

Variations In The Levels Of Physico-Chemical Parameters Of Waste Water Before And After Passing Through Tibia Wetland And Conformity To Nema (Kenya) And General Standards Permissible Effluent Discharge Limits.

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Abstract: Information on wetland function in waste water treatment is very important as the information can be used to remove undesirable qualities of water. The objective of the study was to determine the levels of physico-chemical parameters in the waste water before and after passing through the Tibia wetland. Four sampling sites were selected which are Limuru Water and Sewerage Company inlet, Bata Shoes Company inlet, inside the wetland and the wetland outlet. Water samples were collected twice every week for a period of four months (November 2012 to February 2013). The parameters measured included pH, electrical conductivity, temperature, BOD, TDS, TS, TSS, DO, phosphate, chromium and nitrate. Standard methods for sampling, storage and analysing according to APHA were used. Statistical analysis informs of T-test (2-tailed), Anova and Microsoft excel program were used to summarize the findings. The study revealed that for all the parameters under study there was high concentration in the levels of the parameters before passing through the wetland and 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. Though the parameters varied after passing through the wetland as compared to before, 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. 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

Keywords: Physico-chemical parameters, Tibia wetland, Waste Water, Wetland.

I. Introduction

Wetlands are areas permanently or seasonally flooded by water (World Conservation Monitoring Centre, 1995). Wetlands are important to human 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 Kenya has 214 species of fish, four-fifth of which are found nowhere else (World Conservation Monitoring Centre, 1995).

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 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 (Cunningham *et al.*, 2003).

The ability of wetlands to improve the quality of water has long been recognized and this had led to proliferation use 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 a means of waste disposal for hundred of years (McEdlowhey *et al.*, 1993).

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).

When the stabilization pond effluents are released without further treatment back into 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. 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 Watson *et al.*, (1989) and Kadlec & Knight (1996).

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 (Haluzan, 2010). According to Kansime & 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.

In Kenya, Wetlands are used for diverse purposes, including the treatment of waste water. Despite their widespread uses and distribution, our understanding on the 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 waste. Our limited understanding especially of their benefits partly explains their under-exploitation 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. There treatment potential of the wetland can be reflected in the variations of the physico-chemical parameters in the water before and after passing through the wetland. Information on the effectiveness of wetland on removal of waste forms vital baseline for use of wetlands as waste water treatment and also their conservation.

The objective of the present study is to determine the variations in physico-chemical parameters levels in the waste water before and after passing through the wetland.

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 plant, 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.

II. 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).

Water samples were collected from the sampling points twice every month for a period of four month (November 2012 to February 2013). Four sampling points were identified which were Limuru Water and Sewerage Company inlet (LWSC), Bata Shoes Company inlet (BSC), Wetland and Wetland Outlet. Using a water scooper, water samples for laboratory analysis from each sampling point were collected at different depths and pulled together into a collection bucket to form a composite sample and transferred into 1 litre plastic bottles and capped. The rainfall amount was also collected during the sampling period. The samples were transported to Nairobi Water and Sewerage Company laboratory for analyses. Samples analyses commenced within a period of four hours, sample preservation was in most occasions not necessary. The data was analysed using analysis of variance (Anova), T-test and Microsoft excel program. $P < 0.05$ was considered as the minimum value for statistical significance.

