EFFECT OF PAPYRUS (*Cyperus papyrus*) ON THE WATER QUALITY IN YALA SWAMP AND LAKE SARE, SIAYA COUNTY, KENYA.

BY

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DECLARATION

I, Violet Achieng Orodo, declare that the work presented in this thesis is my original work and has not been presented for the award of degree or diploma in any other University.

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DEDICATION

To my beloved husband Adongo S. Odongo ,my wonderful children Chelsea, Favour, Edger Davids and Amanda, my adorable dad Joshua Korodo as well as my loving mom Dorothy Korodo.

ABSTRACT

Access to safe water is a fundamental need and basic human right. Wetlands around the globe are being modified, reclaimed and overexploited due to high levels of resource consumption and land conversion that alter the quality of water. Yala swamp, the largest fresh water wetland in Kenya supports a large biodiversity and part of this wetland has been converted into large-scale agriculture resulting into a conflict and controversy amongst key stakeholders. The papyrus being destroyed to create room for agriculture are important because they help in adsorbing contaminants in their tissues, increasing the residence time of water and filter contaminants like heavy metals thus cleaning the water. Despite this role of papyrus in phytoremediation the information is limited, lacks supportive evidence and the empirical aspect on the levels of these pollutants in relation to the papyrus biomass is limited. The main objective of this study was to determine the effects of papyrus reeds on the water quality in Yala Swamp and Lake Sare. The specific objectives were to; determine the variation of physicochemical parameters (Temperature, Dissolved Oxygen (DO), pH, Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), Turbidity, Electrical conductivity (EC) and Total Dissolved Solids (TSS), investigate the levels of nitrate s and phosphates in water and sediments, examine the levels of heavy metals (Pb, Zn, Cu and Fe) in water and sediments and to analyze the bioaccumulation of these heavy metals in the tissues of papyrus in River Yala, Yala swamp and Lake Sare. The study adopted a longitudinal sectional design. Six sampling sites were selected where samples were collected in triplicates during the wet and dry seasons (May and September 2015 respectively). Data on physicochemical parameters were obtained *insitu* using a muiltimeter model (YSI 556 MPS Multimeter USA). Data on nitrates and phosphates were determined using Ultraviolet spectrometry and data on heavy metals determined by use of Atomic Absorption Spectrophotometer. Statistical analysis was done using SAS V9.0 software while levels of significance determined using one way ANOVA at $p \leq 0.05$ and Duncan Multiple Range test (DMRT) for separation of means. Student's t-test was used to determine the difference between the values in the dry and wet seasons. Mean temperature was 26.19 ± 0.71^0C, DO:3.72±1.02Mg/l, BOD:3.9±0.32Mg/l, pH:7.52±0.17, TDS:109±86.33, EC:173.26±13.8 µS/cm, TSS: 12.42±18.51 Mg/l and Turbidity: 12.29±10.03 NTU. The values varied significantly at $P<0.05$ among all the sites. The values for nitrates and phosphates also varied significantly in both water and sediments in all the sites at $P< 0.001$ but there was no significant difference in the values of phosphates in the two seasons (Student's t-test p=0.1772). The values for heavy metals; lead, copper, zinc and iron varied significantly among all the sites in water and sediments at $P< 0.001$. Similarly there was no significant difference in the values of the heavy metals in the two seasons (Student's t-test $P<0.05$). The sequence from highest was Fe > Pb > Zn > Cu. However, the values were above the guideline limits for drinking water and aquatic life as per NEMA and USEPA standards. The concentrations of all the heavy metals in sediments were higher in sediments than in water which confirmed the capacity of sediments to accumulate heavy metals compared to freely moving water bodies. The heavy metals were also determined in the tissue of papyrus i.e. the stems, flowers roots and rhizomes. The levels were higher in roots than stems and flowers except for Zn and Pb that were high in stems than roots. This is a further proof of confirmation of phytoremediation by the papyrus. The results show that papyrus is useful in biological monitoring of heavy metal contamination in water bodies. The study will assist in conservation of the papyrus to help phytoremediate pollutants from Dominion farms and the adjacent farms in order to have ecologically sound wetland.

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ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectroscopy
ANOVA	Analysis of Variance
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
LBDA	Lake Basin Development Authority
MCL	Maximum Contaminant Level
SPSS	Statistical Package for Social Science
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
KEBS	Kenya Bureau of Standards
WASREB	Water Services Regulatory Board
WHO	World Health Organization
NTU	Nephelometric Turbidity Units
US EPA	United States - Environmental Protection Agency
USA	United States of America
USEPA	United States - Environmental Protection Agency
UVS	Ultra Violet Spectrophotometry.
UNEP	United Nations Environmental Programme
FAO	Food and Agriculture Organization
LVEMP	Lake Victoria Environmental Management Programme
NEMC	National Environment Management Council
EU	European Nations

UK	United Kingdom
KWF	Kenya Wetland Forum

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OPERATIONAL DEFINATION OF TERMS

Water quality. The chemical, physical biological and radiological characteristics of water. A measure of condition of water relative requirements of one or more biotic species to any human need specification.

Wetland A distinct ecosystem that is flooded by water either permanently or seasonally where oxygen free processes prevails.

Aquatic Macrophytes. Aquatic plants that grow near or in water and is either emergent, submergent or floating.

Reclamation. The process of creating land from oceans, seas, swamps, riverbeds or lake beds

Phytoremediation. A bioremediation process that uses various types of plants to remove, transfer, stabilize or destroy contaminates in soil and ground water.

Phytoetraction. The uptake of heavy metals from substrate by plants using their roots. The heavy metals I soluble form are then translocated to other plant tissues for storage in plant parts that can be harvested like stems and leaves**.**

Pollutant. A substance or energy introduced into the environment that has undesired effects or adversely affects the usefulness of a resource.

Toxicity. A degree to which a chemical substance or mixture of substances tha can damage an organism.

Sedimentation. Tendency of particles in suspension to settle out of the fluid in which they are entrained and come to rest against a barrier.

Adsorption Adhesion of atoms ions or molecules from a gas liquid or dissolved solid to a surface.

Contamination presence of o constituent, impurity or some undesirable element that spoils, corrupts, infects, and makes unfit a material, physical body or natural environment.

Conservation preservation or efficient use of resources to prevent exploitation.

Purification process of removing undesirable chemicals, biological contaminants, suspended solids and gases from water to produce water fit for specific purposes.

Biomagnification any concentration of toxin such as pesticides in tissues of tolerant organisms at successively higher levels in a food chain or condition where chemical concentration in organisms exceeds the concentration of its food when major exposure rout occurs from the organism’s diet.

Ecosystem a community of living organisms in conjunction with non-living components interacting in a system through nutrient cycles and energy flows.

Denitrification.A microbial facilitated process where nitrate is reduced and ultimately produces molecular nitrogen through a series of intermediate gaseous nitrogen oxide products.

CHAPTER ONE

INTRODUCTION

1.1 Background information to the study

1.1.1. Water and wetlands

Access to safe water is a fundamental need and basic human right (WHO, 2000). It is important to constantly protect and control the quality of water. For example, in Africa fresh water quality is a major concern WHO, (2000); Mamba *et al*., (2009) and Lobanga *et al*., (2009). Agriculture is the single largest user of freshwater on a global basis and a major cause of degradation of surface and groundwater resources through erosion and chemical runoff (Anyona *et al.,* 2014; FAO, 1993).

Wetlands around the globe are being modified, reclaimed and overexploited due to high levels of resource consumption, land conversion or upstream developments that alter the quality and flow of water that feeds into them (WHO, 2000). Decision makers often have little understanding of the economic value of wetlands because wetlands are often perceived as having little or no value compared with uses that yield more visible and immediate economic benefits (Schuyt and Brander, 2004). In the United States, 87 million hectares (54%) of original wetlands (Tiner, 1984) have been converted, primarily for agriculture. In Portugal, 70% of the Algarve region has been converted for agriculture and industrial development (Pullan, 1988). An *et al.* (2007) indicate that land reclamation has so far taken the largest role in wetland loss, estimated at 82% of all the land loss in China. The Sanjiang Plain of Northeast China presents an example of China's wetland loss due to reclamation.

The largest wetlands in the African continent include the Okavango Delta in Botswana, the Sudd in the Upper Nile, the wetlands of Lake Victoria and Lake Chad and the floodplains and deltas of the Congo, Niger and Zambezi Rivers (UNEP, 2000). Despite their importance of purifying water, African wetlands are being modified or reclaimed; their resources are over exploited and converted to other uses or upstream developments that alter the magnitude, timing and quality of River water feeding the wetlands. The forces are so intense that many wetlands such as Nakivubo Wetland in Uganda and Yala Swamp in Kenya have previously been reported to be heavily degraded (Abila, 2002). Geita wetland in Uganda has been converted to rice fields where accidental release of agrochemicals is common (Fredrick *et al*., 2011) The need to determine the extent of degradation and further illustration of scientific knowledge on the role of papyrus in sustaining the Yala swamp ecosystem integrity highlight the need for a study to provide scientific support to management and conservation strategy in River Yala and Lake Sare.

1.1.2. Activities in Yala swamp

The Dominion Company, a subsidiary of Dominion Group of Companies based in Edmond, Oklahoma USA, moved into the Yala Swamp in 2003 through an arrangement with the Lake Basin Development Authority (LBDA) (Simonit and Perrings, 2004). The initial proposal was that Dominion would engage in rice production, in a section of the swamp known as Area I, covering about 2,300 ha. This land portion had been reclaimed in the 1970's and used by the LBDA for agricultural activities, mainly to produce cereals, pulses and horticultural crops. An environmental impact assessment (EIA) was commissioned for large-scale rice production, for which a license was issued in 2004, specifically for the rice irrigation (KWF, 2006). Instead of the originally intended rice cultivation in the 2,300 ha once owned by the LBDA, Dominion Farms Limited embarked on other additional agricultural and development activities in the swamp such as construction of irrigation dykes and weirs, water-drilling, construction of an airstrip, fish farming and sugarcane farming among others (KWF, 2006).

For such activities to take place the papyrus plants have to be cut to create room which leaves the area unprotected. This destruction of natural habitat reduces vegetation cover exposing soils to both wind and water erosion worsening the degradation problem. The near annual flash floods in Budalangi and Kano plains have been linked to such forces emanating from point and non-point processes (Gichuki, 2003). The locals also burn the reeds during land preparation; this could be increasing carbon load which may have effects on the water pH and soil, with similar repercussions on living organisms. The empirical information on how destruction of papyrus affect the physicochemical parameters (temperature, dissolved oxygen, pH, and conductivity, dissolved and suspended solids, turbidity and biological oxygen demand) in the Yala Swamp needs further investigation. Furthermore, several studies on water quality have focused mainly on the physico-chemical characteristics of water but not on the interrelationship of these parameters and phytoremediation of papyrus on improved water quality. Therefore the study determined the levels of these physicochemical parameters whose findings will help to determine the extent of compromise to the Yala Swamp water quality and help policy makers on the relevant action to take.

1.1.3. Heavy metals and other pollutants

Associated agro food-processing industry is also a significant source of organic pollution in most countries (FAO, 1993). Aquaculture is now recognized as a major problem in freshwater, estuarine and coastal environments, leading to eutrophication and ecosystem damage (FAO, 1993). The fish feeds and fish processing effluents get into the waters and cause contamination of the waters as is the case in Yala Swamp from Dominion farms. The pesticides, herbicides and fertilizers used in the farms contributed to high levels of nitrates and phosphates that lead to eutrophication (Di and Cameron, 2002). Case studies have illustrated important highlights on the effect of organic pollutants from industries, pesticides, herbicides and fertilizers on the levels of nutrients (phosphates and nitrates). However they have not specifically touched on the role the papyrus vegetation play in removing organic compounds and excess nutrients of phosphorus and nitrogen. Additionally there is no empirical information on the levels of these nutrients in relation to the papyrus biomass available in the area of study of Yala Swamp. The earlier studies could not clearly link the levels of such nutrients in the waters and sediments of Yala Swamp to the papyrus reeds in the study area. Thus the study was carried out to determine the levels of these nutrients in the waters and sediments of Yala Swamp and determine the role of papyrus reeds in controlling their levels in the study area. The findings will guide the sub county policy makers of the study area in regulation of the levels of the pollutants that lead to increased levels of nutrients in the waters and sediments.

The fate of other organic particles which arises from small scale industries in the area is unknown both in plant tissues and water, even as it is well known that fertilizers used in the farms contain certain levels of heavy metals e.g. cadmium (Farr, 2004), whose effects on human and animals health are devastating and have been associated with kidney and liver damages, and methemoglobinemia in infants. The pesticides, herbicides, fuel and other chemicals used in the farms may also contain some levels of lead (Sharma and Dubey, 2005) which is highly carcinogenic. This may contribute immensely to water pollution of the Yala Swamp and Lake Sare.

