	16.4	0.134
Conductivity (μScm^{-}	845.6	498.5	1344.0	717.3	0.001*
DO (mgL^{-1})	0.0	1.2	1.2	1.9	0.279

*** significant difference**

Parameters are means of the eight collected samples.

P-value in the above table is the result of T-test between waste water in the wetland and that leaving the wetland.

4.2.1 pH

The study revealed that the pH of water varied among the study site during the study period. The pH in LWSC ranged from 6.41 to 9.71± 0.1 with a mean of 7.1. In BSC pH ranged from 7.34 to 8.43 ±0.1 with a mean of 8.1, in the wetland it was between 6.88 and 8.17 ±0.1 with a mean of 7.6 while at the wetland outlet it varied from 7.18 to 7.90±0.1 with a mean of 7.8 (Table 4.1 and Fig. 4.1). T-Test (2-tailed) analysis ($p<0.05$ as the minimum value of significance), showed that there was no significant difference (0.714) between pH in the waste water in the wetland and after passing through the wetland.

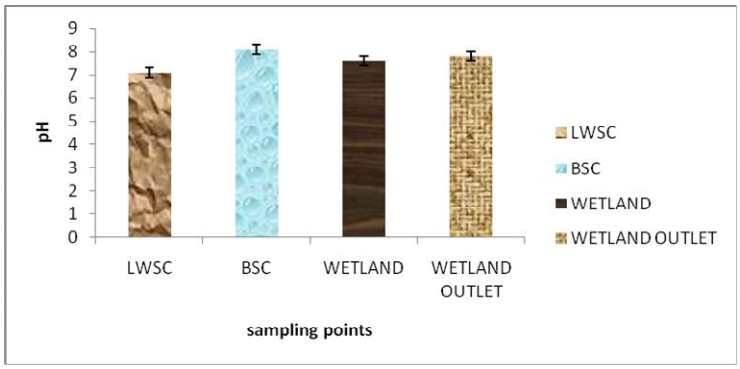

Fig. 4.1 : The mean values of pH recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

Variations in pH can be attributed to microorganisms in the water which breaks down organic materials to simpler products like CO_2. The CO_2 dissolves in water to produce carbonic acid (H_2CO_3), which lowers the pH. The lowering of pH of water also comes from decaying vegetation and organic matter. Photosynthesis, and respiration are also responsible for variations of pH in water (Pidgeon & Cains, 1987, Michaud, 1994).

The low pH recorded at LWSC and the wetland could be attributed to high BOD (Table 4.2). The Limuru Water and Sewerage Company sewer system receive water from surrounding industries and households and the water contains a high organic matter which is a source of organic acid. The high pH recorded at the BSC could probably be due to the low organic matter in the waste water (Table 4.2) while the high pH recorded at the outlet could be attributed to reduced concentration of organic acid at the outlet and photosynthesis by wetland

vegetation which uses up available carbon dioxide. The micro-organisms use oxygen for decomposition and gives out carbon dioxide.

4.2.2 Electrical conductivity (µScm^{-1})

Electrical conductivity recorded in (µScm^{-1}) varied among the study site during the study period. In LWSC it ranged from 810.32 to 912.00 ± 0.1 with a mean of 845.6. In BSC, it ranged from 397.70 to 690.00 ±0.1 with a mean of 498.5, in the wetland µScm^{-1} ranged from 1208.00 to 1602.00 ±0.1 with a mean of 1344.0 while at the wetland outlet the value varied from 703.00 to 727.00±0.1 with a mean of 717.3. (Table 4.1, Fig. 4.2). T-Test (2-tailed) analysis ($p<0.05$ as the minimum significance) showed that there was a significant difference ($P<0.001$) between the conductivity of waste water in the wetland and after coming out of the wetland.

Conductivity in waste water is attributed to the presence of negative and positive ions (Gosselink & Mitsch, 2000, Vinod & Chopra, 2012), the amount of total dissolved solids, total suspended solids and diatomic nitrates in water (Shama *et al*., 2013). Wetland plants also influences conductivity of water as they trap sediments and pollutants (USDA-SCS, 1992).

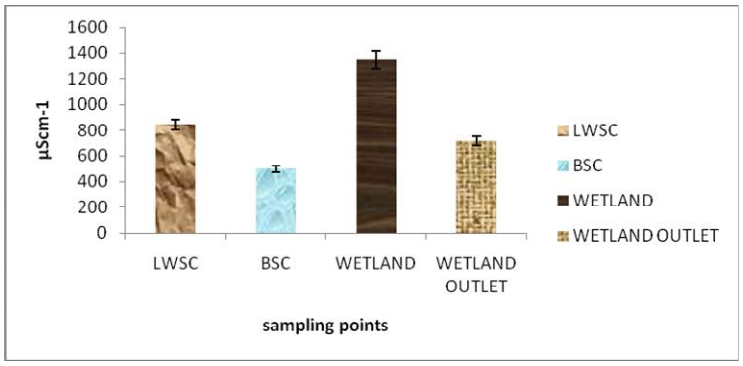

Fig. 4.2 :The mean values of electrical conductivity recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

The difference in conductivity in water before (in the wetland) and after passing through the wetland could be attributed to the fact that the waste water before it enters the wetland has high concentration of TDS and TSS. The TDS and TSS settles at the bottom of the wetland inform of sediment as the water passes through the wetland and this causes a decrease in conductivity. The TSS is trapped by plants as the water passes through the wetland and this result in decrease in μScm^{-1} as the water leaves the wetland. The decrease could also be attributed to conversion of NO_3-N into diatomic molecular nitrogen (N_2) as the concentration of NO_3-N decreases (Table 4.2).

4.2.3 Dissolved Oxygen (mgL^{-1})

The study revealed that Dissolved Oxygen (mgL^{-1}) of the water varied among the study site during the study period. Dissolved Oxygen in LWSC ranged from 0.01 to 0.03 ± 0.1 mgL^{-1} with a mean of 0.0 mgL^{-1}. In BSC, DO ranged from 0.02 to 2.61 ± 0.1 mgL^{-1} with a mean of 1.2 mgL^{-1}, in the wetland it was between 0.03 to 2.64 ± 0.1 mgL^{-1} with a mean of 1.2 mgL^{-1} while at the wetland outlet it ranged from 0.78 to 2.40 ± 0.1 mgL^{-1} with a mean of 1.9 mgL^{-1}. (Table 4.1, Fig. 4.3). Using T-Test (2-tailed) analysis ($p<0.05$ as the minimum significance) it showed that there was no significant difference (0.279) between DO in the wetland and after passing through the wetland.

The amount of dissolved Oxygen in water is influenced by photosynthesis, respiration and decomposition, atmospheric oxygen and high organic matter

(Bastviken, 2006, USDA, 1992). The slight increase in the level of dissolved oxygen at the outlet could be attributed to photosynthesis by phytoplanktons and biodegradation of compounds present in wastewater that previously used dissolved oxygen for various oxidation-reduction reactions and thus the release of oxygen through roots into the rhizosphere.