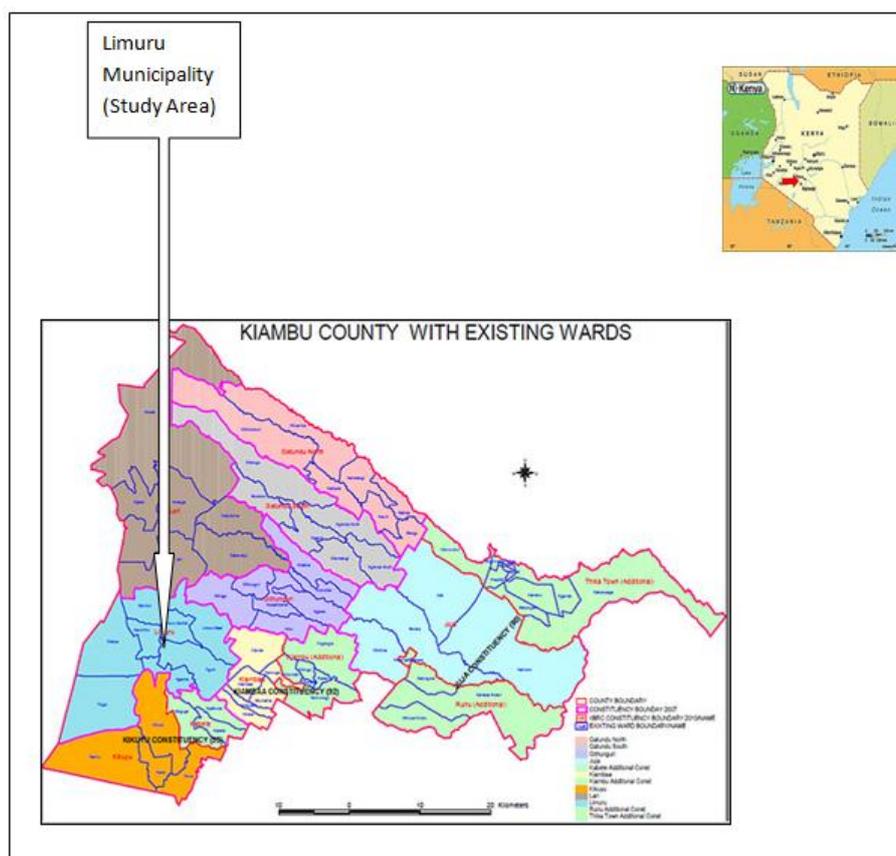


Fig. 3.1: Map of Kiambu County showing Tibia Wetland the Study Area.

(Source: Flickrriver.com)

III. Materials And Methods

Temperature

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.

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.

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} .

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 and allowed to equilibrate before the readings of the dissolved Oxygen of the water sample was read and recorded in mgL^{-1} .

Biological Oxygen Demand

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.

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.

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.

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.

Nitrate-Nitrogen

Nitrate-nitrogen concentration was determined by the modified Sodium salicylate procedure (Scheiner 1974). Nitrate-nitrogen reacts with sodium salicylate 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°C 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 NO₃-N concentration was subjected to the same treatment as water sample and readings used to determine the actual concentration of nitrate in the sample.

Total Phosphate

Total phosphate concentration was determined using the ascorbic acid reduction procedure (APAH 1998). Unfiltered water was oxidized to Po₄-P by autoclaving the samples at 120°C for 40 minutes using Ammonium persulfate oxidizing agent. Phosphate ions combine with ammonium molybdate to form a molybdophosphate complex. The complex is readily reduced by ascorbic acid to an intensely blue phosphomolydenium complex. Colour intensity was measured calorimetrically at a wavelength of 690 nm using a digital spectrophotometer (HACH Model).

Chromium

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.

IV. Results And Discussions

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	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 (µS _{cm} ⁻¹)	845.6	498.5	1344.0	717.3	0.001*
DO (mgL ⁻¹)	0.0	1.2	1.2	1.9	0.279

pH

pH at LWSC was 7.1, 8.1 at BSC, 7.6 at the wetland and 7.8 at the wetland outlet. Variations in pH is attributed to microorganisms in water which breaks down organic materials to simpler products like CO₂. The CO₂ dissolves in water to produce carbonic acid (H₂CO₃) which increases the pH. The pH in 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 pH recorded at the outlet could be attributed to breakdown of organic matter inside the wetland by micro-organisms into simpler products like carbon dioxide and water. The micro-organisms use oxygen for decomposition and gives out carbon dioxide.