1.1.4. Role of aquatic macrophytes and *Cyperus papyrus*

Aquatic plants have been used frequently to remove suspended solids, nutrients, heavy metals, toxic organics and bacteria from acid mine drainage, agricultural landfill and urban storm-water runoff. Phytoremediation involves the use of plants for environmental cleanup (Prasad, 2007) and has been known to immobilize, destroy or extract contaminants from soil and polluted water. Wetlands increase the residence time or reduce velocity of water and thereby increase the sedimentation of particles and associated pollutants (Mitch and Gosselink, 1993). Thus, they are indirectly involved in water cleaning. Papyrus occurs naturally in tropical and subtropical areas from sea level up to 2500 m altitude, in swamps and along margins of Lakes and Rivers (Popay, 2014 and Voughan, 2011). Papyrus is a stout, aquatic perennial rhizomatous sedge that grows up to 3.5 m in height. The roots are tough and able to extend 1 m or more with numerous rootlets. Papyrus culms are erect and roundly trigonomous, smooth and 15-45 mm in diameter, photosynthetic, contain a solid pith and white light brown in colour. The leaves are alternate, have reduced sheathing and reddish blackish brown in colour when young. The inflorescence looks like an umbel, hemispherical when young. The can be browsed or cut for livestock feeding, used to make furniture, mats, baskets, handicrafts, roofing material and boat construction (Rooney 2013 and Jones *et al.*, 2018)

Plants also add oxygen, providing a physical site of microbial attachment to the roots generating positive conditions for microbes and bioremediation. In Yala swamp there is lack of scientific information relating the role of papyrus to its water cleaning role.

For efficient removal of pollutants, a high biomass per volume of water of the submerged plants is necessary. According to Kaldec, (1995), uptake of metals in emergent plants only accounts for 5 % or less of the total removal capacity in wetlands. In Microcosms wetland, a higher concentration of metals has been found in submerged than emerged plants, the removal by *Elodea canadensis* and *Potamogeton natans* showed a 69 % removal of Zn (Kadlec, (1995); Kadlec and Knight, 1996). This shows that the accumulation of the heavy metals is bound to vary in the various parts of the plants such as roots, stems or leaves. The papyrus vegetation has been shown to play part in phytoremediation by removing heavy metals (Sekomo, 2012 and Okurut, 2000). However, the role that the papyrus reeds of Yala Swamp and Lake Sare play in phytoremediation and hence improvement of water quality of the swamp and Lake Sare has limited supportive evidence in terms of documentation. For this reason this study was necessary in order to add information to the available knowledge and emphasize the importance of the papyrus plants.

A study by Kiwango and Wolanski, (2008) reported that the future of Lake Victoria and welfare of its human population are highly related to future of its papyrus wetlands. They speculated the papyrus plants have the potential to cleanse the water by trapping of domestic wastes without any analytical tests. In Yala Swamp the many contaminants that get into the waters, could be phytoremediated by the papyrus plants through adsorption as well. It has been confirmed that phytoremediation using papyrus could be the easiest biological, low-cost and environmental friendly clean-up technology which can be exploited for local set up on heavy metal removal (Claudia *et al*., 2008). This study has examined the water quality in terms of the physico-chemical parameters, nutrients levels and heavy metal levels before it gets within the papyrus swamp and after it has left the papyrus to confirm that they actually help in improving the water quality in the study area. It has further looked at the accumulated levels of the heavy metals within the tissues in the stems, leaves, flowers and roots of the papyrus. Although naturally occurring wetlands have always served as ecological buffers (Kaldec *et al*., 2000, Kaldec and Knight 1996 and Vyamal *et al*., 1998), research and development of wetland treatment technology is a relatively a recent phenomenon. Moreover, little is known about the physico-chemical and biological principles and mechanisms underlying their ecological functioning. The findings would help to emphasize on the need to conserve the papyrus reeds and hence help the policy makers in the sub county to minimize its exploitation.

1.1.5. Lake Sare

Lake Sare lies within the greater Yala swamp complex and together with Lake Kanyaboli and Lake Namboyo and the surrounding Yala swamp wetland in western Kenya have been recognized as important biodiversity hotspots (Maithya, 1988). Recent population genetic and phylogenetic studies by Abila *et al*., 2004 confirm the evolutionary importance Lake Sare in preserving the cichlid fish fauna of Lake Victoria. Lake Sare has a unique advantage of having a direct link with Lake Victoria. The lake and adjoining swamp play a critical role in the livelihood of the local communities, who heavily depend on the adjoining wetland resource. Lake Sare is a high priority ecological site for conservation and management of the resources of Lake Victoria basin. Fish populations stocked in the Lake Sare are likely to find their way to Lake Victoria. In view of this the lake can be used as a launch site for restocking Lake Victoria with juveniles of endangered fish species (Gichuki *et al*., 2005). The fact it has a direct link to Lake Victoria make it a good site to trace the movement of contaminants from River Yala to Yala Swamp to lake Sare and finally to Lake Victoria.

1.2 Problem statement

Aquatic ecosystems play a vital role in sustenance of aquatic life and human needs, and any changes in their environmental quality may have a devastating effect on the ecology and society in general. Increase in population and industrialization in Kenya have resulted to conversion of wetlands into settlement and industrial occupation. In addition, climate change has caused food shortages making the Government of Kenya and private companies to look for additional farm lands through reclamation of initially swampy land. Dominion farm is an example of such a company and is involved in large scale production of rice, maize, soya beans, bananas, fish and sugarcane via irrigation using water from River Yala. Cultivation of these crops involves the use of heavy machinery, fertilizers, fumigants, pesticides and acaricides. Some of the chemicals increase the level of nutrients (nitrates and phosphates) in the waters and sediments. A study by Fredrick *et al*., (2011) indicated that Dominion Farms was undertaking intensive agricultural activities with devastating impacts on the swamp and related lakes. Most of the chemicals contain heavy metals as additives or impurities which could affect the water quality of the Swamp, Lake Sare and eventually Lake Victoria. Heavy metals such as copper and lead are dangerous to living organisms, even in trace levels when ingested in elemental forms or as soluble compounds. For instance, lead affects the brain development of infants and contributes to loss of memories at old age while cadmium may result to kidney, liver and borne malformations. The papyrus plants have been destroyed by Dominion farms to increase acreage of land for agriculture, the local communities use the papyrus plants for weaving mats, baskets, coffins and for thatching huts yet they are important for cleaning the water.

Although studies have been conducted on the water quality of Lakes Kanyaboli and Namboyo which are also part of Yala Swamp ecosystem, information on the effect of papyrus plants on improving water quality of Lake Sare is limited. Such studies have been done by Romulus *et al* (2008), Anyona, (1997)) and scientific data is lacking on physicochemical parameters, nutrient levels and heavy metal levels in water, sediments in order to establish the phytoremediation role of papyrus plants. Further the water quality parameters that have been compromised for mitigation measures is still not known. Hitherto this study the levels of pollutants specifically nitrates, phosphates, and heavy metals (lead, zinc, copper and iron) in the papyrus wetland in River Yala and Lake Sare in conjunction with physico-chemical parameters of the waters has not been well documented.

1.3 Objectives.

The main objective of the study was to investigate the effect of papyrus plants on the water quality in Yala swamp and Lake Sare in Siaya County, Western Kenya.

Specific objectives

The specific objectives of this study are:

1. To determine the variation of physicochemical parameters in water from River Yala, Yala Swamp and Lake Sare in the dry and wet seasons.
2. To investigate the levels of nitrates and phosphates in water and sediments from River Yala, Yala Swamp and Lake Sare in the dry and wet seasons.
3. To examine the levels of lead, zinc, iron and copper in the water and sediments from River Yala, Yala Swamp and Lake Sare in the dry and wet seasons.
4. To analyze the extend of seasonal bioaccumulation of lead, zinc, copper and iron in the flowers, leaves and roots of papyrus plants in Yala Swamp.

1.4 Research hypotheses.

H_o1: There is no significant difference in the physic- chemical parameters of water in River Yala, Yala Swamp and Lake Sare.

H_o2: There is no significant difference in the levels on nitrates and phosphates in the water and sediments of River Yala, Yala Swamp and Lake Sare.

H_o3: There is no significant difference in the levels of lead, cadmium, zinc, copper and iron in the water and sediments of River Yala, Yala Swamp and Lake Sare.

H_o4: The flowers, leaves and roots of papyrus plants do not accumulate significant amounts of lead, cadmium, zinc, copper and iron.

1.5. Justification of the Study

The contamination of the environment with toxic metals has become a worldwide problem, affecting crop yields, soil biomass and fertility, contributing to the bioaccumulation and bio magnifications in the chain (Prasad 2007). Most of the measures currently being taken are very expensive and sometimes they are done after a lot of damage to the ecosystem has occurred including loss of lives due to pollution and other sources. As an alternative, an ecological technological approach has been developed involving the use of plants to clean up or remediate soils contaminated with toxic metals (Prasad 2007), this can be extended to cleaning of swamps, rivers and lakes of Africa and beyond.

Natural purification that is done by the papyrus plants in the swamps surrounding Lake Sare would be of little costs, energy and the level of purification would be much higher than that done either chemically or physically. This would also help in the maintenance of the ecosystems including increase in the number of fish species in Lake Sare compared to those found in the adjacent already polluted Lake Victoria. The remediation of contaminated water containing heavy metals has assumed great relevance in the last decades. Unlike organic pollutants, metals do not undergo degradation and generally need to be removed through highly expensive clean-up methods. The wetland being a contested resource with multiple users who claim to stake on it, it requires holistic approach in its management that caters for divergent needs and views of key stake holders. As an alternative, phytoremediation is a biological and environmental friendly clean-up method, which can be exploited for heavy metal removal (Claudia Bragato *et al*., 2008). Increasing public and regulatory acceptance are likely to extend the use of phytoremediation beyond current applications (Ensley, 2000; Tucker and Shaw, 2000).

For these reasons, this study seeks to determine the role of papyrus reeds in phytoremediation of Yala Swamp and Lake Sare. The result may be used as a basis for control of the pollutants that find their way into fresh water bodies. It will also be used to educate the people on the need to conserve the papyrus reeds. Farmers will be advised on the need to regulate the use of pesticides and fertilizers which may accumulate to levels that may not be remediated by the papyrus reeds.

1.6 Scope and Limitations of the Study

The study involved the analysis of physico-chemical parameters, nutrient levels (nitrates and phosphates) and levels of selected heavy metals (lead, cadmium, zinc, copper and iron) in water from River Yala, Yala Swamp and Lake Sare during dry and wet seasons. The levels of these metals were also be analyzed in sediments from River Yala, Yala Swamp and Lake Sare and in different parts (roots, leaves and stems) of papyrus reeds surrounding the Yala Swamp. There were a number of challenges in the study including difficulty in navigation within the swamp, difficulty in collecting sediment samples in mid Lake Sare ,conducive weather especially during the wet season and unavailability of UVS and AAS analysis machines in the university which forced me to seek them outside at very high costs.

CHAPTER TWO

LITERATURE REVIEW

This section gives an overview of existing information relevant to the topic under study and also seeks to identify gaps in knowledge that need attention or further research. It gives an overview of the physiochemical parameters under study that affect water quality and highlights the effects of nitrates and phosphates levels on water quality. Further it outlines the heavy metals under study and effects of their levels in water and sediments on water quality. In addition it analyzes the accumulation of the heavy metals in the tissues of papyrus reeds which brings about phytoremediation including phytoextraction and rhizofiltration. Finally conceptual framework guiding this study is described.

2.1.0 Physico-Chemical Parameters of water that affect water quality.

Physico-chemical parameters are key indicators used in evaluating environmental fate specifically used to determine the phase equilibrium distribution of a substance in a closed system (Domenech *et al*., 2006). These are some of the variables known to represent general water quality according to the monitoring requirements for domestic and industrial wastewater release. They include turbidity, pH, salinity, temperature, total solids, dissolved oxygen concentration and electrical conductivity. These parameters have been discussed in the following sub-sections.

2.1.1 Electrical Conductivity

Electrical conductivity (EC) is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations (Brian *et al.*, 2001). Electrical conductivity is a measure of the dissolved ionic component in water and in most fresh waters ranges between 50-500 µS/cm (Yilmaz and Koc 2014). The values of highly mineralized waters go up to 100 µS/cm and even higher for some industrial waters that may be in excess of 10,000 µS/cm (WHO, 2004). Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity measurements are reported as conductivity at 25 ^{o}C.

The ideal EC range for Hydroponics is between 1.5 to 2.5 ds/m and higher EC hinders nutrient absorption due to increase in osmotic pressure whereas lower EC may severely affect plant health and yield (Samarakoon *et al*., 2006). These findings from studies indicate that Papyrus plants could also help in regulating EC by absorbing and adsorbing some of the ions and cations for a cleaner environment. However they have not outlined what happens to the EC levels when the papyrus is destroyed and the levels of pollutants increase like what is happening currently in the study area. This necessitates this study and the results would help to inform policy. From literature, studies conducted in the study area e.g. by Gichuki *et al*., (2005) and Abila, (2003) on EC were done before massive reclamation activities taking place currently.

Comparing the results on EC considering the reclamation activities going on now would bring a clear picture of current status of the area and inform policy accordingly.