Lower levels at LWSC (0.0 mgL^{-1}) could be attributed to high levels of organic matter which is being decomposed by micro-organisms in the presence of Oxygen into simpler products like carbon dioxide and water (Table 4.2). Reduction in organic pollution load and bacterial population due to their retention in the beds and simultaneous mixing of atmospheric oxygen could also have caused improvement noticed in DO after passing through the wetland (Table 4.2).

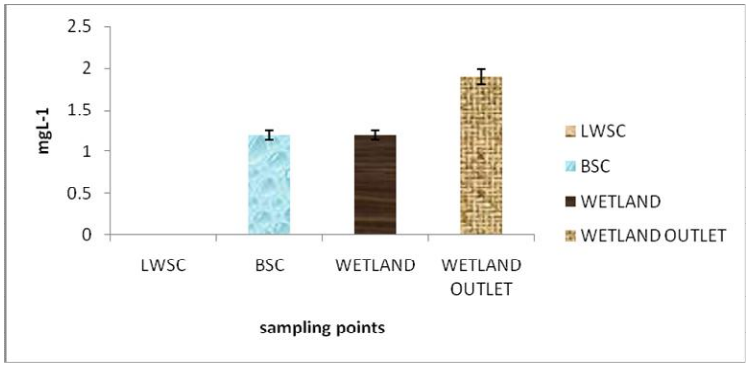

Fig. 4.3 :The mean values of DO concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

4.2.4 Temperature (°C)

Temperature recorded at all points varied among the study site during the study period . In LWSC temperature ranged from 17.20°C (rainfall 4.75mm) to 19.10 ±

0.1°C (4.75mm). The mean temperature recorded at LWSC was 18.4°C. In BSC temperature ranged from 15.40°C (4.75mm) to 17.89±0.1°C (4.75mm) with a mean of 16.6°C. In the wetland temperature recorded ranged from 16.35°C (4.75m) to 18.20 ±0.1°C (4.75mm) with an a mean of 17.5°C while at the outlet temperature ranged from 15.80°C to 17.20 ±0.1°C with rainfall of (4.75mm) respectively. The mean temperature at the wetland outlet was of 16.4°C. (Table 4.1, Fig 4.4). High temperature was recorded at LWSC while low temperature was recorded at the wetland outlet. Using the t-test, it was noted that there was no significant difference (0.120) between temperature in the wetland and after passing through the wetland.

Water temperature is influenced by time of the day, season and presence of vegetation and amount of dissolved solids (Michaud, 1994; Water Protection Plan Development Guidebook, 2001). The higher temperature in the wetland could be attributed to high amount of organic matter (BOD) and TDS (table 4.2). The decomposition of organic matter produces heat while the TDS absorbs heat from the sun and this could be responsible for the higher temperature in the wetland. The lower temperature at the outlet could be attributed to the shading effect of wetland vegetation and decreased organic matter concentration (Table 4.2).

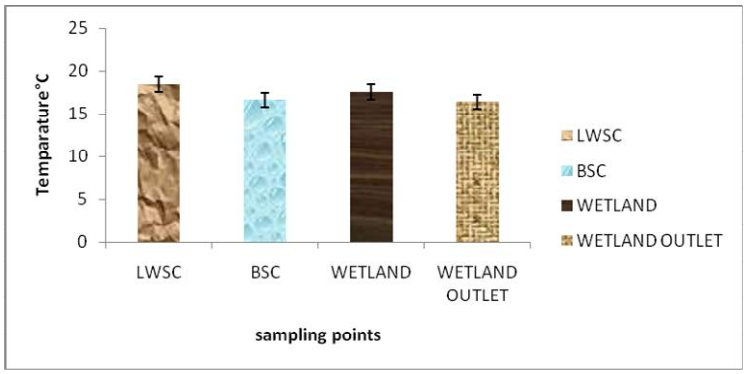

Fig. 4.4: The mean values of temperature recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

4.2.5 Nitrate-Nitrogen (mgL^{-1})

The Nitrate-nitrogen concentration recorded in (mgL^{-1}) at all the sampling points varied throughout the study period. In LWSC, Nitrate-nitrogen concentration ranged from 6.15 (4.75mm rainfall) to 55.97±0.1mgL^{-1} (4.75mm), with a mean value of 23.71mgL^{-1}. In BSC Nitrate-nitrogen concentration ranged from 5.44 (4.75mm) to 18.80±0.1 mgL^{-1} (4.75mm) with a mean of 13.19mgL^{-1}. The values in the wetland ranged from 11.60 to 56.70±0.1 mgL^{-1} with a mean of 39.23mgL^{-1} while at the wetland outlet the values ranged from 2.16 to 6.28±0.1 mgL^{-1} (appendix 3). The mean value at the wetland outlet was 4.20mgL^{-1} (Table 4.2, Fig 4.5). The high mean values were recorded at the Joint while low values were recorded at the wetland outlet. Using a T-Test (2-tailed analysis) it was found that there was a significant difference (0.006) between nitrate concentration in the waste water in the wetland and that leaving the wetland.

Table 4.2: Mean values of the chemical parameters of waste water of LWSC, BSC, Wetland and Outlet of Tibia wetland.

Parameters	BOD mgL^{-1}	TS mgL^{-1}	TDS mgL^{-1}	TSS mgL^{-1}	NO_3 mgL^{-1}	PO_4 mgL^{-1}	Cr_3 mgL^{-1}
LWSC	873.4	5282.3	864.3	4418.2	23.7	7.8	2.4
BSC	43.8	986.6	387.5	599.1	13.2	6.5	4.8
WETLAND	917.2	6269.0	1251.8	5017.3	39.2	12.6	8.0
OUTLET	38.9	717.0	659.9	59.6	4.2	1.8	0.5
T-test P value	0.020*	0.004*	0.030*	0.009*	0.006*	0.001*	0.005*

*** significant difference**

Parameters are means of the eight collected samples.

P-value in the above table is the result of T-test between waste water in the wetland and that leaving the wetland.

Variations in concentration of nitrate-nitrogen in reservoir are attributed to runoff from vegetated watershed, effluent discharge and runoff from fertilized cropland (Hemond & Benoit, 1988), Denitrification (Jameel , 1998, Sather & Smith, 1984, Debusk & Debusk, 2000, Kadlec & Knight, 1996), uptake by vascular plants and subsequent burial when the plants die (Delaune *et al*., 1986).

The high level of nitrate-nitrogen concentration recorded in the Wetland could be attributed to waste water from Limuru water and sewerage company and Bata Shoes Company which contains high organic matter, while the low nitrate-nitrogen concentration recorded at the wetland outlet could be attributed to denitrification where nitrate is converted to diatomic molecular nitrogen, deposition of nitrate in sediments at the wetland bottom and plant uptake.