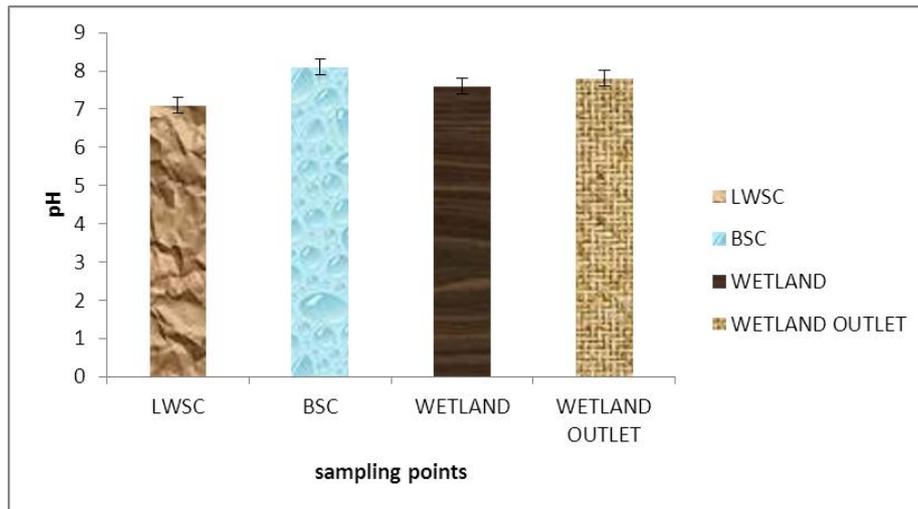


Fig. 4.1 : The mean values of pH recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

Conductivity

At LWSC conductivity was 845.6, at BSC 498.5, at the wetland 1344.0 and at the wetland outlet 717.3. Conductivity in waste water is attributed to the presence of negative and positive ions (Gosselink & Mitsch, 2000, Kumar & Chopra, 2012), the amount of total dissolved solids, total suspended solids and diatomic nitrates in water (Shama *et al.*, 2013). Decrease in the conductivity level after the wetland could be attributed to decrease in the concentration of TDS and TSS and the conversion of NO₃-N into diatomic molecular nitrogen (N₂) as the concentration of charged ions decreases.

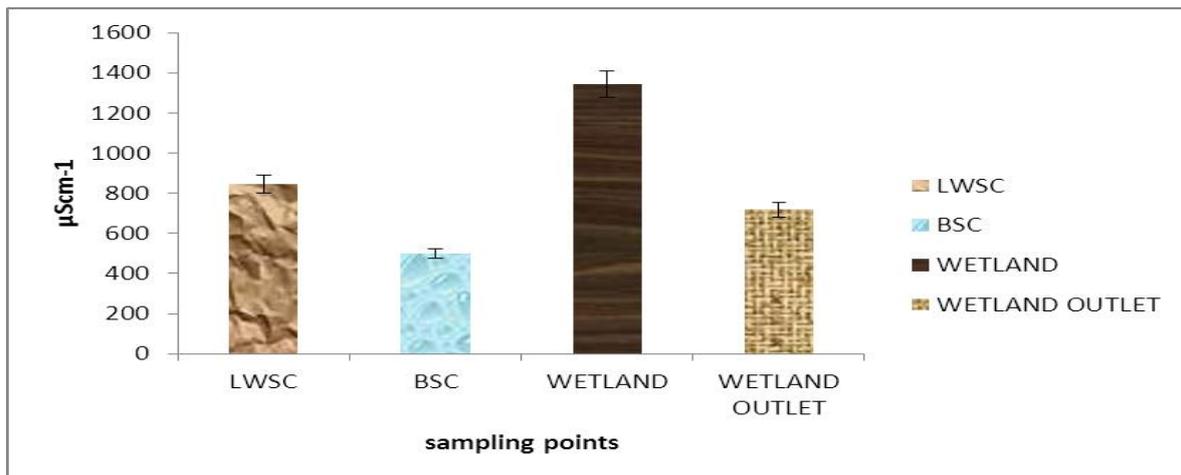


Fig. 4.2 :The mean values of electrical conductivity recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

Dissolved Oxygen

The DO at the LWSC was 0.0, 1.2 at BSC, 1.2 at the wetland and 1.9 at the wetland outlet. 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 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.