2.1.2 pH

The term pH is used to indicate the alkalinity or acidity of a substance as ranked on a scale from 1.0 to 14.0. The pH of water affects many chemical and biological processes in water (Brian *et al*., 2001). Different organisms flourish within different ranges of pH and Dida *et al.*, (2015), identified the pH range that is not directly lethal to freshwater organisms as 5.0-9.0 with few exceptions. When the pH is outside this range, diversity within the water body may decrease due to physiological stresses and reduced reproduction. Low pH can also allow toxic elements and compounds to become more mobile and available for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly to sensitive species.

Nevertheless, the primary productivity of freshwater aquatic ecosystems is reduced considerably below pH 5.0, which, in turn, reduces the food supply for higher organisms. Hence, organisms that remain present would likely experience reduced numbers and/or growth rates (Dida *et al.*, 2015). A pH range of 6.0 to 9.0 appears to provide protection for the life of macro invertebrates in fresh water systems. With regards to fish, most resistant fish species can tolerate pH ranges from 4.0-10.0 (Alabaster and Lloyd, 1980). However, at the extremes, fish eggs may hatch, but young ones produced are often deformed (Brian *et al*., 2001). A study conducted in Navikubo wetland in Uganda dominated by papyrus plants showed that the pH was slightly acidic (6.6-6.8) probably due to decomposition of waste products and components trapped in the roots sedge plants as well as decomposing plant materials (Joseph *et al*.,2003). A similar study conducted in Nyaruzinga wetland dominated by papyrus reeds in Rwanda had a pH range of 6.5 to 8.3 (Safari *et al*., 2012). Papyrus are known to help in correcting the pH especially in areas with a lot of pollutants that affect pH by adsorbing them and facilitating their breakdown hence it is important to study their levels. These findings above have illustrated important highlights regarding how papyrus plants help in correcting pH in wetlands. However the studies have failed to explain what happens to the levels of pH when the papyruses are destroyed. With the vigorous agricultural activities taking place in the Yala Swamp and papyrus plants destruction this study was necessitated to find out the effects and the results that would help the county policy makers in making decisions.

2.1.3 Turbidity

This constitutes total solids which are dissolved solids plus suspended and settleable solids in water. In stream water, dissolved solids consist of calcium, chloride, nitrate, phosphorus, iron, sulfur, other ions, and particles that will pass through a filter with pores of approximately 2 microns (0.002 cm) in size (Brian *et al*., 2001). Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. Turbidity is caused by presence of suspended matter in a liquid (Willar *et al*., 1992). It is measured in Nephelometric Units (NTU), in drinking water. Particulate matter that creates turbidity can contain toxins that harbor micro-organisms and interfere with disinfection (Matsumura *et al*., 2005). Suspended solids can serve as carriers for organic compounds. This is particularly of concern where the more water-insoluble pesticides are being used on irrigated crops. Turbidity also affects water clarity which decreases the passage of light through water, thereby slowing photosynthesis of submerged aquatic plants. Water also heats up more rapidly and holds more heat as total dissolved solids increase. This, in turn, may adversely affect aquatic life that has adapted to a lower or higher temperature regime (Brian *et al*., 2001). Both WHO (1998) and KEBS (1996) recommend turbidity of not more than 5 NTU in drinking water. A study conducted in Chemelil constructed wetland in Kenya in the year 2003 for a period of three months showed that there was a 96.4% reduction in TSS from 1.10 mg/l to 0.04 mg/l (Oketch, 2002). The wetland is dominated by papyrus reeds which suggest their efficiency in reducing turbidity. A similar study conducted in Splash constructed wetland in Nairobi Kenya in the year 1996 also dominated by papyrus plants and phragmites indicated a 97.6% reduction turbidity from 195.4 mg/l to 4.7 mg/l (Oketch, 2002). These studies by Oketch, 2002 have highlighted the importance of papyrus plants in reducing turbidity levels in wetlands. However they have failed to explain what happens to turbidity levels when papyrus reeds are destroyed leading to reduction in their numbers. This is necessary considering the many changes taking place within Yala Swamp to increase land acreage which leads to papyrus destruction. Since papyrus plants help in filtering sediments and pollutants it was important to examine the levels of turbidity of Yala Swamp and Lake Sare in order to inform policy.

2.1.4 Biological Oxygen Demand

This is the amount of oxygen consumed by micro-organisms in breaking down the wastes. BOD also measures the chemical oxidation of inorganic matter. Storm water runoff can contribute large amounts of BOD to surface water systems. BOD is the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials (Patil and Deshumkh, 2012). It is a key indicator of the environmental health of a surface water supply commonly used in waste water treatment. BOD directly affects the amount of dissolved oxygen in surface waters. The greater the BOD, the more rapidly oxygen is depleted, resulting in less oxygen available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die (Brian *et al*., 2001). High nutrient concentration in this effluent also contributes to algal blooms promoting eutrophication of surface waters (Matsumura *et al.*, 2005). Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food processing plants; failing septic systems; and urban storm water runoff. BOD is affected by the same factors that affect dissolved oxygen (Brian *et al*., 2001). The maximum allowable level of BOD is 30p.p.m. (EMCA, 2006). These findings have highlighted the importance of papyrus plants in improving the levels of BOD for a better environment. They have shown that papyrus are believed to give time for pollutants to decompose by increasing the residence time of water which directly affects the levels of BOD as the water leaves the Swamp. However they have not explained what happens to these levels when the papyruses in these wetlands are destroyed. It is justifiable to study the levels of BOD in Yala Swamp considering the immense agricultural activities taking place that would introduce pollutants to the study area not forgetting the destruction of the papyrus reeds.

2.1.5 Dissolved Oxygen

Oxygen is measured in its dissolved form as dissolved oxygen (DO). If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may move away, weaken, or die. Dissolved oxygen levels fluctuate seasonally, daily, and with water temperature since cold water hold more oxygen than warm water (Brian *et al*., 2001). Aquatic animals are most vulnerable to lowered DO levels in the early morning on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset. Water discharge high in organic matter and nutrients can lead to decrease in DO concentration as a result of increased microbial activity occurring during the degradation of organic matter. Concentrations of D.O in unpolluted waters are usually close to but less than 10 Mg/l (Chapman and Kimstach, 1992).

Adequate dissolved oxygen is necessary for good water quality. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 Mg/L, many forms of aquatic life are put under stress. The lower the DO concentration, the greater the stresses. Oxygen levels that remain below 1 Mg/L for several hours can result in large fish kills (Brian *et al*., 2001). Total dissolved gas concentrations in water should not exceed 110 percent. Concentrations above this level can be harmful to aquatic life. Fish in waters containing excessive dissolved gases may suffer from gas bubble disease where the bubbles (emboli) block the flow of blood through blood vessels causing tissue rapture. Aquatic invertebrates are also affected by gas bubble disease but at levels higher than those lethal to fish (Brian *et al*., 2001).

Dissolved oxygen levels below 5 mg/l may adversely affect the functioning and survival of biological communities and below 2 mg/l may lead to death of most fish (Chapman and Kimstach, 1992). These facts have highlighted the importance of the right DO levels for survival of living organisms. The large masses of papyrus plants in Yala Swamp could be promoting high DO levels but it is not known if high levels of pollutants from agricultural activities especially nitrates getting in may interfere with the DO levels. This study is thus necessary to determine this in order to inform policy.

2.1.6. Temperature

It is the basic environmental factor that affects chemical and biological reactions in water and it affects the biological, chemical and physical activities of water (Yilmaz and Koc, 2014). Water temperature is a regular factor for variations in physico-chemical and biological activities i.e. ecosystems which fluctuates markedly with variations in air temperature (Sharma and Kumar, 2002). In general atmospheric and water temperature depend on geographical location and meteorological conditions such as rainfall, humidity, cloud cover, wind velocity etc. Since temperature affects the rate at which chemical and biological reactions occur some of which affect physico chemical parameters, this study is necessary to find out if the papyrus reeds play a role in regulating temperature in Yala Swamp. This will help to inform policy makers and emphasize the importance of conserving the papyrus reeds.

2.2. Nutrients (nitrates and phosphates)

Nutrients chiefly nitrogen, potassium and phosphorus promote plant growth (USEPA, 1998). Nutrients can enter the water sources through runoff, leaching or irrigation water. When they are in excess they cause environmental pollution with effects as will be discussed in this section.

2.2.1 Nitrates

Inorganic nitrogen may exist in the Free State as a gas (N_2), or as nitrate (NO_3^-), nitrite (NO_2^-), or ammonia (NH_3^+). Organic nitrogen is found in proteins and is continually recycled by plants and animals. High nutrient content such as nitrates pollution in drinking water is harmful to human and other animals (Carpenter, 1998). Nitrate reactions in water can cause oxygen depletion. Thus aquatic organisms depending on the supply of oxygen in the stream may be at risk. Bacteria in water quickly convert NO_2^- to NO_3^-. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream (Matsumura *et al.,* 2005). This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 Mg/l or higher) under certain conditions. Nitrites can produce a serious condition in fish called "brown-blood disease" (Brian *et al.,* 2001*).*

High concentration of nitrates can interfere with oxygen transport in the blood of infants younger than one year causing blue baby syndrome, methemoglobinemia which is known to cause brain damage (Di and Cameron, 2002). Children should not be allowed to drink water that exceeds 10 mg/l No_3-N. Pregnant women, adults with reduced acidity and people deficient in enzyme that changes methemoglobia back to hemoglobin are susceptible to Nitrite induced methemoglobinemia. Symptoms include bluish colour around the eyes and mouth, headache, dizziness and difficulty in breathing (Self and Waskom, 2008).

Decomposition of the organic matter lowers the dissolved oxygen level, which in turn slows the rate at which ammonia is oxidized to NO_2^- and then to NO_3^-. Under such circumstances, it might be necessary to also monitor for nitrites or ammonia, which are considerably more toxic to aquatic life than nitrate (Brian *et al*., 2001). In Navikubo wetland in Uganda a study conducted showed markedly higher nutrient removal efficiencies with higher N and P levels in plant tissues (Joseph *et al.*, 2003). While beneficial as a plant nutrient, nitrate may indicate contamination from excessive use of fertilizers or from sewage. In Yala Swamp from the immense agricultural activities from Dominion farms may that introduce nitrates from fertilizers and other wastes which warrant investigation. These findings have indicated the effects of excess nitrates to the environment some of which are highly detrimental. Studies have also indicated that nitrogen removal in wetlands occurs by plant uptake, microbial assimilation and denitrification (Zhu and Sikoral, 1994), however they have not indicated the extent of nitrates that the plants are capable to remove considering the levels of pollution taking place in the study area and the destruction of papyrus reeds that is going on. This study is thus necessary to determine the levels of the nitrates in Yala Swamp and the role of the papyrus in controlling their levels which would help to inform policy.

2.2.2. Phosphates

The relative contribution of phosphorus (P) from agricultural nonpoint sources to surface water quality problems has increased in recent years as point sources of P have been reduced significantly (Southern cooperative series bulletin, 2000). Phosphorus components find their way into a water body through both natural and anthropogenic deposition by surface runoff of contaminated soil and other surface dumping of industrial and domestic waste. In aquatic environment they distribute themselves in water but since their solubility in water is low, most are found deposited is sediments (LVEMP, 2003).

Waste disposal sites, construction sites, fertilizers and farm yards also make substantial contribution to the total phosphorus load (Hooda *et al.*, 2000; Morga *et al.*, 2000; Sharply *et al.*, 2000 and Tonny *et al.*, 2000). However all this have not been adequately evaluated. Forested areas surrounding Lake Victoria and rivers have been cleared for settlements and agricultural activities (Majiwa *et al*., 2001). In Yala swamp large chunks of papyrus have been cleared to create space for agriculture. These poor land management practices have resulted in severe soil erosion (Schever *et al*., 2001) resulting in high impact on nutrients loading into the lake thereby contributing to eutrophication. Eutrophication resulting from phosphorus loads restricts water use for fisheries, recreation, industry, and human consumption due to increased growth of undesirable algae and aquatic weeds, followed by oxygen shortages as the biomass decomposes (Southern cooperative series bulletin, 2000). Massive algal bloom is a major indicator of Phosphorus and Nitrogen imbalances in aquatic environment as well as a source of excess nutrient exposure in water e.g. water hyacinth (LVEMP, 2002**).** Papyrus is believed to utilize excess phosphorus for their growth according to White *et al.*, (2004), which helps to reduce their levels in the environment. However just like for nitrates the studies have failed to relate the phosphate removal efficiency of the papyrus plants available in relation to the amount of pollutants being introduced in the environment. This fact necessitates this study to find out if they perform the same role in Yala swamp that helps in promoting a cleaner environment.

2.3. Heavy Metals in water and sediments.

Contaminants that add heavy metals to soils and waters are of serious concern due to their persistence in the environment and carcinogenicity to human beings. They cannot be destroyed biologically but are only transformed from one oxidation state or organic complex to another (Garbisu and Alkorta, 2001; Gisbert *et al*., 2003). The release of trace heavy metals from contaminated sediments may increase their concentrations in the overlying water to undesirable levels at the local scale that affect the environment and ecosystem health due to its characteristics of persistence and toxicity (Payán *et al*., 2012).