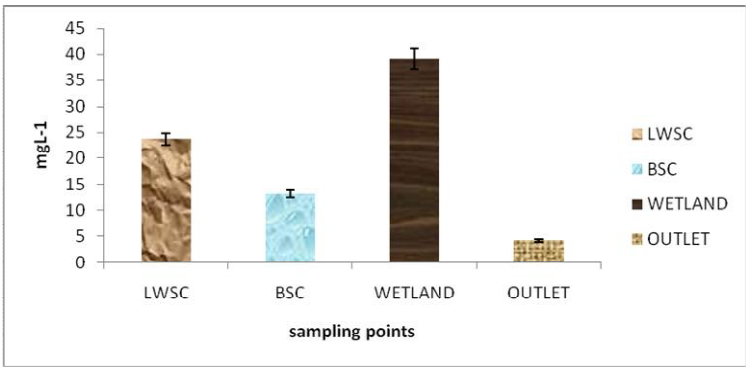

Fig. 4.5: The mean value of Nitrate-Nitrogen concentration recorded at LWSC, BSC, Joint and Outlet during the study period (November 2012 to February 2013).

4.2.6 Phosphate concentration (mgL^{-1})

The study revealed that Phosphate concentration in the water samples ranged from 1.83 to 14.70±0.1 in LWSC, 5.20 to 8.44±0.1in BSC, 8.50 and 17.10±0.1 in the wetland while at the wetland outlet it ranged from 0.80 to 3.03±0.1 (Appendix 3). The mean values were LWSC 7.8, BSC 6.5, Wetland 12.6 while at the wetland outlet it was 1.8 (Table 4.2, Fig. 4.6). Using T-Test (2-tailed analysis) it was found that there was a significant difference (0.03) between phosphate at the wetland and after coming out of the wetland.

Variation in concentration phosphate is attributed to runoff, effleunt discharge and runoff from fertilized cropland and adsorption of phosphates onto mineral sediments. (Hemond & Benoit, 1988). The presence of Ca^{2+}, Fe^{3+} or Al^{3+} in sediments which determines adsorption capacity (Verhoen & Arthur, 1999). Introduction of detergent-rich effluent from washing from factories, anthropogenic

activities, domestic and industrial inputs of phosphorous from sewage disposal and type of vegetation and catchment. physical, chemical and biological processes (Kadlec & Knight, 1996). Precipitation with metal oxides to form new mineral compounds (Nicholas, 1983).

The significant difference between Wetland and wetland outlet could be attributed to the fact that water in the wetland has high organic substance (high BOD, Table 4.2) as much of it is sewage from LWSC (mainly domestic) and BSC (industrial), while after passing through the wetland it could be that plants use up the phosphate or some of it is deposited in the wetland bottom with sediments and adsorption on to metal sediments.

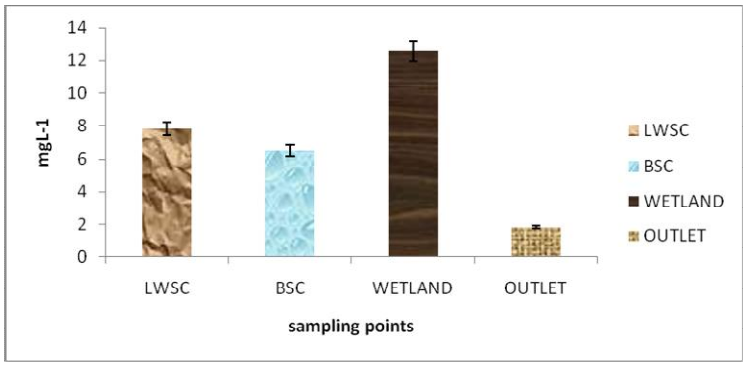

Fig. 4.6: The mean values of Phosphate concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

4.2.7 Biochemical Oxygen Demand (BOD) mgL^{-1}

The study revealed that Biological Oxygen Demand concentration (mgL^{-1}) in water sample ranged from 63.33 to 1866.70±0.1 in LWSC, 13.33 to 130.00±0.1 in BSC,

76.70 to 1996.70±0.1 in the wetland while at the outlet it ranged from 8.33 to 71.70±0.1 (appendix 1). The mean BOD values were LWSC 873.4, BSC 43.8, Wetland 917.2 while at the wetland outlet it was 38.9 (Table 4.2, Fig. 4.7). The wetland had the highest BOD while outlet had the lowest. Using T-Test (2-tailed analysis) it was found that there was a significant difference ($p<0.020$) between BOD in the waste water in the wetland and the water leaving wetland.

Variation in BOD concentration is attributed to organic matter such as sewage effluent, surface runoff and natural biotic processes (Mitch & Gosselink, 2000). Wetland vegetation, decomposing micro-organisms and temperature also influence the BOD in a water body (Hemond & Bonoit, 1988, Steinmann *et al*., 2003).

Waste water discharge from LWSC and waste water from BSC is mainly the reason for the high concentration of BOD_5 in the wetland which have high concentration of organic matter mostly from domestic waste.

The noteworth reduction in BOD_5 concentration at the outlet can be attributed to biodegradation of the organic matter by microorganisms in the wetland. The trapping of particulate organic matter by wetland vegetation, might have also contributed to decrease in BOD_5 concetration at the outlet as the organic matter settle as sediment off the water column.

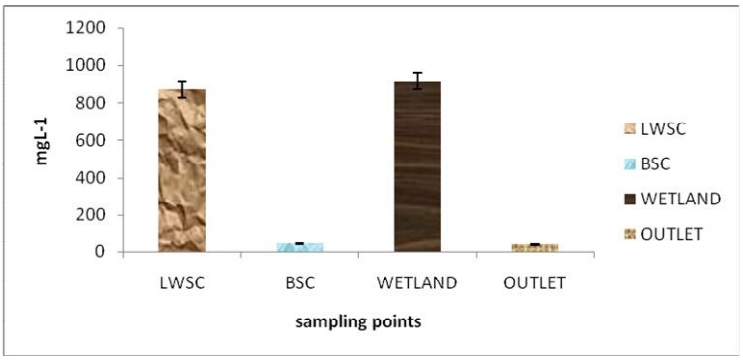

Fig. 4.7: The mean values of BOD concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

4.2.8 Total Suspended Solids (TSS) mgL^{-1}

The study revealed that the Total Suspended Solids in the water samples ranged from 835.33 to 7576.30±0.1 in LWSC, 6.70 to 3316±0.1, 993.30 to 8853.80±0.1 in the wetland while at the wetland outlet TSS ranged from 24.00 to 99.30±0.1 (appendix 3). The mean values in mgL^{-1} were, LWSC 4418.2, in BSC 599.1, wetland 5017.3 while at wetland outlet it was 59.6 (Table 4.2, Fig. 4.8). Using T-Test (2-tailed analysis) it was found that there was a significant difference (0.009) between TSS in the waste water in the wetland and water leaving the wetland.