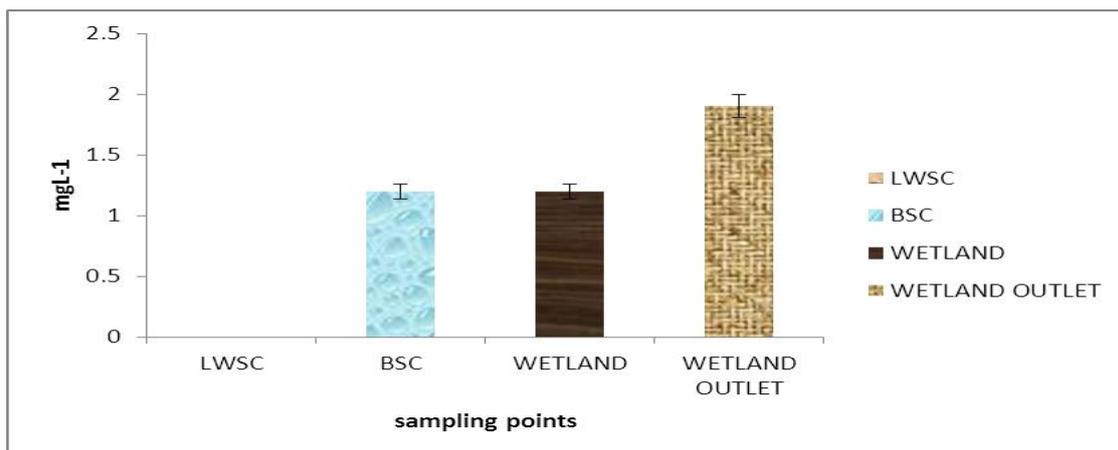


Fig. 4.3 :The mean values of DO concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

Temperature

At LWSC water temperature was 18.4 while at BSC it was 16.6, at the wetland 17.5 and 16.4 at the wetland outlet. 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). Low temperature at the outlet could be attributed to the shady effect of wetland vegetations and decreased organic matter concentration.

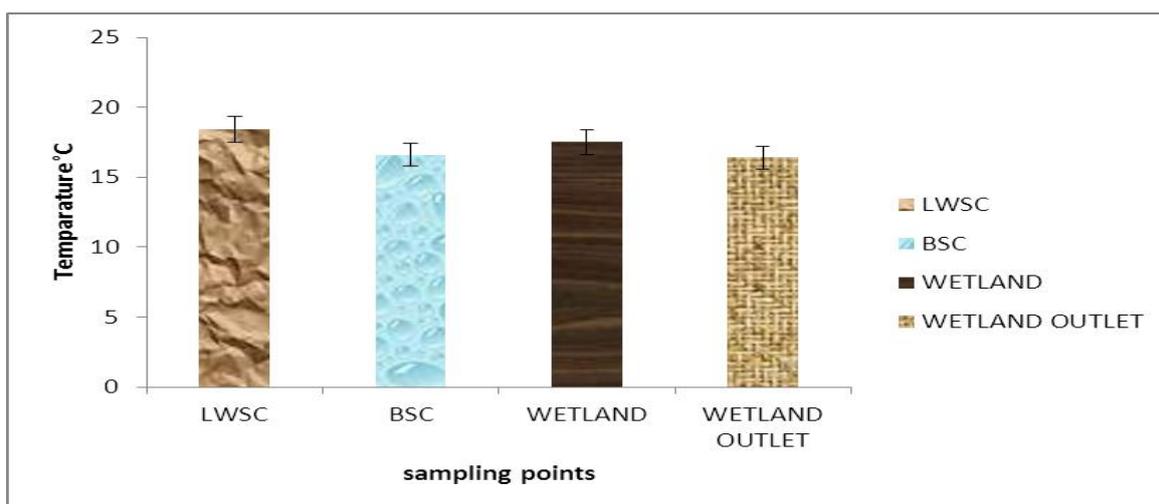


Fig. 4.4: The mean values of temperature recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

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 -N mgL ⁻¹	PO ₄ mgL ⁻¹	Cr ₃ mg L ⁻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	29.0	717.0	650.0	50.6	4.2	1.9	0.5
P value	0.020	0.004	0.030	0.009	0.006	0.001	0.005

Nitrate-Nitrogen

Nitrate-nitrogen in LWSC was 23.7, in BSC 13.2, in the wetland 39.2 while in the wetland outlet it was 4.2. Decrease in the concentration of nitrate-nitrogen can be as a result of 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). 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.