In Lake Victoria, industrial, agricultural and domestic waste discharges have increased the levels of heavy metals in the lake (NEMC, 1993; Muli, 1996). When metals associate with other chemicals compound in the fertilizer discharge may cause distortion in the cell organelles and inhibit the activity of various enzymes (Valarmathi and Azariah, 2003; Yadav *et al*., 2007), which may greatly disturb the physiological state of the exposed living organism. The heavy metals present in the fertilizer industry discharge are usually in dissolved state which could easily be up taken by fish and enter human food chain.

There have been studies that show that metals will cause damage to the human kidney and liver even at low concentration. The early studies suggested that higher concentration of metals can be carcinogenic and teratogenic (O'Brien *et al*., 2003; Yadav *et al*., 2007). According to Khayatzadeh and Abbasi (2010), high concentrations of Copper in combination with low pH are believed to be fatal to fish. The heavy metals are also dangerous to fish juveniles and may considerably reduce the size of the fish population or cause extinction of the entire fish population. According Begum *et al.,* (2009), water polluted with heavy metals inhibits fish growth and toxic sediments kill benthic organisms reducing food availability for larger fish. Some benthic organisms bio accumulate the heavy metals which when taken up by larger animals the toxins are taken up into their bodies and move up the food chain. Aquatic macrophytes take up metals from the water, producing an internal concentration several fold greater than their surroundings. Many of the aquatic macrophytes are found to be the potential scavengers of heavy metals from water and wetlands. A study on heavy metals in plants of Sultan Marsh showed that, higher heavy metals concentrations occurred in submerged than in emergent macrophytes (Aksoy and Duman, 2005). Similar results were also obtained in a study conducted in Nairobi dam. It has also been revealed that submerged plants tend to accumulate higher levels of metals consistently more than emergent or free floating plants (Outridge and Noller 1991; Ramdan, 2003). From studies the presence of heavy metals even at trace level causes toxic effects if exposed to human population. With this knowledge the origin of these metals and possible interactions with soil property should be a priority in many environmental monitoring systems. Since papyrus is an emergent macrophyte chances are that it can accumulate high concentrations of heavy metals and help in cleaning the environment however the extent to which they can achieve this in regard to the levels of heavy metals available in relation to papyrus plants needs to be determined. For this reason this study is necessary to find out if the papyrus in Yala Swamp plays a role in controlling the levels of heavy metals in the study area.

2.3.1. Lead

Lead is one of the most hazardous pollutants of the environment and its pollution in air, water and agricultural soil is an ecological concern due to its impact on human health and environment. The Kenya Bureau of Standards (KEBS) (1996) reported that lead content in drinking water should not exceed 0.05 p.p.m. A safe guideline value of 0.01 p.p.m. of lead in drinking water has been given by WHO, (1998). Allowable maximum limits for Lead in drinking water in the UK, EU and USA are 0.05 p.p.m., 0.01 and 0.05 p.p.m. respectively (Neubauer and Wolf, 2004). Lead could accumulate in kidney, liver, bone, and brain. Chronic intoxication can lead to encephalopathy mainly in children (Jordao *et al*., 2002). Lead is a nonessential element in metabolic processes and may become toxic or lethal to many organisms even when absorbed in small amounts. Boonyapookana *et al*. (2005) showed that Pb caused phytotoxic effect including chlorosis, necrosis, stunt growth of root/shoot, and less biomass production on *Helianthus annuus*, *Nicotianatabacum* and *Vetiveria zizanioides*.

The main sources of Pb pollution in the environment are mining and smelting of Pb ore, industrial effluents, fertilizers, pesticides, and municipal sewage sludge (Sharma and Dubey, 2005). In plants, lead affects several metabolic activities in different cell components. Lead toxicity leads to decreases in the percentage of seed germination, as well as growth, dry biomass of roots and shoots, disruption of mineral nutrition (Sharma and Dubey, 2005), reduction in cell division and inhibition of photosynthesis (Ekmekci *et al*., 2009). Excessive concentrations of heavy metals may also affect different aspects of water use, such as oxygen consumption by organisms in the environment, water permeability and osmoregulation (Ahern and Morris, 1998). Lead being one of these heavy metals its study is necessary to examine its levels in the Yala Swamp environment. The chemicals used within the Yala Swamp from agricultural activities could have some contents of lead which could contribute to its high levels in the Swamp and lake. The study will assist to determine the role of the papyrus plants in reducing their levels.

2.3.2. Zinc levels

Zinc is one of the important trace elements that play a vital role in physiological and metabolic processes of many organisms (Aboub and Naudini, 2009). It plays an active role in a variety of enzyme systems which contribute to energy metabolism, transcription and translocation (Abassi *et al.*, 1998). It can be released by natural processes but mostly results from anthropogenic activities. Surface waters can be impacted by discharges from chemical industrial wastes or runoff following precipitation of soils with high zinc content due to zinc fertilizer applications. Zinc is an enzyme co factor in several enzyme systems including carbonic anhydrase found in red blood cells. Chance of being poisoned by zinc is rare because salts of alkaline earth elements reduce toxicity of zinc. High temperature and low dissolved oxygen concentration lead to increased toxicity of zinc. Studies have shown that it could be toxic to some aquatic organisms such as fish. It has been found to have low toxicity effect on man. However prolonged consumption of large doses can result in some health complications such as fatigue, dizziness and neutropenia (Hess and Schmid, 2002). This study is necessary to analyze the levels of Zinc in water and sediments in Yala Swamp considering the problems it possess to the environment when found in high concentrations as discussed above. Its accumulated levels in the papyrus plants will also be accessed to prove their usefulness in trying to control Zinc levels in the environment and later inform policy.

2.3.3 Iron levels

It is a non-conservative trace element found in significant concentration in drinking water because of its abundance in the earth's crust (Ghulman *et al.*, 2008). Human activities such as burning of coal, acid mine drainage, mineral processing, sewage and landfill leachates contribute to excessive concentrations in water bodies (NCSU, 2006). In water, iron occurs mainly in ferrous and ferric state.
Its chemical behavior in aquatic environment is however determined by oxidation reduction reaction and presence of coexisting inorganic and organic complexing agents (Anon, 1996). Shortage of iron causes anemia and prolonged consumption of drinking water with high concentration of iron may lead to liver diseases (Rajappa *et al.*, 2010). Laar *et al.*, (2011) conducted a survey of trace elements in the Sakumono wetlands of Ghana and reported significant concentrations of Fe varying from 63.9 to 17.2 Mg/Kg. This was attributed to human activities such as discharge of untreated sewage, use of metals in industrial processes and ability of sediments to act as sinks for the metal. Hagan *et al*., (2011) assessed the levels of heavy metal contamination of Densu River basin in Ghana and found that iron exceeded maximum guideline of 0.3 Mg/l and attributed this to the weathering of rocks underlying the basin. These studies have highlighted important facts regarding iron availability in the environment and may help to explain the concentrations of iron in Yala Swamp. Since the agricultural activities done in Yala swamp may increase the levels of iron, this study is necessary to find out if the papyrus plants play a role in controlling the levels of iron in Yala Swamp.

2.3.5. Copper levels

Copper is an essential micro nutrient required by all organisms being rapidly accumulated by plants and animals (Avenant –oldewage and Marx, 2000). Copper compounds are used in food additives, fungicides, algaecides, insecticides, wood, and preservatives or can be added to fertilizers and animal feeds as a nutrient to support plant and animal growth (Abbas *et al*., 1998). In water supply systems copper is used to control biological growths in reservoir and distribution pipes (WHO, 2004). Although copper toxicity in humans is rare, it can be potentially serious if high levels are present in drinking water (Adriano, 2001). Long term exposure to copper causes irritation of nose, eyes, headache, diarrhea, chronic anaemia and kidney damage in humans (Abbasi *et al*., 1998). Copper shows a lot of effects in the environment as indicated but the documented information on the same in Yala Swamp was limited. Papyrus plants can play a role in controlling the levels of copper in Yala Swamp and other areas by phytoremediation which makes this study necessary to determine this role.

2.4. Phytoremediation of Waters in the Lake

Phytoremediation is a biological treatment process that utilizes natural processes harbored in plants to enhance degradation and removal of contaminants in contaminated soil or groundwater (Alvarez and Illman, 2006). Macrophytes with their ability to survive adverse conditions and high colonization rate are excellent tools for phytoremediation (Okurut *et al.,* 1999). Further they redistribute metals from sediments to water and finally take up in the plant tissues and hence maintain circulation. In Yala Swamp papyrus reeds constitute over 95 % of the area (Elery *et al.,* 1995) and form a dense canopy which limits mixing of the water column by both light and wind penetration intercepting over 90 % of incoming radiation (Jones and Muthuri, 1997). In combination with high rates of organic decomposition, these conditions results in extremely low oxygen levels in water beneath the swamp canopy and create a unique habitat for aquatic habitats (Chapman *et al.*, 1998).

Macrophytes readily take up metals in their reduced form from sediments, which exist in anaerobic situations due to lack of oxygen and oxidize them in the plant tissues making them immobile and hence bio-concentrate them to a high extent (Okurut *et al.*, 1999). Phytoremediation utilizes physical, chemical and biological processes to remove, degrade, transform, or stabilize contaminants within soil and groundwater. The mechanisms for heavy metal remediation are; phytoextraction, rhizofiltration, phytovolatization, and phytostabilization (Ghosh and Singh, 2005; Suresh and Ravishankar, 2004; Schnoor, 1997; Raskin & Ensley, 2000). In this study the papyrus plants would be analyzed to find out if they utilize some of these mechanisms for phytoremediation especially phytoextraction and rhizofiltration considering their structural make up. They cover a vast area of Yala Swamp and considering the level of pollution the area was exposed to due to agricultural activities it is important to study the levels of these pollutants especially heavy metals in there tissues.

2.5. Conceptual Framework

Lake ecosystems play a vital role in the sustenance of life of aquatic animals and human beings. In River Yala found in Siaya County that discharges its waters to Lake Sare a lot of pollution is introduced mainly from anthropogenic activities. An example of such a source includes Dominion farms where immense agricultural activities take place. Such pollutants have a lot of detrimental effects. They affect the physico-chemical parameters including turbidity, temperature, BOD, DO, pH, and EC, TSS and TDS. They also lead to introduction of heavy metals like lead, copper, zinc, iron and cadmium that are lethal to water users since they remain in the food chain for a long period of time. The chemicals used in agriculture also lead to introduction of nutrients like nitrates and phosphates with detrimental effects. Researchers worldwide have developed a number of methods such as chemical precipitation, oxidation or reduction, ion exchange, filtration, membrane separations, reverse osmosis, coagulation e.t.c. for removing toxic metals form effluents before discharging in aquatic streams (Patil p. *et al.*, 2012). These conventional treatments produce toxic chemicals and in turn disposal becomes costly and not ecofriendly. Most of these pollutants can be controlled by phytoremediation using papyrus plants which is economic and environmental friendly. For this reason they need to be preserved and the people enlightened on the need to regulate and control the pollutants introduced in the waters. In this study the papyrus plants constitute the independent variable while water quality is the dependent variable. Destruction of the reeds probably leads to poor water quality while there conservation probably leads to improved water quality.

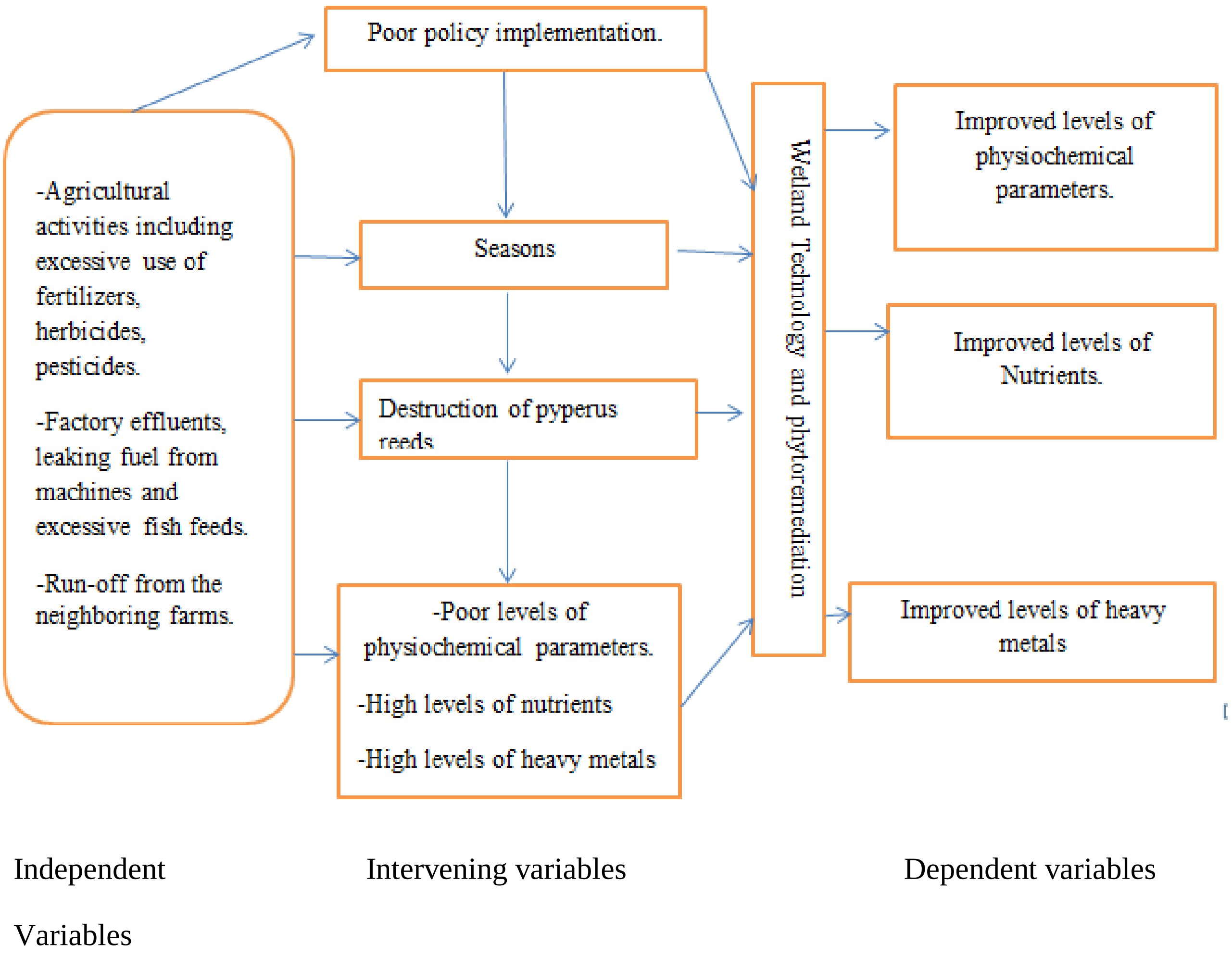


Figure 1: Conceptual framework showing the effects of pollution in waters and the possible solution of phytoremediation using papyrus plants.