Variation in concetration of Suspended solids is attributed to runoff, or inflow from associated water bodies (Mitch & Gosselink, 2000). Low velocity coupled with the presence of the luxuriant vegetation and gravel substrate also contributed to lower TSS (Kadlec & Knight, 1996). Removal of other pollutants like BOD, COD, heavy metals from the water also leads to decrease in TSS concentration. Erosion, urban runoff and agricultural land, industrial wastes, bank erosion, bottom feeders,

algal growth or wastewater discharges increase TSS in water (Lawson, 2011). Changes in pH can influence concentration of suspended solids.(www.stevenswater.com).

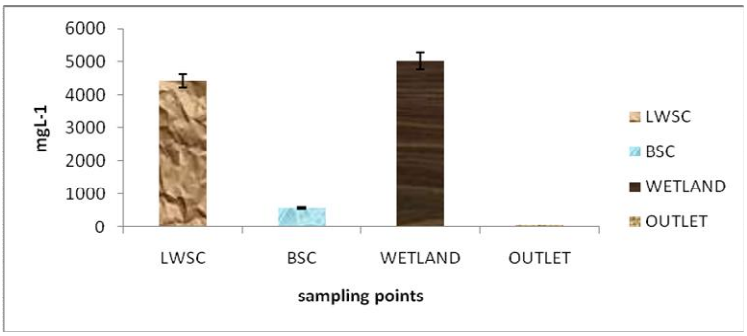

Fig. 4.8: The mean values of TSS recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

The higher TSS value recorded in the wetland could be attributed to discharges from BSC and LWSC (high BOD, Table 4.2). Runoff from the surrounding areas which ends up into the wetland also contributes to increased TSS. The decrease in TSS concentration noted at the outlet can be attributed to the luxuriant vegetation which traps some of the solids as well as reduced water velocity as the water flows through the wetland hence causing most of the suspended solids to settle from within the water column.

4.2.9 Total Dissolved Solids (TDS) mgL^{-1}

The study revealed that the Total Dissolved Solids concentration in the water sample ranged from 235.0 to 1881.3±0.1 in LWSC, 241.7 to 698.7±0.1in BSC, 476.7 to 2224.0±0.1 in the wetland while at the outlet it ranged from 342.0 to

948.0±0.1 (appendix 3). The mean values were, LWSC 864.3, in BSC 387.5, in the wetland 1251.8 while in the wetland outlet it was 659.9 (Table 4.2, Fig. 4.9). Using T-Test (2-tailed analysis) it was found there was a significant difference between TDS concentration in the waste water in the wetland and after passing through the wetland (0.03).

Variations in concentrationof Total Dissolved Solids is attributed to presence of organic matter, runoff, from urban areas road salt use in street fertilizers and pesticides used in farms. Inorganic materials and air that contains calcium bicarbonate, nitrogen, iron phosphorous, sulfur and other minerals (Lawson, 2011), Fertilizer, decaying of plants and animals, solids and ions deposition onto pea-gravel in wetland (www.rmotc.doe.gov).

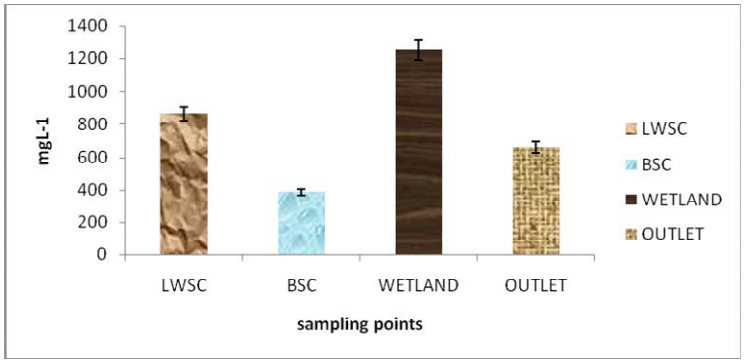

Fig. 4.9: The mean values of TDS concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

Industrail discharge from BSC and Sewage from LWSC contributes to the higher concentration of TDS at the wetland. The decrease in TDS noted at the outlet could be attributed to solid deposition due to reduced water speed as the water passes

through the wetland. The decrease could also be attributed to uptake of some of the dissolved solids by wetland plants.

4.2.10 Total Solids (TS) mgL^{-1}

The study revealed that the TS concentration in the water sample ranged from 1982.00 to 7811.30±0.1 in LWSC, 278.70 to 3784.00±0.1 in BSC, 2838.70 to 9764.00±0.1 in the wetland while at the outlet it ranged from 415.33 to 1017.33±0.1 (appendix 3). The mean values in mgL^{-1} were LWSC 5282.3, BSC 986.6, in the wetland 6269.0 while in the wetland outlet it was 717.0 (Table 4.2, Fig. 4.10). Using T-Test (2-tailed analysis) it was found that there was a significant difference (0.004) between TS in the waste water in the wetland and after passing through the wetland.

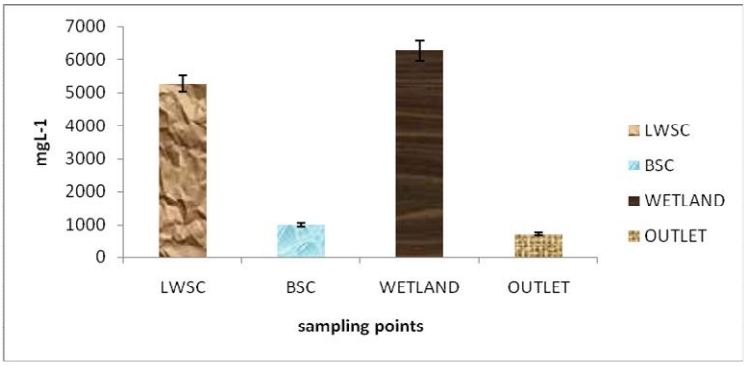

Fig. 4.9: The mean values of TS concentartion values recorded at LWSC, BSC, Wetland and Outlet of the wetland during the study period (November 2012 to February 2013).

Low velocity coupled with the presence of the luxuriant vegetation and gravel substrate contributes to reduction in TS (Kadlec & Knight, 1996). Wetland higher concentration of TS in the wetland could be attributed to Industrial discharges from

BSC and sewage discharge from LWSC. The decrease in the concentration of TS at wetland outlet might be as a result of reduced velocity of the waste water as it flows through the wetland due to the luxuriant wetland vegetation hence causing the solids to settle at the bottom or be attached on the roots of the wetland vegetations.