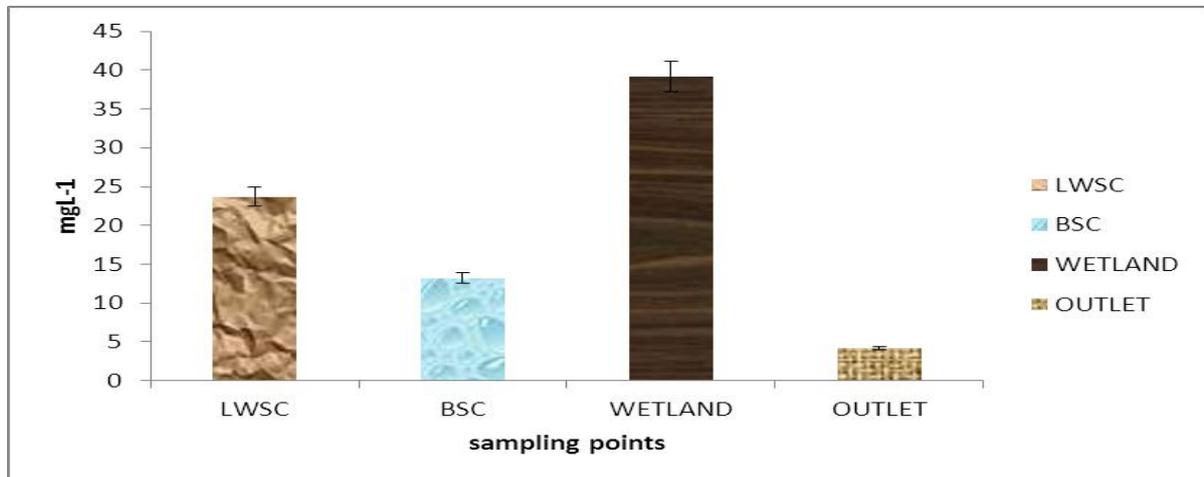


Fig. 4.5: The mean value of Nitrate-Nitrogen concentration recorded at LWSC, BSC, Joint and Outlet during the study period (November 2012 to February 2013).

Phosphate

At the LWSC phosphate concentration was 7.8, at BSC 6.5, at the wetland 12.6 while at the wetland outlet concentration was 1.8. Decrease in the concentration of phosphate could be due to 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). type of vegetation and catchment. physical, chemical and biological processes (Kadlec & Knight, 1996). Decrease could be attributed to plants uptake of the phosphate or some of it is deposited in the wetland bottom with sediments and adsorption.