Source: Researcher 2019.

CHAPTER THREE

METHODS AND MATERIALS

3.1 Introduction

This chapter presents the methods and procedures used in sample selection, data collection, analysis and presentation. It includes; sampling techniques, data collection methods, description of instruments, validity and reliability, study population, sources of data, sampling and sample size, data presentation and analysis methods, and anticipated limitations of the study.

3.2. Study Area

3.2.1. Location and size

Yala swamp is one of the few extensive wetlands found in western Kenya located in Siaya and Busia counties. The wetland covers an area of 17,500 ha and contains three freshwater lakes, Kanyaboli, Sare, and Namboyo (GoK, 1987). The swamp vegetation is mainly papyrus (*Cyperus papyrus*) and *Phragmites* reeds (Aloo, 2003). It is drained by Hwiro River to the North and Yala River to the south and is separated from Lake Victoria by a sand bar through which the Yala River cuts in many deltaic outflows into the Lake (GoK, 1987). It is the largest papyrus swamp in the Kenyan section of Lake Victoria (Nasirwa and Njoroge, 1997).

3.2.2. Soils and hydrology

The weathered soil materials are transported by floodwaters and deposited in the flood plain, swamp or the lake making the soil youthful. Decomposing organic matter that forms the substrate modifies the soils. The river banks have light and textured soils, while the low-lying areas have generally clay silt. The edges of the swamp have soils with lots of salts (Anyona, 1999). The wetland terrain is characterized by gullies and creeks most of which are inundated.

3.2.3. Climate and rainfall

The reclamation of part of the wetland has changed the hydrology of the swamp. The climate of the area is mild with small variation in monthly averages, temperatures between 18 °C and 25 °C throughout the year (Anyona, 1999). Humidity is high with a mean evaporation rate of between 1800 mm to 2000 mm of mercury (Mavuti, 1989). The annual average rainfall is low approximately 760mm. The rainfall pattern is bimodal erratic and unreliable.

3.2.4. Biodiversity

This wetland is nationally important in that it is one of the few habitats where the threatened Sitatunga antelope (*Tragelaphus spekeii*) is found. The associated lakes contain some critically endangered tilapiine and haplochromine cichlid fish species including *Oreochromis esculentus* and *Xystichromis phytophagus*, some of which are no longer found in Lake Victoria (Abila, 2003). A rich community of invertebrates and birds is also found in the Yala River outlet into Lake Victoria, (Mavuti, 1989).

3.2.5. Economic activities

Economic activities in the Yala swamp include grazing, hunting, fishing, agriculture, tourism, papyrus exploitation, brick making, transport, collection of salt lick and collection of water for domestic use (Abila 2003).

3.2.6. Lake Sare

Lake Sare is located 0º 02' 25''S; 034º 03' 42''E and lies at an altitude of 1140 m above sea level within the greater Yala swamp complex (Opiyo, 1991). The lake has a surface area of 5 km^2 with a mean depth of 1.8m and forms part of the outlet of Yala River into Lake Victoria (Aloo, 2003). It is surrounded by papyrus swamps which merge with the Yala Swamp.

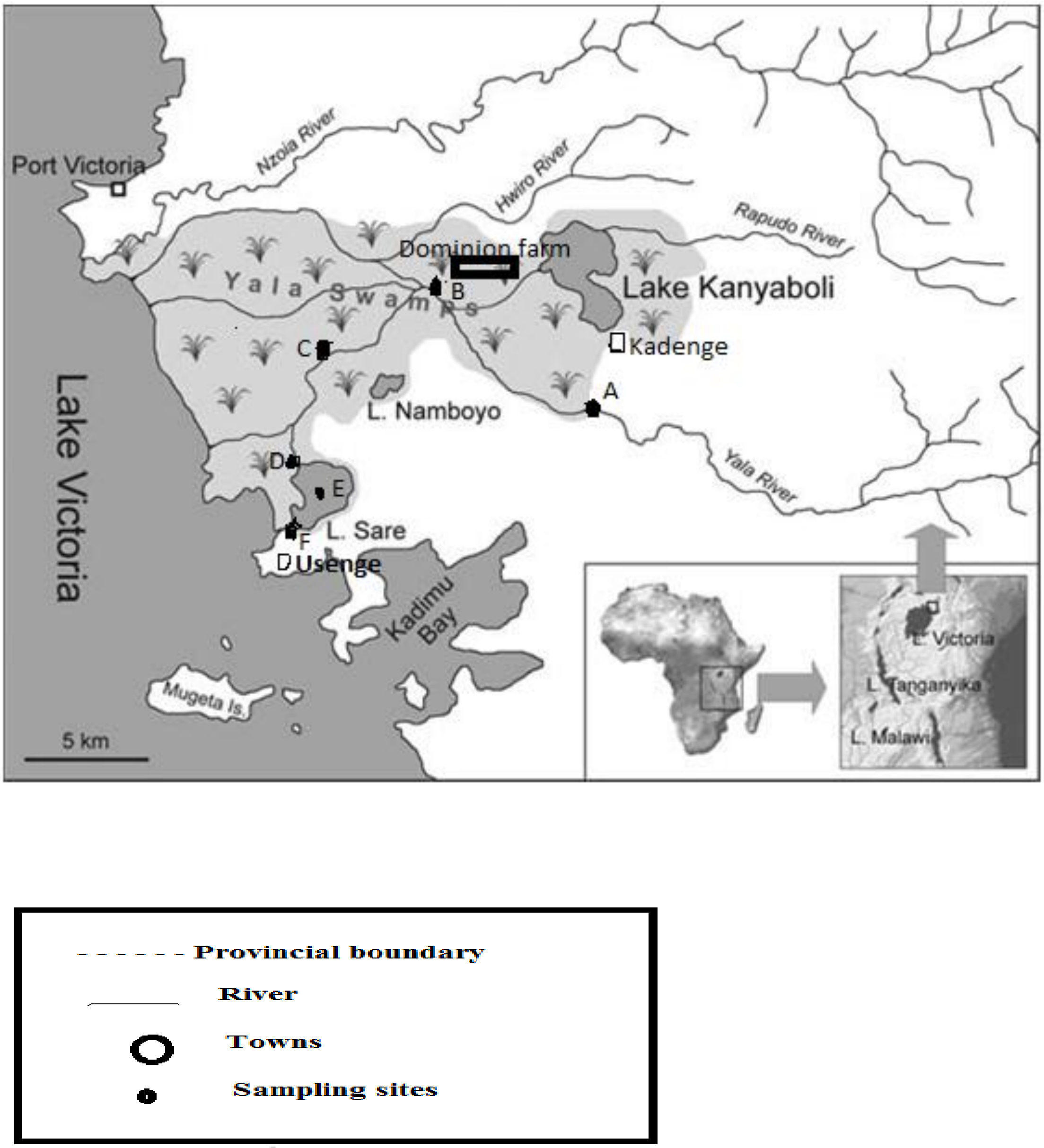


Figure 2: Map of Yala Swamp showing the position of Lake Kanyaboli, lake Namboyo and Lake Sare (Abila *et al* ., 2004). The letters A, B, C, D, E and F are sampling sites with their actual names and coordinates taken (Appendix I). A is the entry of River Yala into Dominion farms, B is the exit of River Yala from Dominion farms, C is Yala Swamp, D is exit from the swamp to Lake Sare, E is Lake Sare and F is the exit of Lake Sare to Lake Victoria.

3.3 Research Design

The study adopted a longitudinal design. It involved stratified sampling and laboratory analysis by use of Atomic Absorption Spectrometer (AAS) and Ultra Violet Spectroscopy. Six sampling sites were selected where physico-chemical parameters of water were determined by taking *in situ* measurements to establish their electrical conductivity, pH, turbidity, temperature and dissolved oxygen (DO) using a multimeter model (YSI 556 MPS Multimeter, USA). The sites were purposefully chosen following the direction of flow of water from River Yala to Dominion Farms to Yala Swamp to Lake Sare and finally to Lake Victoria.

The first sampling site was the entry of River Yala into Dominion farms (station A). It was thought to be unpolluted since its water had not traversed through Dominion farms and was used for comparison purposes with the rest of the sites that were perceived to be polluted. The second sampling site was the entry point of River Yala from Dominion farms into Yala Swamp (station B). This site was perceived to be highly polluted since its water had passed through Dominion farms where industrial and rigorous agricultural activities were taking place which are believed to produce a lot of pollutants. Third sampling site was within the Swamp approximately 3 km to Lake Sare (station C). It was dominated with papyrus plants with some regions completely submerged which necessitated the use of boats. The exit of Yala Swamp into Lake Sare constituted the fourth sampling site (station D). It was also dominated by papyrus plants with River Yala flowing in between as it enters Lake Sare. The central part of Lake Sare was the fifth site (station E). It was about 3km from the shores of Lake Sare hence necessitated the use of boats. The lower part of Lake Sare just before it empties its waters into Lake Victoria formed the sixth sampling site (station F). The site had a bridge where water flowed below and was a busy site full of human activities. The bridge was in a bad state with a lot of rusting taking place on metallic parts below it. The activities that took place included fishing, washing of clothes and utensils, bathing, watering of animals and washing of vehicles. Also people would collect water from this site to take home for domestic use or use in the local restaurants that were available. The site also had papyrus plants on the sides. The sites are indicated in figure 2. Permission to carry out the research was sought from the relevant authorities prior to the study. After the necessary approval and permits were granted, sampling and field collections began on 7^{th}May to 12^{th}May 2015 for the wet season and from 5^{th}October to 10^{th} October 2015 for the dry season.

3.4. Sampling of Water, Sediments and Papyrus Reeds.

The study involved collection of water samples obtained from the six sampling areas. The water samples were collected using plastic amber bottles in triplicates during all the sampling times**.** These were put in a cooler box at 4^0C before transferring to the laboratory for analysis. They were labeled according to the site where they were obtained e.g. form station A as A1,A2,A3 e.t.c. and from station B as B1,B2,B3 e.t.c. until all the stations were sampled. The same was also done to sediment samples taken from the different stations. *Cyperus papyrus* plants were dug out using an auger washed thoroughly and rinsed using deionized water to remove foreign matter such as soil and sand. A knife disinfected with deionized water was used to separate the different parts (roots, stems and flowers). The leaves were cut into small pieces of approximate 5 cm in length for quick drying and grinding during analysis. They were then washed thoroughly and rinsed using deionised water to remove foreign matter especially soil or sand (Sidney, 1984). The different plant parts from each sampling point were then put in labeled polythene bags and transferred to the laboratory where they were dried at room temperature. All the plant parts were also labeled according to the site where they were obtained e.g. roots from station C as rtsC1, rtsC2, rtsC3 e.t.c. flowers from station D as fsD1, fsD2, fsD3 e.t.c. Sediment samples were also taken in all the sites in addition to water samples and taken to the laboratory for analysis of levels of lead, copper, zinc, iron and cadmium as well as the levels of nitrates and phosphates. Plate 1 labeled A shows the determination of physicochemical parameters in River Yala (Station A) using the multimeter *insitu* while plate 2 shows within the papyrus plants (station C) labeled B.