4.2.11 Chromium (mgL^{-1})

The study revealed that Chromium concentration in the water sample ranged from 1.96 to 2.64±0.1 in LWSC, 0.78 to 7.34±0.1 in BSC, 3.40 to 14.70±0.1 in the wetland while at the outlet of the wetland it ranged from 0.33 to 0.73±0.1 (appendix 3). The mean values were LWSC 2.37, BSC 4.76, in the wetland 8.02 while at the wetland outlet it was 0.53 (Table 4.2, Fig. 4.11). Using T-Test (2-tailed analysis) it was found that there was a significant difference (0.005) between Chromium concentration in the waste water in the wetland and after passing through the wetland.

Variation in concentration of chromium can be attributed to industrial effleunts (Lawson, 2011). Accumulation on the roots surfaces of plants (Gosselink & Mitsch, 2000). Traps or sinks onto wetland soils, accumulation in roots and leaves of wetland vegetation. Adsorption onto suspended sediment (mineral and organic), and buried in the sediment when it settles (Hemond & Bonoit, 1988). Wetland plants are able to take up metals from water and sediments.

The higher concentration of Chromium in the wetland could be attributed to discahrges from LWSC and BSC. The decrease in the concentration of the amount

of chromium at Tibia wetland outlet could be attributed to plant roots and leaves accumulation or sinking into the wetland soil.

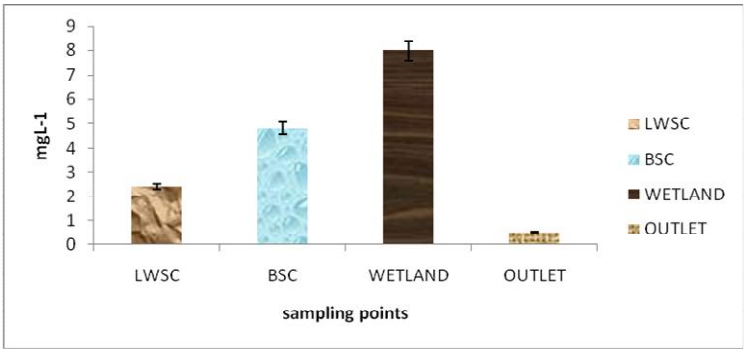

Fig. 4.4: The mean values of Chromium concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

4.3 Wetland removal efficiency of contaminants from the waste water.

The study revealed that wetland plays a role in the removal of pollutants from waste water. The removal efficiency was different for the different physical and chemical parameters (Table 4.3). The wetland removed 98.81% of TSS, BOD 95.76%, chromium 93.75%, nitrate 89.29%, phosphate 85.71%, TS 88.56% and TDS 47.28%. The other parameter which improved after the waste water passed through the wetland were temperature and DO. The pH changed by -2.63% (Table 4.3). The wetland efficiency in the removal of nitrate and phosphate could be attributed to plant uptake in the wetland and also since flow is reduced by resistance of the plants some the nutrients settle in the sediments.

Table 4.3: Table of the percentage removal of the physico-chemical parameters by the wetland and maximum permissible level .

Parameters	Unit	Influent	Effluent	%removal	GS	NEMA
pH	**pH**	**7.6**	**7.8**	**-2.63**	**5.5**	**6.5-8.5**
Conductivity	**µScm^{-}**	**1344.0**	**717.3**	**46.63**	**-**	**-**
TSS	**mgL^{-1}**	**5017.3**	**59.6**	**98.81**	**100**	**30**
BOD	**mgL^{-1}**	**917.2**	**38.9**	**95.76**	**30**	**30**
Nitrate	**mgL^{-1}**	**39.2**	**4.2**	**89.29**	**10**	**-**
Phosphate	**mgL^{-1}**	**12.6**	**1.8**	**85.71**	**-**	**-**
TDS	**mgL^{-1}**	**1251.8**	**659.9**	**47.28**	**-**	**1200**
Chromium	**mgL^{-1}**	**8.0**	**0.5**	**93.75**	**2.0**	**2.0**
DO	**mgL^{-1}**	**1.2**	**1.9**	**-58.33**	**-**	**-**
TS	**mgL^{-1}**	**6269.0**	**717.0**	**88.56**	**-**	**-**
Temperatur	**°C**	**17.5**	**16.4**	**6.29**		

NEMA-Guidelines for discharge of effluent into the Environment as found in the Environmental Management and Coordination(Water Quality Regulations), 2006 Third schedule.

GS- Genaral Standards for discharge of Environmental pollutants (–Effluent) into inland water bodies.

The efficiency in the removal of TS, TSS and TDS can mainly be attributed to reduced water speed inside the wetland, hence the solids getting more time to settle off the water column while for BOD could be attributed to settling of organic matter with sediment and breakdown of the organic matter by micro-organisms into simpler compounds like carbon dioxide and water. The improvement in DO could be attributed to reduced concentration of organic matter hence reduced demand for oxygen and pumping of atmospheric oxygen by wetland vegetation into the water.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS.

5.1 Summary of findings

The samples from LWSC, BSC, Wetland and the wetland Outlet varied in the physical parameters studied. LWSC had the lowest dissolved oxygen (0.0) while the wetland outlet had the highest (1.9mgL^{-1}). pH in the Wetland was 7.6 and 7.8 at the wetland outlet, temperature in the wetland was 17.5°c while at the wetland outlet it was16.4°c, conductivity in the wetland was 1344.0µScm^{-1} and 717.3 µScm^{-1} at the wetland outlet (Table 4.1).

The samples from LWSC, BSC, Wetland and the wetland Outlet varied widely in the chemical parameters studied. BOD in the wetland was 917.2 mgL^{-1} while at the wetland outlet it was 38.9 mgL^{-1}, TS in the wetland was 6269.0 mgL^{-1} while at the wetland outlet it was 717.0 mgL^{-1}, TDS in the wetland was 1251.8 mgL^{-1} while at the wetland outlet it was 659.9 mgL^{-1}, TSS in the wetland was 5017.3 mgL^{-1} while

at the wetland outlet it was 59.6 mgL^{-1}, Nitrate-nitrogen in the wetland was 39.2 mgL^{-1} while at the wetland outlet it was 4.2 mgL^{-1}, phosphate in the wetland was 12.6 mgL^{-1} while at the wetland outlet it was 1.8 mgL^{-1} and chromium in the wetland was 8.0 mgL^{-1} while at the wetland outlet it was 0.5 mgL^{-1} (Table 4.2).

The wetland had efficiency in removal of 98.81 % TSS, BOD 95.76%, Chromium 93.75%, Nitrate 89.29%, Total Solid 88.56% and Phosphate 85.71%. In the case of conductivity and Total Dissolved Solids they were less than 50% at 46.63% and 47.28% respectively. Dissolved Oxygen concentration increased by 23.40% after the water passed through the wetland and pH changed by -0.79% hence the effluent water was less acidic as compared with influent water (Table 4.3).