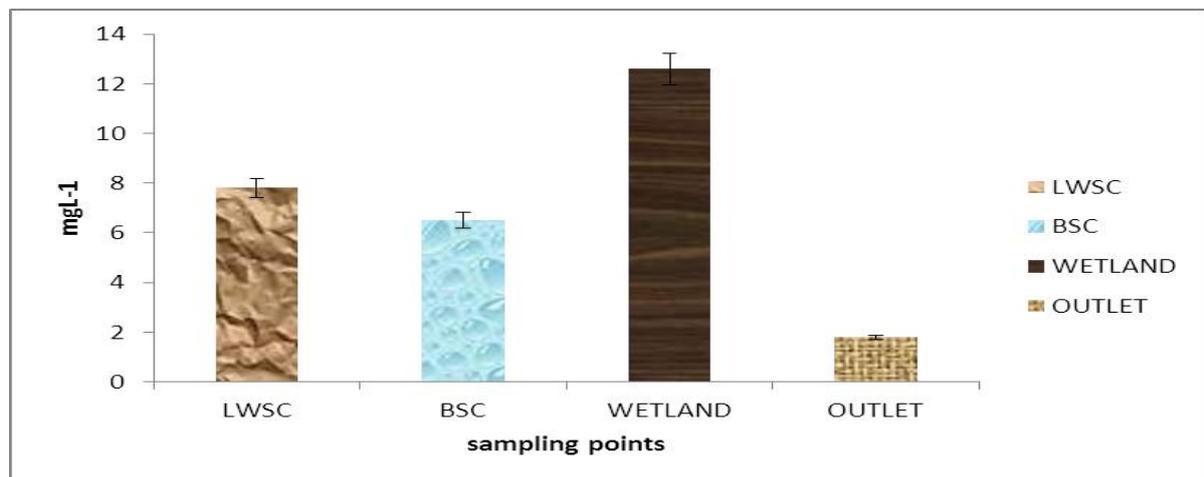


Fig. 4.6: The mean values of Phosphate concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

Biological Oxygen Demand

BOD concentration at LWSC was 873.4, 43.8 at BSC, 917.2 at the wetland and at the wetland outlet it was 38.9. Wetland vegetation, decomposing micro-organisms and temperature influence the BOD in a water body contributes to low BOD (Hemond & Bonoit, 1988, Steinmann *et al.*, 2003). The noteworthy reduction in BOD_5 concentration at the outlet can be attributed to biodegradation of the organic matter by microbial bacterias in the wetland. The trapping of particulate organic matter by wetland vegetation, might have also

contributed to decrease in BOD₅ concentration at the outlet as the organic matter settle as sediment off the water column.

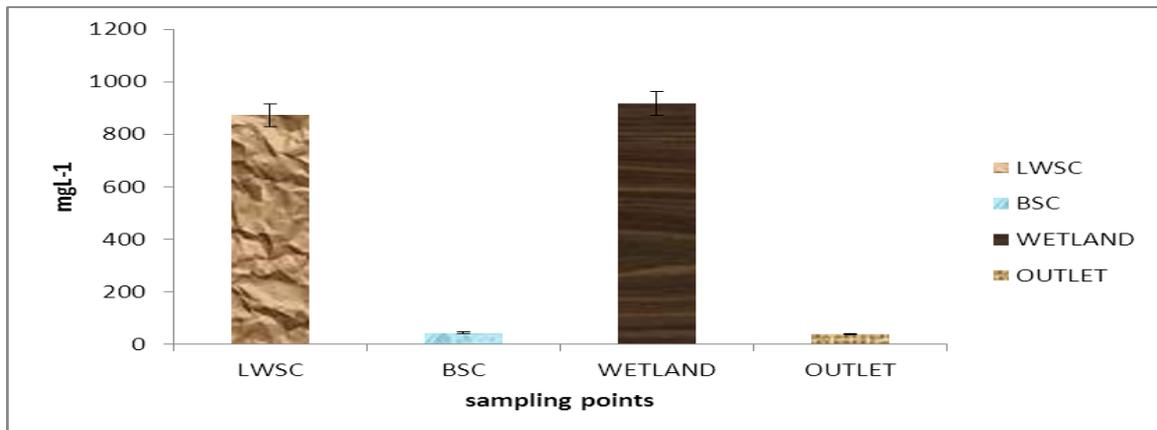


Fig. 4.7: The mean values of BOD concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

TSS

Concentration of TSS at LWSC was 4418.2, at BSC it was 599.1, at the wetland it was 5017.3 while at the wetland outlet it was 59.6. Low velocity coupled with the presence of the luxuriant vegetation and gravel substrate 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. The decrease in TSS concentration noted at the outlet can be attributed to the luxuriant vegetation at the wetland which reduces speed of the water flowing through the wetland hence causing most of the suspended solids to settle from within the water column.