Plate 1. Determination of the physico-chemical parameters in River Yala (station A) insitu by (Violet (researcher)

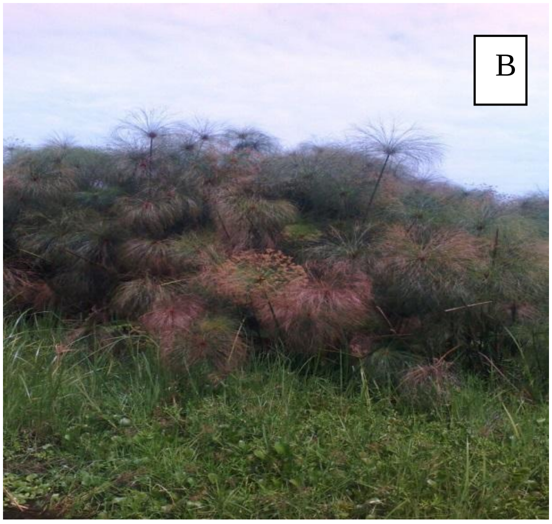


Plate 2. Within the papyrus reeds (station C).

(Photos courtesy of Jim research assistant).

3.4.1 Determination of BOD in the water samples.

The BOD was determined by taking the difference between the DO samples immediately after collection and the DO samples after incubation at 20 ^{0}C for five days.

3.4.2 Determination of TSS in the water samples

Total suspended solids (TSS) for each water sample were determined by filtering 50 ml of water through a pre-weighed standard glass-fiber filter. The residue retained on the filter was dried to a constant mass in an oven at 103°C to 105°C for 1 hour then cooled in a desiccator. Mass of total suspended solids in mg was determined according to Equation 1.

$$\text{Total Suspended Solids/L} = \frac{(A-B) \times 1000}{\text{Sample volume (ml)}} \qquad \text{..........Equation 1}$$

Where: A = weight of filter + dried residue (mg),

B = weight of filter, (mg).

L= TSS

3.4.3 Determination of total nitrogen in water and sediment samples.

Total N was determined in accordance with the method proposed by Wetzel and Likens (1991). Both organic and inorganic nitrogen is converted to nitrates by alkaline oxidation at 100^0C to 110^0C and the total nitrogen in a sample is determined. Unless otherwise stated, the chemicals used in this section were AR grade from Thomas Baker chemicals Ltd Mumbai India. Potassium nitrate was used as calibration standard for the analysis. KNO_3 was dried at 105^0C in an oven for 2 hrs and after cooling, it was stored in a desiccator. A standard stock solution was prepared by dissolving 0.7218 g of KNO_3 in deionised water followed by addition of 2 ml $CHCI_3$ and finally diluting to the 1000 ml mark in a 1000 ml volumetric flask using deionized water to make a standard stock solution of 100 mg/L of NO_3^-. Chloroform was added for preservation purposes and mixture was then stored in a dark glass bottle 4^0C prior to analysis. The standard stock solution was brought to room temperature. An immediate stock solution of 10 Mg/l was prepared from the original stock solution by transferring 10 ml of the 100 Mg/l solution into 100 ml volumetric flask and topping the volume to the 100 ml mark using deionized water. Six dilution standards (0.1, 0.5, 1.0, 1.5, 2.0, 3.0 mg NO_3^-N/L) were prepared by measuring 0.5, 2.5, 5.0, 7.5, 10 and 15 ml respectively, of the immediate stock solution (10 Mg/L) into 50 ml volumetric flasks. 1 ml of colour reagent was added and each flask was topped up to the 50 ml mark using deionized water. Nitrate is diazotized with the colour reagent to form a red azo dye (Andrew *et al*., 1995).

Control stock solution (24.64 Mg/L) was prepared by dissolving approximately 0.3274 g of Na_2-EDTA ($C_{10}H_{14}N_2O_8.2H_2O$) in deionised water and diluted to 1000 ml in a volumetric flask then stored in a dark glass bottle at 4 ^{0}C. 5.00 ml of control stock solution was diluted to 50 ml using deionized water in a volumetric flask after addition of 1 ml of the colour reagent to make working solutions of 2.464 Mg/L N. Blanks was prepared by deionized water and adding 1 ml of the colour reagent to deionized water in 50 ml volumetric flask and the volume topped to the 50 ml mark using the same water. Both the blank and control were treated as samples.

For water and sediment analysis, a volume of 10 ml of each sample (water and sediment filtrate samples), blank and control were transferred into separate digestion containers and 5ml of the oxidizing reagent (potassium persulphate reagent) was added to each sample. The digestion containers were closed tightly with caps and then autoclaved at 121 ^{0}c for 30 min. After digestion, the samples were left to cool to room temperature and filtered using a Whatman no 125 mm ø filter paper. Each sample (filtrate) was then transferred into 100 ml measuring cylinder and filled to 60 ml using ammonium chloride buffer (pH = 8.5) and mixed thoroughly. Each sample was then transferred into a 250 ml conical flask, poured into a Cd-reduction buffer column (length and 3.5mm) containing (cadmium in ammonium chloride buffer at pH 8.5) and collected at a rate of 7 to 10 ml/min. The first 25 ml was discarded. The next 25 ml was collected and transferred into a 250 ml conical flask. 1 ml of the colour reagent was added within 15 min of reduction and the mixture was diluted to 500 ml using deionized water. Blank, calibration standards, control and samples were then analyzed at 543 nm using a UV/Vis spectrophotometer within 2 hour from addition of reagent.

Preparation of reagents

The colour reagent was prepared by combining 375 ml deionised water, 50 ml conc H_3PO_4, 5.0 g of sulphanilamide and 0.25 g of N-(1-napthyl)–ethylenediamine dihydrochloride ($C_{10}H_7NHCH_2CH_2NH_2.2HCI$) in a 500 ml volumetric flask. The mixture was diluted to the 500 ml mark using deionized water. The oxidizing reagent was prepared by dissolving about 20.1 g of potassium persulfate ($K_2S_2O_8$) and 3.0 g of NaOH in deionized water, diluted to 1000 ml using water and stored in a dark bottle at 4 ^{0}C. The ammonium chloride buffer (pH = 8.5) was prepared by dissolving 10.0 g of NH_4CI in 1000 ml distilled water and adjusted to pH 8.5 by adding 3 or 4 NaOH pellets.

3.4.4. Determination of total phosphorus in water and sediments samples using Ascorbic acid method.

Ammonium molybdate and potassium antimony tartrate react in acid medium (0.2 mol/l) with orthophosphate to form a heteropoly acid phosphomolybdic acid that is reduced to intensely coloured molybdenum blue by ascorbic acid .The absorbance of the blue color is measured in a photometer at 880 nm.

The ascorbic acid method was used for determination of total phosphorus in water and sediment samples as proposed by Wetzel and Likens (1991) with slight modifications just like for nitrates. Potassium dihydrogen phosphate (KH_2PO_4) was used as calibration standard. Potassium dihydrogen phosphate was dried at 105^{0}c for 2 hrs and stored in a desciccator. For preparation of a standard stock solution, 0.1099 g of KH_2PO_4 was dissolved in 250 ml of deionized water in a 500 ml volumetric flask. 5 ml of a 4 M H_2SO_4 solution was added for preservation and the solution diluted to 500 ml using deionized to make 50 Mg /L solution. This solution was stored in a glass bottle at 4 ^{0}C prior to analysis. The standard stock solution was brought up to room temperature. The immediate stock solution (1000 µg/l) was prepared by transferring 10 ml of the standard stock solution into a 500 ml volumetric flask and diluting to the 500 ml mark using deionized water. Calibration standards were prepared by diluting standard intermediate solution to 10, 20, 50, 100, 250, 500 and 750 µg/L, using deionized water. This was achieved by transferring 1.0, 2.0, 5.0, 10.0, 25.0, 50.0 and 75.0 ml respectively of the immediate stock solution into separate 100 ml volumetric flasks. A volume of 4 ml of 4 M H_2SO_4 was added to each flask after mixing and the volume was topped up to the 100 ml mark using deionized water. The blank was prepared by adding 4 ml of 4 M H_2SO_4 to deionised water in a 100 ml volumetric flask and diluting the solution to 100 ml.

A volume 25 ml of each preserved sample, blank and calibration standard solution were transferred into separate reaction bottles. 5 ml of the ammonium persulfate solution was then added to each sample and the mixture autoclaved for 30 min (137 kPa). The sample was then allowed to cool to room temperature and analyzed using UV/Vis spectroscopy at 880 nm.

Preparation of reagents

Ammonium molybdate (13.0 g of $(NH_4)_6MO_7O_{24}$ was dissolved in 100 ml of deionized water), potassium antimony tartrate (0.35 g of $K(SbO)C_4H_4O_6$ was also dissolved in 100 ml deionized water), ascorbic acid (5 g of ascorbic acid was dissolved in 100 ml of distilled water to get (50 g/l)) and conc. H_2SO_4 (120 ml of conc. H_2SO_4 was added to 170 ml distilled water and allowed cool to room temperature). The reagent mixture was prepared by adding ammonium molybdate solution to the ascorbic acid solution in a beaker while stirring followed by potassium antimonyl tartrate solution.

3.4.5. Analysis of heavy metals in water, sediments and different parts of *Cyperus papyrus*

The the Atomic Absorption Spectroscopy working principle is based on the sample being aspirated into flame and atomized. The AAS's light beam is directed through the flame into the monochromatic and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Metals have their own characteristic absorption wavelength hence a source lamp composed of that element is used making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

3.4.6. Digestion of samples

A mass of 1.00 g of each ground sample (leaves, stems, roots and sediments) was weighed accurately using an electronic analytical balance (science tech manufactured in the year 2000.) and transferred into a dry 250 ml conical flask. A volume of 8.0 ml of concentrated analytical grade nitric acid was added to each flask in a fume chamber. The mixture was then subjected to wet digestion using an electric digester. After digestion, the mixtures were left to cool for 10 min. Thereafter, 2 drops of 30% hydrogen peroxide was added to each reaction mixture and further heating was done until white fumes were formed and a clear solution obtained. The sample mixtures were left to cool and then filtered using whatman filter papers (125 mm ø). Each filtrate was transferred into 100 ml volumetric flasks. Each conical flask was rinsed using deionised water and contents transferred into the corresponding filtrate mixture in a volumetric flask. Each sample was then topped to 100 ml mark using deionised water and transferred into a dry plastic vial, closed, and stored at room temperature prior to analysis.

3.4.7. Determination of levels of selected heavy metals in water, sediments and different plant parts of *C. papyrus*

Copper stock solution was made by dissolving 1g of copper salt in 15 ml of nitric acid and diluted to 1000 ml with distilled water. A series of standards ranging from 1 mg to 5 mg were made and were used to generate a calibration curve.

Lead stock solution (1000 Mg/l) was prepared by dissolving 1.59 g of lead (II) Nitrate in 500 ml distilled water. Through serial dilutions, standard working solutions of lead were made ranging from 1 to 5 mg which were used to generate a calibration curve.

Zinc stock solution (100 Mg/l) was prepared by dissolving 0.289 g of zinc nitrate salt in 300 ml of distilled water and then made up to 1liter of solution using distilled water. A working solution (20 Mg/l) was made by diluting 20 ml of the stock solution to 100 ml of distilled water. The calibration curve was made using solutions with the following concentrations.0.5, 1, 1.5, 2 and 2.5 Mg/l.

Iron stock solution was prepared by dissolving 1 g of iron in 50 ml of nitric acid and diluted to 1000 ml with distilled water. A series of standards ranging from 1 mg to 5 mg were made and used to generate a calibration curve.

The blank consisted of only deionised water. For sample analysis, the blank, calibration standards, water samples, the digested plant part and sediments samples were analyzed using an Atomic Absorption Spectrophotometer (Shimadzu AA-630). Pb, Cu, Zn and Fe were analyzed at 217.0 nm, 324.8nm, 213.9 nm, 248.3 nm and 228.8 nm, respectively using the appropriate lamps.

AAS system had 10 cm one sit burner head and used standard air- acetylene flame. Single element hollow cathode lamps and an automatic background correction mechanism were used for all elements. The instrument settings and other experimental conditions were in accordance with the manufacturers specifications. The operating conditions for the AAS system are shown in Table 3.1

Table 3.1 Operating conditions for the AAS system.

Metal	Pb	Zn	Cu	Fe
Wavelength (nm)	217.0	213.9	324.8	248.3
Slit width (nm)	1.0	1.0	1.0	0.3
Lamp current (mA)	5.0	3.0	3.0	8.0
Sample flow rate flow (ml/min)	6.0	6.0	6.0	6.0
Oxidant flow rate (ml/min)	8.0	8.0	8.0	8.0
Fuel flow rate (ml/min)	2.0	2.0	2.0	2.0
Burner height (cm)	25.0	25.0	25.0	25.0
Sensitivity	0.1760	0.0220	0.3384	0.2095
Flame	Air/c_2H_2	Air/c_2H_2	Air/c_2H_2	Air/c_2H_2

3.5. Data Analysis

Data entry and cleaning was done in Microsoft Excel spreadsheet, while statistical analysis was done using SAS V9.0 software. Descriptive statistics was used to summarize the data characteristics, presented as means and standard deviations on non-transformed data, while physico-chemical parameters, total nitrogen, total phosphorus and heavy metals, was determined using One-way ANOVA on transformed data normalized by log transformation using $\log_{10}(n+2)$. For effects that were found significant at $p<0.05$, post hoc separation of means was done by Duncan Multiple Range Test (DMRT), to find significant differences in means. One Way ANOVA was also carried out between heavy metal contents in the roots, leaves and flowers to check if significant difference exists between the accumulation rates of the heavy metals in the plant parts. Student's t-test was used to establish the significant difference of all the parameters under study in the wet and dry season.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the study findings obtained from the field as per the study objectives, in tables, figures and textual forms. Observations made in all the sampled sites are also presented.