5.2 Conclusions

The study revealed that wetland plays a role in the removal of pollutants from waste water. Chemical and physical parameters showed variations after passing through the wetland. Dissolved oxygen increased while BOD, TS, TSS, phosphate, nitrate, chromium and temperature decreased. The pH was also higher after water passed through the wetland than before. Tibia wetland was observed to decrease the observed water quality parameter of the waste water from Limuru water and Sewerage Company and Bata Shoes Company resulting in increasing water quality.

For the parameters observed there was a significant difference between the wetland and wetland outlet except for DO, Temperature and pH. From the comparison of water qualities of the waste water entering the wetland and that leaving Tibia wetland was effective in waste water treatment though its performance needs to be

improved to meet the required standards (Anova overall comparison of inlet and outlet content).

Though the wetland was efficient in removal of pollutants and significantly improved water quality by reducing loads of the pollutants, some of the water quality parameters in the effluent water did not meet the required standards even after passing through the wetland. For the General Standards for discharge of environmental pollutants into inland surface water, TSS, pH, Chromium, Nitrate-Nitrogen were within the permissible standards for discharge into surface water bodies as they were 59.6mgL^{-1}, 7.8, 0.5mgL^{-1}, 4.2mgL^{-1} respectively while the permissible limits are 100 mgL^{-1}, 5.5 to 9.0, 2.0 mgL^{-1} and 10mgL^{-1} respectively. BOD failed to meet the General Standard as it was 38.9mgL^{-1} while the maximum permissible value is 30mgL^{-1}(Table. 4.3).

From the NEMA standards pH, Chromium, TDS were within the permissible NEMA standards with values of 7.8, 0.5mgL^{-1} and 659.9mgL^{-1} respectively while the permissible limits are 6.5-8.5, 2.0mgL^{-1} and 1200mgL^{-1}. BOD and TSS were higher than NEMA limits with values of 38.9 mgL^{-1} and 59.6mgL^{-1} while the maximum permissible limits are 30mgL^{-1} for both (Table. 4.3).

The LWSC lagoons are overstretched as it can be evident by the levels of parameters in the waste water flowing from them into the wetland. BSC pretreatment system is not overstretched as the level of parameters in the waste water flowing from it into the wetland are lower.

The study null hypotheses were rejected and the alternatives upheld because there were significant differences between most of the physico-chemical parameters in the waste water entering the wetland and water leaving the wetland.

5.3 Recommendation

The recommendations made from this study are;

Recommendation for management action

1. The facilities discharging waste water into the wetland should ensure that it is pre-treated before being discharged into the wetland. Measures should be put in place to improve the final effluent quality to ensure that the levels of the parameters in the effluent are within the permissible limits.

2. It must be ensured that wastewater flowing into the swamp is well distributed over the whole expanse/ width of the wetland hence all the zones of the wetland interacts with wastewater. This will help to avoid short circuiting (channelized) flow into natural wetland treatment system and to increase retention time hence improved treatment.

3. Regular monitoring, analysis and assessment of the efficiency level of the wetland to remove pollutants from the waste water must be done in Tibia wetland.

4. Wetlands can be used as waste water treatment facility instead of regarding them as waste land.

5. More lagoons for pre-treating waste water form LWSC should created to ensure that waste water flowing into the wetland is pre-treated to prevent the wetland from being overloaded with pollutants.

Recommendation for Further study

1. Vegetation dominating the wetland should be identified. Further research should be carried out on the vegetation potential to reduce the pyhsico-chemical parameters in the waste water at different seasons to see if they can be recommended for use in other waste water treatment sites.

2. The rate of accumulation of the pollutants in the wetland should be studied to help in planning for sustainable use of the wetland in treatment of waste water. Effort should be made to reduce the loads of effluents/ pollutants being discharged into the swamp so as to avoid overloading and to ensure sustainable use of the wetland.

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Appendices

Appendix 1: Results of Levels of Waste Water Parameters

pH

Week	LWSC	BSC	WETLAND	OUTLET
1	7.91	8.43	8.17	7.59
3	7.98	8.34	8.16	7.61
5	6.41	7.34	6.88	7.18
7	6.50	8.10	7.30	7.90
9	6.60	8.12	7.36	7.90
11	6.90	8.10	7.50	7.80
Mean	7.05	8.07	7.56	7.66

Temp (°C)

Week	LWSC	BSC	WETLAND	OUTLET
1	17.20	15.50	16.35	17.10
3	17.80	15.40	16.60	17.20
5	18.80	16.70	17.75	15.83
7	19.10	16.90	18.00	15.90
9	18.90	16.89	17.90	15.80

11	18.50	17.89	18.20	16.80
Mean	18.38	16.55	17.47	16.44

Conductivity (μScm^{-1})

Week	LWSC	BSC	WETLAND	OUTLET
1	907.00	686.00	1593.00	703.00
3	912.00	690.00	1602.00	710.00
5	810.32	397.70	1208.00	727.00
7	813.00	401.20	1214.20	725.00
9	819.00	402.00	1221.00	727.00
11	812.00	414.00	1226.00	712.00
Mean	845.55	498.48	1344.03	717.33

DO (mgL^{-1})

Week	LWSC	BSC	WETLAND	OUTLET
1	0.01	0.02	0.03	1.99
3	0.02	0.03	0.05	2.10
5	0.03	2.61	2.64	0.78
7	0.03	1.90	1.93	2.10
9	0.02	1.20	1.22	2.20
11	0.01	1.40	1.41	2.40

Mean	0.02	1.19	1.21	1.98

BOD (mgL^{-1})

Week	LWSC	BSC	WETLAND	OUTLET
1	1866.70	130.00	1996.70	48.33
3	816.70	13.67	830.40	8.33
5	63.33	13.33	76.70	18.33
7	450.00	15.70	465.70	25.00
9	1041.70	45.00	1086.70	71.70
11	1001.70	45.00	1046.70	61.70
Mean	873.36	43.78	917.15	38.90

TS (mgL^{-1})

Week	LWSC	BSC	WETLAND	OUTLET
1	5980.00	3784.00	9764.00	415.33
3	7811.30	289.67	8101.00	602.00
5	1982.00	856.67	2838.70	1017.33
7	4636.70	400.70	5037.40	999.30
9	5592.00	278.70	5870.70	616.00

11	5692.00	310.00	6002.00	652.00
Mean	5282.33	986.62	6268.97	716.99

TDS (mgL^{-1})

Week	LWSC	BSC	WETLAND	OUTLET
1	442.70	468.00	910.70	342.00
3	235.00	241.67	476.70	554.70
5	1146.67	698.67	1845.30	948.00
7	1881.30	342.70	2224.00	898.70
9	640.00	272.00	912.00	608.00
11	840.00	302.00	1142.00	608.00
Mean	864.28	387.51	1251.78	659.90

TSS (mgL^{-1})