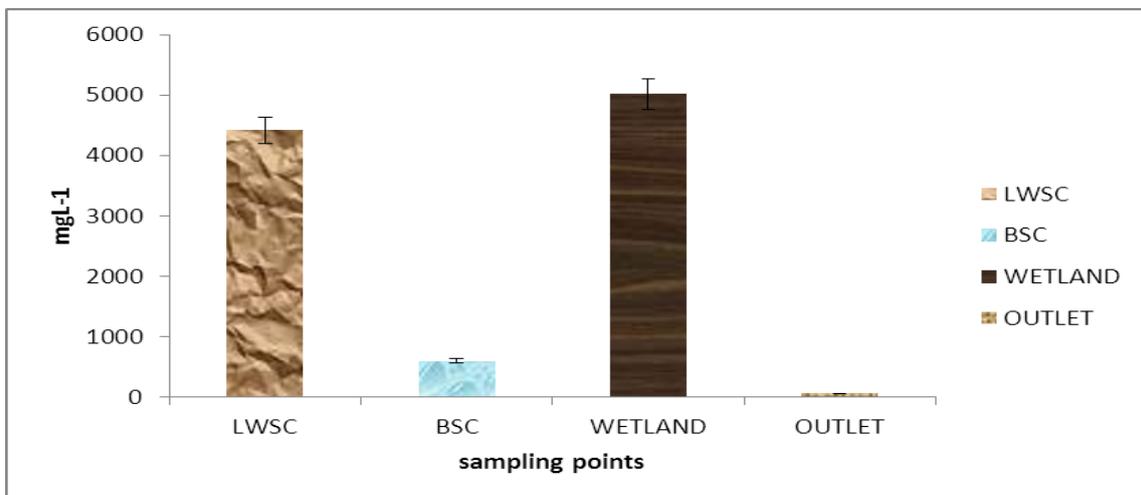


Fig. 4.8: The mean values of TSS recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

TDS

At LWSC TDS was 864.3, 387.5 at BSC, 1251.8 at the wetland and 659.9 at the wetland outlet. Variations in concentration of 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). 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.

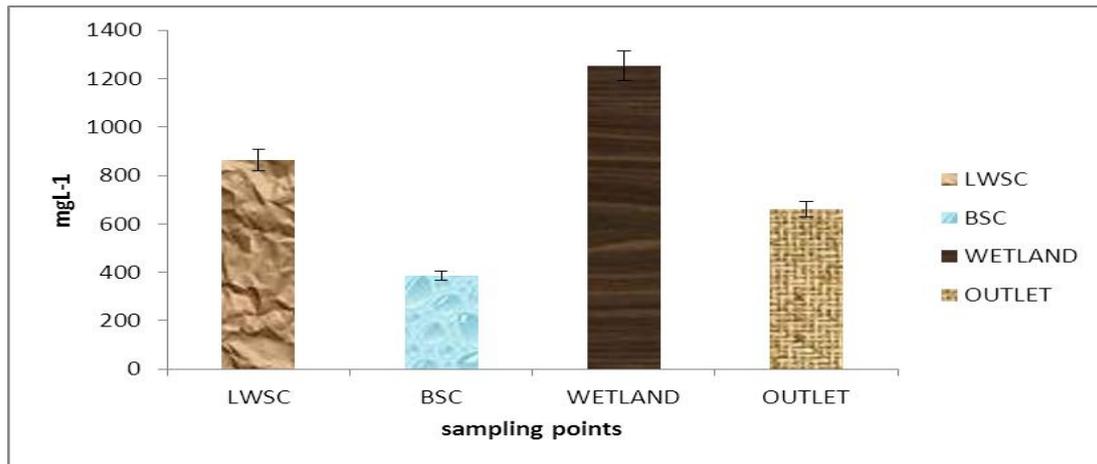


Fig. 4.9: The mean values of TDS concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

TS

TS at LWSC was 5282.3, 986.6 at BSC, 6269.0 at the wetland while at the wetland outlet TS was 717.0. Low velocity coupled with the presence of the luxuriant vegetation and gravel substrate contributes to reduction in TS (Kadlec & Knight, 1996). 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.