4.2. Physico-chemical Parameters of water.

The data obtained from the analysis of the physicochemical parameters of water (temperature, pH, DO, Conductivity, Turbidity, TDS, TSS and BOD) from

the selected sampling sites along River Yala, Yala Swamp and Lake Sare during the rainy and dry seasons are shown in figures and tables below. There standard deviations have been calculated and represented in tables.

4.2.1. Temperature levels in water.

The data obtained from measurement of temperature between the different sampling sites is presented in Figure 4.1.

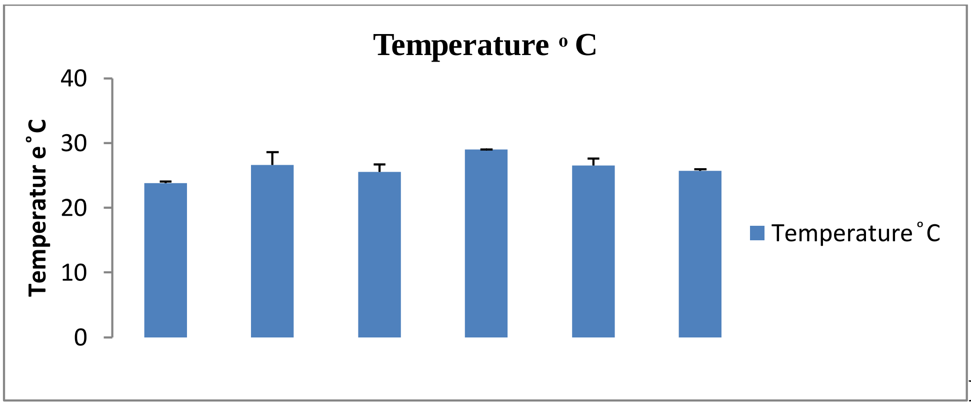


Figure 4.1. Temperature levels in the various station*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The mean temperature levels varied between the different sampling sites (one-Way ANOVA, $F_{(5,11)}$ = 5.2920, P < 0.03) . The lowest temperature level (23.79 ±0.26 °C) recorded at the entrance of River Yala to Dominion farms (station A) and the highest temperature level (28.99 ±0.44 °C) recorded at the exit of Yala Swamp to Lake Sare (Station D). Duncan Multiple Range Test (DMRT) further established that the mean temperature values varied significantly between sampling sites A and B, between sites C and D and between sites D and E while there were no significant differences in mean temperature values in stations B and C and also in stations E and F. (Figure 4.1)

Lower temperatures were recorded in River Yala at station A (entrance of River Yala to Dominion farms) (23.79 ± 0.26^0c) could be because of the rigorous water movement and turbulences of the waters as it meets obstacles like stones and twigs which bring about a cooling effect. The water also contained a lower organic matter compared to other stations. At station B (exit of River Yala from Dominion farms) the temperatures were higher (26.60 ± 1.98^0c) and this could be because the waters here were flowing from Dominion farms where a lot of pollutants had been introduced. The waters were different in colour brown to black and not as clear as that of station A. The speed of water was also slow with no turbulence and the sediments had a foul smell in some sections. Ndubi *et al*. (2015) reported that the high water temperature could result from exothermic reactions of pollutants that influence the adsorption of hydrocarbons in soil. This could be the reason for the high water temperatures in station B and it implies that the introduced pollutants could undergo reactions that release heat which lead to the increased temperatures.
At Yala Swamp (station C) and the entrance of River Yala to Lake Sare (station D), the temperatures were higher with D having the highest mean temperature (28.99 ± 0.04^0c). These sites were dominated by papyrus plants and the water velocity was very low. The high temperature could also be attributed to decrease in depth of water as reported by Ombaka and Gathumbi, (2012) who observed that the waters can spread in a large area due to the papyrus as obstacles and this would allow heat to penetrate the sand and consequently raise the temperature of water. Ndubi *et al*. (2015) also observed that a wetland with high vegetation density will correspond to low flow rate. For this reason, most of the pollutants from Dominion farms settled here some being trapped by the papyrus roots and more reactions took place leading to the increased temperatures.

Additionally, an increase in photosynthetic processes of aquatic plants and algae also increase water temperature as observed by Madigan and Martinko, (2006). This further explains the high temperatures at station D. The temperatures then reduced at Lake Sare (station E, 26.54 ± 1.07^0c) and the entrance of Lake Sare to Lake Victoria (station F, 25.72 ± 0.19^0c) and this could be because most of the pollutants had been broken down and some diluted thus no further reaction was taking place. Physiochemical water quality parameters temperature included are influenced by human activities along and within the River channel which in turn influence the biological reactions within the aquatic systems (USEPA, 1998).

4.2.2 Seasonal variation in temperature levels.

Data obtained from analysis of temperature measurements in the dry and wet season are represented in table 4.1 below.

Table 4.1. Temperature levels in the Dry and Wet seasons.

Stations	Temperature in Dry season (^{0}c)	Temperature in Wet season (^{0}c)
A	24.0 ±0.1^D	23.6 ±0.1^D
B	28.0±0.6^B	25.2±0.4^C
C	26.3±1.3^C	26.3±1.3^{BC}
D	29.0±0.3^A	29.0±1.3^A
E	25.8±0.2^C	27.3±0.2^A
F	25.6±0.2^C	25.9±0.4^C
MEAN	**26.45±0.45**	**26.22±0.4**

*Values represent means ±Sd of triplicate analysis. *Means with different superscripts in the same column are significantly different at p < 0.05. (Data analysed by Duncan's Multiple Range Test.
Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

During the wet season the mean temperatures were lower (26.22±0.4^{0}c) and they varied significantly (one-Way ANOVA, $F_{(5,41)} = 113.12$, $P < 0.0001$) . In the dry season the mean temperature levels were higher (mean of 26.45±0.45^{0}c) and they also varied significantly (one-Way ANOVA, $F_{(5,41)} = 53.63$, $P < 0.0001$). Duncan Multiple Range Test (DMRT) further established that mean temperature values did not vary significantly between station A in the dry season and in the wet season. This was the same for stations C, D and F. In stations B and E there were significant differences in mean temperature values in the dry and wet seasons (Table 4.1). However, in general there were no significant differences in the mean temperature levels in the two seasons (Student's t-test, p = 0.43785).

The slight difference between the dry and wet season mean temperature values could be attributed to the cooling and diluting effects of rain water. According to Ndubi *et al*. (2015) during the wet season increased water inflow could result in lower water temperature and increased D.O values. Similarly, according to (Ombaka and Gathumbi, 2012), low water temperatures could be due to increased water volume from rain water and decreased penetration of light rays due to deposition of silt and suspended materials. The findings of this study are also in agreement with a study by Ogundiran *et al.* (2014) in sections of Asa River in Nigeria that had mean temperature ranges of 25.04^{0}c to 30.13^{0}c. The mean temperatures for rainy and dry seasons were between 28.22 ±0.96^{0}c and 24.60±0.21^{0}c respectively. A similar study by Mulongaibalu *et al*. (2014) at Ishasha River and Lake Edward in Uganda had temperature ranges from 22.62 to 23.8 ^{0}C in the sampling sites.

A study by Dhirendra *et al*. (2009) in River Ganga at Hardwar in India ranged between 10.18 ºC to 19.73 ºC. These are lower than the once obtained in this study and this could be because River Ganga is located close to the Himalayas where melting of snow decreases its temperatures. Gichuki *et al.* (2005) in the same study area i.e. Yala Swamp obtained a mean temperature value of 27.02^{o}C. This is higher than the values obtained in this study both in the dry and wet seasons i.e. 26.45±0.45 ^{o}C and 26.22±0.4 ^{o}C respectively. This could be because at that time reclamation activities were still at a lower scale and much of the papyrus plants had not been interfered with and as mentioned earlier by Madigan and Martinko, (2006) increase in photosynthetic processes of aquatic plants and algae also increase water temperature. The average temperatures for all the sampling sites were less than 40^{o}C which depicts a temperature range that is supportive of good surface water quality and survival of plants and animals as reported by WHO (2011).

4.2.3. Conductivity Levels in Water

The data obtained from measurements of conductivity in the various sampling site are represented in Figure 4.2 below.

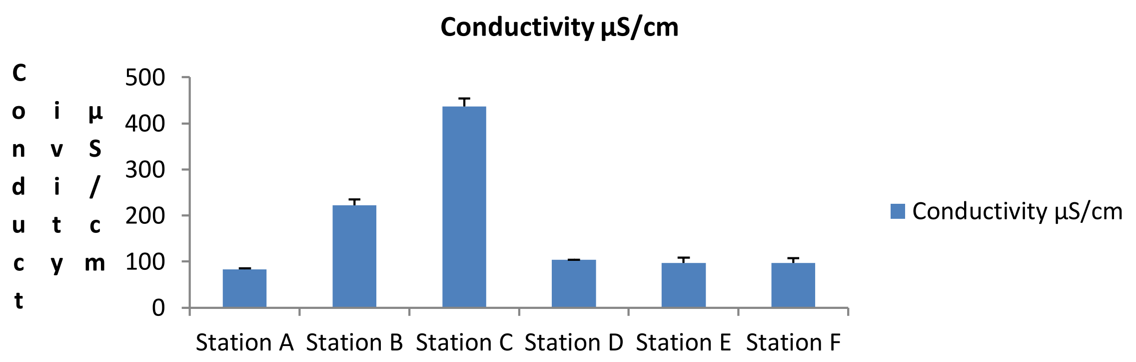


Figure 4.2. Conductivity values in the various stations.

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

Conductivity levels along the various sampling stations in River Yala, Yala Swamp and Lake Sare varied significantly (One-Way ANOVA, $F_{(5,35)}$ =5628, $P < 0.0001$). Duncan Multiple Range Test further established that station C (Yala Swamp) was significantly different from any other station. There were significant differences in mean conductivity levels in stations A, B, C and D where the highest value 436.51 ±17.3 µS/cm was recorded at Yala Swamp (Station C) and lowest value 83.28 ±1.98 µS/cm recorded at the entry of River Yala to Dominion farms (station A) Figure 4. However, there were no significant differences in conductivity between station E (Lake Sare) and F (Entry point of Lake Sare to Lake Victoria).

The permissible conductivity limit for domestic water supply is 200 µS/cm according to WHO (2004). Highest values were recorded at Yala Swamp (station C. 436.51±51 µS/cm) where the pollutants first settle within the papyrus plants. The second highest value was also recorded at the exit of River Yala from Dominion farms (station B, 226.6±12.20). This station receives most of the pollutants from Dominion farms which join the River water and they are later transferred to station C (Yala Swamp). The pollutants probably are the reasons behind the high conductivity levels. The high levels also indicate that the waters have a high concentration of electrolytes and dissolved solids since according to Raza *et al.*, (2015), EC of water can be termed as the total count of dissolved salt or as the forecaster of the individual ions. The conductivity levels reduce from the exit of Yala Swamp to Lake Sare (station D, 103.62±0.33 µS/cm). This could be because most of the pollutants are absorbed by the papyrus plants and some decompose and change into other forms that are utilized by microorganisms.

According to Alloway, (1995) the increase in EC is due to increase in ionic mobility especially when a lot of pollutants dissolve in water forming ions. The levels further reduce to Lake Sare (station E, 97.17±11.8 µS/cm) and station F (the entrance of Lake Sare to Lake Victoria) had the least value (96.38±10.9 µS/cm) after station A (83.28±1.98 µS/cm) which is attributed to the papyrus plants. The nutrients that get into the waters of River Yala from Dominion Farms could be contributing to high conductivity levels in station C (Yala Swamp). The immense cutting and burning of the papyrus plants to create room for agriculture could cause increase in temperatures which further increase EC. Station A had the lowest level of conductivity (88.28±1.98 µS/cm) could be because it is less polluted hence has less concentration of electrolytes.

4.2.4. Seasonal variation in conductivity levels.

Data obtained from analysis of conductivity measurements in the dry and wet season are represented in table 4.2 below.

Table 4.2. Conductivity values in the Dry and Wet seasons

Stations	Conductivity in Dry season (µS/cm)	Conductivity in Wet season (µS/cm)
A	81.9 ± 0.2^{D}	84.7 ± 2.6^{D}
B	126.0 ± 1.7^{B}	309.3 ± 18.0^{A}
C	448.8 ± 3.7^{A}	424.3 ± 10.7^{A}
D	103.4 ± 4.4^{C}	103.9 ± 2.9^{C}
E	88.8 ± 0.9^{D}	106.0 ± 3.0^{C}
F	88.6 ± 0.6^{D}	104.1 ± 0.8^{C}
Mean	**156.25±1.9**	**188.72±7.3**

*Values represent means ±Sd of triplicate analysis. *Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

In the wet season the difference in conductivity levels varied significantly between stations (one-Way ANOVA, $F_{(5,35)} = 1587.79$, $P < 0.0001$). The highest level 424.3 ± 10.7 µS/cm was recorded at Yala Swamp (station C) and the lowest level 84.7 ± 2.6 µS/cm recorded at the entry of River Yala to Dominion farms (Station A) Table 4.4. In the dry season the conductivity levels also varied significantly between stations (one-Way ANOVA, $F_{(5,35)} = 19{,}890.3$, $P < 0.0001$). The highest level 448.75 ± 3.40 µS/cm recorded at Yala Swamp (station C) and the lowest level 81.9 ± 0.16 µS/cm recorded at the entry of River Yala to Dominion farms (station A). Duncan Multiple Range Test further established there were significant differences in mean conductivity values between station B in the dry season and station B in the wet season. This was similar to stations E and F in the dry seasons that were significantly different to the same stations in the wet season (Table 4.2). However, there were no significant differences in the mean conductivity values in the dry and wet seasons of the remaining stations i.e. A, C and D. In the two seasons there were no significant differences in conductivity (Students t-test p =0.3389).