Week	LWSC	BSC	WETLAND	OUTLET
1	5537.30	3316.00	8853.30	73.33
3	7576.30	48.00	7624.30	47.33
5	835.33	158.00	993.30	69.33
7	2756.30	58.00	2814.30	99.30

9	4952.00	6.70	4958.70	24.00
11	4852.00	8.00	4860.00	44.00
Mean	4418.21	599.12	5017.32	59.55

Nitrate (mgL^{-1})

Week	LWSC	BSC	WETLAND	OUTLET
1	10.12	15.80	25.90	3.53
3	22.22	16.67	38.90	3.89
5	6.15	5.44	11.60	2.16
7	15.80	18.80	34.60	4.04
9	55.97	11.70	67.70	6.28
11	45.97	10.70	56.70	5.28
Mean	23.71	13.19	39.23	4.20

Phosphate (mgL^{-1})

Week	LWSC	BSC	WETLAND	OUTLET
1	5.25	7.20	12.50	1.20
3	8.68	8.44	17.10	2.17
5	1.83	6.69	8.50	0.80

7	6.52	6.50	13.00	1.45
9	14.70	5.23	9.30	3.03
11	9.70	5.20	14.90	2.03
Mean	7.78	6.54	12.55	1.78

Chromium (mgL^{-1})

Week	LWSC	BSC	WETLAND	OUTLET
1	2.64	0.78	3.40	0.36
3	1.96	4.55	6.50	0.58
5	2.50	4.45	6.90	0.73
7	2.50	4.45	6.90	0.73
9	2.32	6.96	14.70	0.33
11	2.32	7.34	9.70	0.44
Mean	2.37	4.76	8.02	0.53

Appendix 2: The rainfall amount during the study period

Sampling date	Rainfall amount (mm)
29/11/2012	11.5
13/12/2012	0
07/01/2013	0.4
15/02/2013	16.6
08/02/2013	0
22/02/2013	0

From Kenya Metrological department

Appendix 3: T-Test Results

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	COD before treatment	2788.6450	6	1790.69005	731.04615
	COD after treatment	99.7733	6	59.00074	24.08695

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	COD before treatment & COD after treatment	6	-.078	.884

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	COD before treatment - COD after treatment	2688.872	1796.23024	733.30792	803.84364	4573.900	3.667	5	.014

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	BOD before treatment	917.1500	6	652.47950	266.37364
	BO4 after treatment	38.8983	6	25.43802	10.38503

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	BOD before treatment & BO4 after treatment	6	.541	.268

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	BOD before treatment - BO4 after treatment	978.25167	639.07157	260.89988	207.58719	1548.916	3.366	5	.020

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	TS before treatment	6268.9667	6	2411.84483	984.63153
	TS after treatment	716.9933	6	240.22789	98.07262

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	TS before treatment & TS after treatment	6	-.892	.017

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	TS before treatment - TS after treatment	5551.973	2628.46711	1073.067	2793.566	8310.380	5.174	5	.004

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	TDS before treatment	1251.7833	6	654.53256	267.21180
	TDS after treatment	659.9000	6	226.95450	92.65379

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	TDS before treatment & TDS after treatment	6	.830	.041

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	TDS before treatment - TDS after treatment	591.88333	483.05026	197.20444	84.95317	1098.813	3.001	5	.030

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	TSS before treatment	5017.3167	6	2918.40050	1191.432
	TSS after treatment	59.5483	6	26.53501	10.83287

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	TSS before treatment & TSS after treatment	6	-.262	.616

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	TSS before treatment - TSS after treatment	4957.768	2925.46106	1194.314	1887.685	8027.851	4.151	5	.009

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Nitrate before treatment	39.2333	6	20.38820	8.32345
	Nitrate after treatment	4.1967	6	1.43003	.58381

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Nitrate before treatment & Nitrate after treatment	6	.989	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Nitrate before treatment - Nitrate after treatment	35.03667	18.97456	7.74633	15.12409	54.94924	4.523	5	.006

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Phosphate before treatment	12.5500	6	3.26787	1.33410
	Phosphate after treatment	1.7800	6	.79785	.32572

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Phosphate before treatment & Phosphate after treatment	6	.165	.755

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Phosphate before treatment - Phosphate after treatment	10.77000	3.23357	1.32010	7.37658	14.16342	8.158	5	.000

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PH before treatment	7.5617	6	.51102	.20862
	PH after treatment	7.6633	6	.27296	.11144

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PH before treatment & PH after treatment	6	.193	.714

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	PH before treatment - PH after treatment	-.10167	.53075	.21668	-.65866	.45532	-.469	5	.659

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Temperature before treatment	17.4667	6	.78592	.32085
	Temperature after treatment	16.4383	6	.66575	.27179

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Temperature before treatment & Temperature after treatment	6	-.715	.110

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Temperature before treatment - Temperature after treatment	1.02833	1.34492	.54906	-.38308	2.43974	1.873	5	.120

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Conductivity before treatment	1344.0333	6	196.44950	80.20017
	Conductivity after treatment	717.3333	6	10.32796	4.21637

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Conductivity before treatment & Conductivity after treatment	6	-.821	.045

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Conductivity before treatment - Conductivity after treatment	626.70000	205.01527	83.69713	411.54967	841.85033	7.488	5	.001

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	DO before treatment	1.2133	6	1.03357	.42195
	DO after treatment	1.9283	6	.57926	.23648

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	DO before treatment & DO after treatment	6	-.566	.242

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	DO before treatment - DO after treatment	-.71500	1.44262	.58895	-2.22894	.79894	-1.214	5	.279

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Chromium before treatment	8.0167	6	3.83688	1.56640
	Chromium after treatment	.5283	6	.17860	.07291

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Chromium before treatment & Chromium after treatment	6	-.358	.486

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Chromium before treatment - Chromium after treatment	7.48833	3.90434	1.59394	3.39098	11.58569	4.698	5	.005

Appendix 4: Plates of Photos of the Study Area.

Plate 1. View of the wetland from the inlet side

Plate 2. View of wetland from the outlet side

Plate 3. Limuru Water and Sewerage Company inlet

Plate 4. Bata Shoes Company inlet

Plate 5. Tibia wetland outlet

Plate 6. Some of the equipments used for sample collection and insitu measurements.