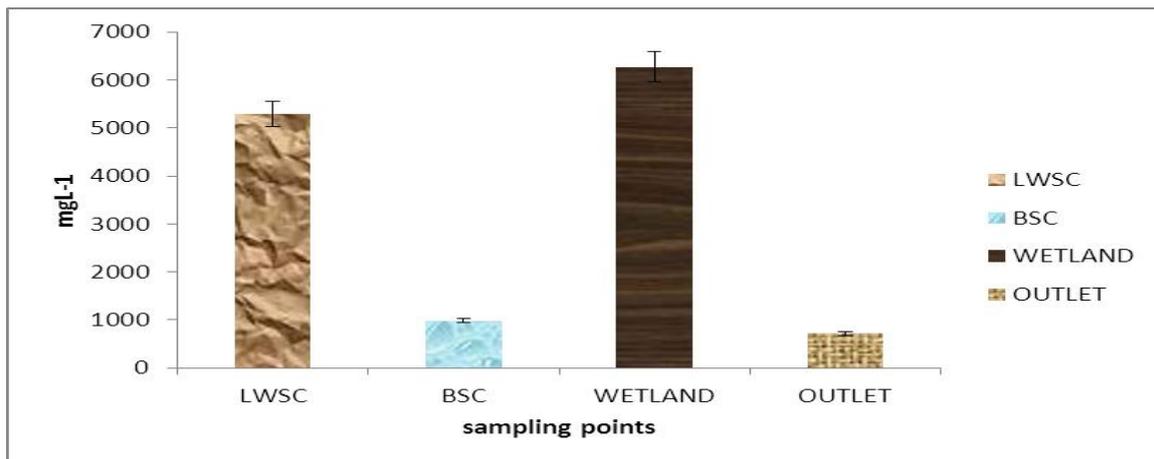


Fig. 4.9: The mean values of TS concentration values recorded at LWSC, BSC, Wetland and Outlet of the wetland during the study period (November 2012 to February 2013).

Chromium

Concentration of chromium at LWSC was 2.4, at BSC it was 4.8, at the wetland it was 8.0 while at the wetland outlet it was 0.5. Decrease in the concentration of chromium can be attributed to 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). 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.

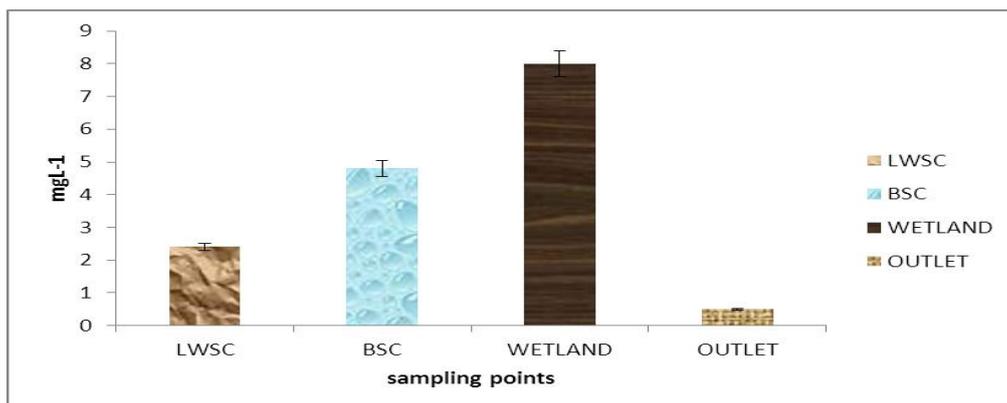


Fig. 4.10: The mean values of Chromium concentration recorded at LWSC, BSC, Wetland and Outlet of Tibia wetland during the study period (November 2012 to February 2013).

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).

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	5.5-9.0	6.5-8.5
Conductivity µScm ⁻¹ µS/cm	µScm ⁻¹	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	-	-
Temperature °C	°C	17.5	16.4	6.29	-	-

V. Conclusion

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 was 16.4°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).

Physico-chemical 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, it is concluded that Tibia wetland was effective in waste water treatment though its performance needs to be improved to meet the required standards.

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 where 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 100mgL^{-1} , 5.5 to 9.0, 2.0mgL^{-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 below the acceptable 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 38.9mgL^{-1} and 59.6mgL^{-1} while the maximum permissible limits are 30mgL^{-1} for both (Table. 4.3). 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.

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