Plate 7. Some of the various birds found in the wetland

Plate 8. A woman harvesting grass for livestock at the wetland

Plate 9. Some of the crops grown at the periphery of Tibia wetland

Plate 10. Researcher on site ready to collect sample at the wetland inlet

Plate 11. Closer look of water at Limuru Water and Sewerage Company inlet and vegetation

Plate 12. Vegetation dominating the wetland outlet

Appendix 5: Standards for Discharge of Effluent

5.1 General Standards for Discharge of Environmental Pollutants

Part – A: Effluents

Sl. No.	Parameter	Standards			
		Inland surface water	Public sewers	Land of irrigation	Marine / coastal areas
1.	Colour and odour	See 6 of Annexure-1	--	See 6 ofAnnexure-1	See 6 of Annexure-1
2.	Suspended solids mg/l, max.	100	600	200	a. For process waste water 100 b. For cooling water effluent 10 per cent above total suspended matter of influent
3.	Particle size of suspended solids	Shall pass 850 micron IS Sieve	--		a. Floatable solids, solids max. 3 mm. b. Setleable solids. Max 856 microns
4.	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
5.	Temperature	Shall not exceed 5°C above the receiving water temperature.	--	--	Shall not exceed 5°C above the receiving water temperature.
6.	Oil and grease, Mg / l max.	10	20	10	20
7.	Total residual chlorine, mg/l max	1.0	--	--	1.0
8.	Ammonical nitrogen (as N), mg/l, max.	50	50	--	50
9.	Total nitrogen (as N); mg/l,	100	--	--	100

	max.				
10.	Free ammonia (as NH3), mg/l, max	5.0	--	--	5.0
11.	Biochemical oxygen demand (3 days at 27°C), mg/l, max.	30	350	100	100
12.	Chemical oxygen demand, mg/l, max.	250	--	--	250
13.	Arsenic (as As) mg/l, max	0.2	0.2	0.2	0.2
14.	Mercury (As Hg), mg/l, max.	0.01	0.01	--	0.01
15.	Lead (as Pb) mg/l, max.	0.1	0.1	--	2.0
16.	Cadmium (as Cd) mg/l, max.	2.0	1.0	--	2.0
17.	Hexavalent chromium (as Cr + 6), mg/l, max.	0.1	2.0	--	1.0
18.	Total chromium (as Cr) mg/l, max.	2.0	2.0	--	2.0
19.	Copper (as Cu) mg/l, max.	3.0	3.0	--	30
20.	Zinc (as Zn) mg/l, max.	5.0	15	--	15
21.	Selenium (as Se) mg/l, max.	0.05	0.05	--	0.05
22.	Nickel (as Ni) mg/l, max.	3.0	3.0	--	50

23.	Cyanide (as CN) mg/l, max.	0.2	2.0	0.2	0.2
24.	Fluoride (as F) mg/l, max.	2.0	15	--	15
25.	Dissolved phosphates (as P), mg/l, max.	5.0	--	--	--
26.	Sulphide (as S) mg/l, max.	2.0	--	--	5.0
27.	Phenolic compounds (as C_6H_5OH) mg/l, max.	1.0	5.0	--	5.0
28.	Radioactive materials :				
	a. Alpha emitters micro cure mg/l, max.	10^{-7}	10^{-7}	10^{-8}	10^{-7}
	b. Beta emitters micro cure, mg/l. max.	10^{-6}	10^{-6}	10^{-7}	10^{-6}
29.	Bio-assay test	90% suivival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% sunfival of fish after 96 hours in 100% effluent.
30.	Manganese (as Mn)	2 mg/l	2 mg/l	2 mg/l	2 mg/l
31.	Iron (as Fe)	3 mg/l	3 mg/l	3 mg/l	3 mg/l
32.	Vanadium (as V)	0.2 mg/l	0.2 mg/l	--	0.2 mg/l
33.	Nitrate Nitrogen	10 mg/l	--	--	20 mg/l

STANDARDS FOR EFFLUENT DISCHARGE INTO THE ENVIRONMENT (ENVIRONMENTAL MANAGEMENT AND CO-ORDINATION (WATER QUALITY) REGULATIONS, 2006).

Parameter	Maximum Allowable(Limits)
1,1,1-trichloroethane (mg/l)	3
1,1,2-trichloethane (mg/l)	0.06
1,1-dichloroethylene	0.2
1,2-dichloroethane	0.04
1,3-dichloropropene (mg/l)	0.02
Alkyl Mercury compounds	Nd
Ammonia, ammonium compounds, NO3 compounds and NO2 compounds (Sum total of ammonia-N times 4 plus nitrate-N and Nitrite-N) (mg/l)	100
Arsenic (mg/l)	0.02
Arsenic and its compounds (mg/l)	0.1
Benzene (mg/l)	0.1
Biochemical Oxygen Demand (BOD 5days at 20° C) (mg/l)	30
Boron (mg/l)	1.0
Boron and its compounds – non marine (mg/l)	10
Boron and its compounds –marine (mg/l)	30
Cadmium (mg/l)	0.01
Cadmium and its compounds (mg/l)	0.1
Carbon tetrachloride	0.02
Chemical Oxygen Demand (COD (mg/l)	50
Chromium VI (mg/l)	0.05
Chloride (mg/l)	250
Chlorine free residue	0.10
Chromium total	2
cis –1,2- dichloro ethylene	0.4
Copper (mg/l)	1.0
Dichloromethane (mg/l)	0.2
Dissolved iron (mg/l)	10
Dissolved Manganese(mg/l)	10
E.coli (Counts / 100 ml)	Nil
Fluoride (mg/l)	1.5
Fluoride and its compounds (marine and non-marine) (mg/l)	8
Lead (mg/l)	0.01
Lead and its compounds (mg/l)	0.1
n-Hexane extracts (animal and vegetable fats) (mg/l)	30
n-Hexane extracts (mineral oil) (mg/l)	5
Oil and grease	Nil
Organo-Phosphorus compounds (parathion,methyl parathion,methyl demeton and Ethyl parantrophenyl phenylphosphorothroate, EPN only) (mg/l)	1.0
Polychlorinated biphenyls, PCBs (mg/l)	0.003
pH (Hydrogen ion activity----marine)	5.0-9.0
pH (Hydrogen ion activity--non marine)	6.5-8.5

Phenols (mg/l)	0.001
Selenium (mg/l)	0.01
Selenium and its compounds (mg/l)	0.1
Hexavalent Chromium VI compounds (mg/l)	0.5
Sulphide (mg/l)	0.1
Simazine (mg/l)	0.03
Total Suspended Solids, (mg/l)	30
Tetrachloroethylene (mg/l)	0.1
Thiobencarb (mg/l)	0.1
Temperature (in degrees celious) based on ambient temperature	± 3
Thiram (mg/l)	0.06
Total coliforms (counts /100 ml)	30
Total Cyanogen (mg/l)	Nd
Total Nickel (mg/l)	0.3
Total Dissolved solids (mg/l)	1200
Colour in Hazen Units (H.U)	15
Detergents (mg/l)	Nil
Total mercury (mg/l)	0.005
Trichloroethylene (mg/l)	0.3
Zinc (mg/l)	0.5
Whole effluent toxicity	
Total Phosphorus (mg/l)	2 Guideline value
Total Nitrogen	2 Guideline value

And any other parameters as may be prescribed by the Authority from time to time. Not detectable (Nd) means that the pollution status is below the detectable level by the measurement methods established by the Authority.