The conductivity values were higher in the wet season than in the dry season (Table 4.2). This could be because according to Brian *et al*. (2001) water bodies are recharged during the rainy season and the salts and nutrients are transported to the water bodies that increase conductivity levels. This could also be because at such times agricultural activities are at their peak which includes the use of herbicides, pesticides and fertilizers which later find their way in water runoff and increase the levels of EC.

In station B (River Yala after leaving Dominion Farms) had the highest conductivity value in the wet season (309.3±2.9 µS/cm). This could be because it receives a lot of pollutants from Dominion Farms and as mentioned earlier it is during this season that agricultural activities are intensive. These pollutants dissolve forming ions which eventually increase conductivity levels and according to Floreseu *et al*. (2010) a higher conductivity reflects higher water pollution. More so land use activities like spraying of crops to control pests and weeds or fertilizers increase the chloride, nitrate and phosphate levels which are known to also increase the conductivity levels. In the same station B the conductivity levels in the dry season are low (126.0 ±1.7µS/cm). This is attributed to the fact that the water levels are lower in this season hence low ions and also agricultural activities are fewer hence less pollutants are introduced to the water.

4.2.5 pH in water.

Data obtained from analysis of pH measurements are represented in Figure.4.3 below.

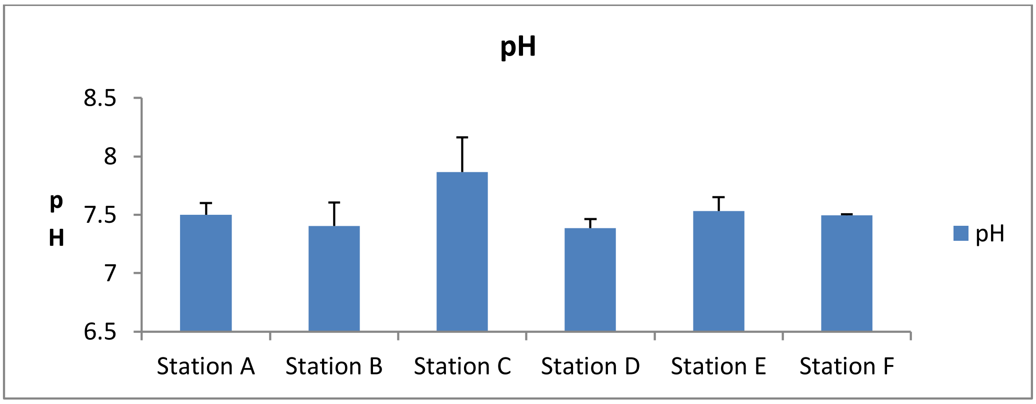


Figure 4.3. pH values in the various stations.

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The pH levels varied in the sampling stations (one-Way ANOVA, $F_{(5,36)} = 10.985$, $P < 0.001$). Duncan Multiple Range Test further established that station C (Yala Swamp) was significantly different from all other stations and had highest mean pH value 7.86±0.30. The lowest value 7.38±0.08 was recorded at the exit of Yala Swamp to Lake Sare (station D) Figure 5. There was also a significant difference in mean pH values between stations B and C and between stations C and D. However, there was no significant difference in mean pH values in the remaining stations.

In most natural waters the pH ranges between 6.5 and 8.5 (Tepe *et al*., 2005). In this study the mean pH values ranged from 7.3 to 8.0 which indicate that they were within the permissible required range. The stations were slightly alkaline with the site within the papyrus reeds (station C), being the most alkaline (7.86±0.30). Alkalinity is an indication of amount of carbonates and bicarbonates that shift the equilibrium producing hydroxyl ions (Brian *et al*., 2001). According to Craig and Louis, (2008) pollutants can raise the amounts of carbonates and bicarbonates in water which explains the alkaline levels in the study area especially at station C (Yala Swamp) with pH level 7.86. This could be because of the pollutants coming from Dominion farms. Other contributors of alkaline pH are phosphorus and nitrogen containing compounds and from the study these elements were detected to some extend which was probably the cause of the alkaline conditions. The exit of Yala Swamp into Lake Sare (station D) had the lowest pH (7.38±0.08). This could be because the station was dominated by papyrus reeds where a lot of biochemical processes between organic and inorganic wastes were taking place some of which produce weak acids that lower pH.

According to Oliver (2004), low pH could be attributed to enhanced ammonification and nitrification processes that result to decay. Reduction in pH may also be due to carbon dioxide released by bacterial breakdown of organic wastes (Matow, 2010). In this case the gases were found in the papyrus debris. This gas combines with water to form weak carbonic acid that lowers pH (Asuquo and Gathumbi, 2011). A study by Mulongaibalu *et al*., (2014) at Ishasa River and Lake Edward in Uganda had pH ranges of 6.34 to 7.33 which are lower than the range obtained from this study, 7.3 to 8.0 which could be because of the difference in geology or anthropogenic activities.

4.2.6 Seasonal variation in pH levels.

Data obtained from analysis of pH measurements in the dry and wet season are represented in table 4.3 below.

Table 4.3. pH values in the Dry and Wet seasons in the various stations.

Stations	pH values in the dry season	pH values in the wet season
A	7.6 ± 0.1^{B}	7.4 ± 0.1^{B}
B	7.4 ± 0.1^{BC}	7.4 ± 0.1^{B}
C	8.0 ± 0.5^{A}	7.6 ± 0.3^{AB}
D	7.3 ± 0.2^{C}	7.5 ± 0.2^{AB}
E	7.4 ± 0.1^{BC}	7.7 ± 0.2^{A}
F	7.5 ± 0.1^{B}	7.5 ± 0.1^{AB}
Mean	**7.5±0.2**	**7.5±0.2**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

During the dry season pH levels varied across the stations (one-Way ANOVA, $F_{(5,41)} = 10.16$, $P < 0.0001$). During the wet season the mean pH values did not vary significantly (one-Way ANOVA, $F_{(5,41)} = 2.38$, $P = 0.0579$). Duncan Multiple Range Test further established that there were no significant differences in mean pH values between the stations in the dry and wet season except between station D 7.3±0.2 in the dry season and D 7.5±0.2 in the wet season and station E 7.4±0.1 in the dry season and E 7.7±0.2 in the wet season (Table 4.3). Station C still had the highest mean pH in both seasons; 8.0±0.5 and 7.6 ±0.3 in the dry and wet season respectively. However, there were no significant differences in pH levels between dry and wet seasons (Student's t-test p=0.9361)

The pH levels in the study had the same mean levels for both seasons as indicated in Table 4.6 (7.5±0.2). However, in some stations like station C (Yala Swamp) the mean pH value was very high in the dry season compared to the wet season. This could be because according to Brainwood *et al*. (2004) during the dry months an increase in pH of a water body is associated with photosynthetic activities which increase uptake of nutrients, a decrease in rainfall volume and an increase in water for irrigation resulting in unstable diurnal pH curve. Station C (Yala Swamp) was dominated by Papyrus reeds hence it is probable that the high photosynthetic activities of the reeds would increase the pH.

A study by Ogundiran *et al*., (2014) in Asa River in Ghana and its tributaries showed that the water had a mean pH of 7.13, 7.92 and 7.56 in the sampling areas. Maximum pH of 7.80 ± 0.06 was recorded in the dry season the minimum value of 7.50 ± 0.10 obtained during the rainy season. These values are in agreement with those obtained in this study i.e. 7.5±0.2 in the dry season and 7.5±0.2 in the wet season. A study by Mutembei *et al*. (2014) in River Irigu in Chuka Kenya had pH ranges of 6.5 to 7.7 and similar values were obtained by Joseph *et al*. (2003) in Navikubo wetland Uganda. These values are lower compared to the ones obtained in this study and could be because they are more polluted. The pH of water reduced after leaving the papyrus reeds which indicates that they play a role in improving pH. The seasons did not have an effect on pH values as indicated by Student's t-test p=0.9361.

4.2.7. Dissolved Oxygen

Data obtained from analysis of DO measurements are represented in figure 4.4 below.

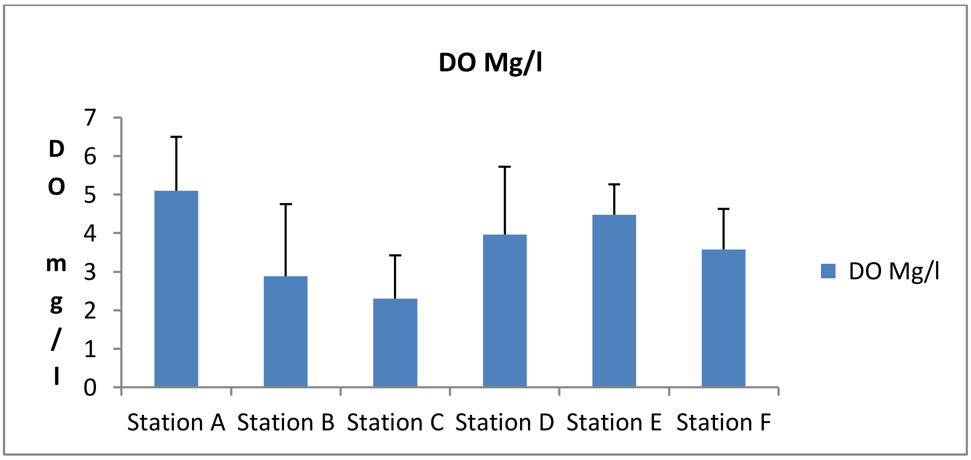


Figure 4.4. DO values in the various sampling stations. *Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The values of Dissolved Oxygen varied between the sampling stations one-Way ANOVA, $F_{(5,36)}$ = 10.98527, P < 0.0001). Duncan Multiple Range Test further established that the mean DO value for station A (entry of River Yala to Dominion farms) was significantly different from all other stations and had the highest value of 5.10±1.412 Mg/l. The lowest value 2.31±1.12 Mg/l recorded at Yala Swamp (station C). There was a significant difference in mean DO values between stations A and B, between C and D and between E and F. However, there were no significant differences in mean DO values between station B and C and also between station D and E (Figure 4.4).

DO is among determining factors for the survival and growth of aquatic organisms. In this study DO values were highest in station A (Entrance of River Yala into Dominion farms) 5.10±1.41Mg/l. This could be attributed to the fact that the water is less polluted with organic matter and is in constant turbulence that promotes aeration which increases the oxygen levels. The waters in station B (exit of River Yala from Dominion farms) and C (Yala Swamp) had the least mean DO values 2.89±1.87 Mg/l and 2.31 Mg/l respectively. This is possible because most of the contaminants released by Dominion farms were introduced in the water in station B (River Yala from Dominion Farms) making it to be loaded with organic matter which later would flow into the water within papyrus reeds (station C).

Some of the wastes would probably use up most of the oxygen in the processes of oxidation to form other products. The papyrus reeds trap most of these contaminants in the roots and create anoxic conditions. According to Allan, (2004), the decreased water volume caused by the reeds result to increased water temperature which decreases the solubility of oxygen in water hence low DO. The low DO values could also be due to aerobic decomposition of plant materials within the reeds, nitrification and mineral surface aeration resulting from vegetation cover. High organic waste load contribute to decreased DO concentrations and increased BOD levels since the wastes use a lot of dissolved oxygen during decomposition (Busulwa and Bailgy, 2004). This is also in agreement with Iqbal *et al*. (2006) who also had the opinion that low DO could possibly be due to increased organic load which requires a high level of oxygen for chemical oxidation and breakdown.

4.2.8. Seasonal variation in Dissolved Oxygen.

Data obtained from analysis of DO measurements in the dry and wet season are represented in table 4.4 below.

Table 4.4. DO values in the Dry and Wet seasons

Stations	DO in the dry season (Mg/l)	DO in the wet season(Mg/l)
A	$6.0±1.1^{A}$	$4.1±0.4^{A}$
B	$4.2±0.1^{C}$	$1.6±1.2^{C}$
C	$3.1±0.8^{D}$	$1.5±0.6^{C}$
D	$5.2±0.5^{B}$	$2.7±0.7^{B}$
E	$5.0±0.1^{C}$	$3.9±0.4^{A}$
F	$4.4±1.0^{BC}$	$2.8±0.4^{B}$
Mean	**4.65±0.6**	**2.77±0.6**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The mean DO values were generally low during the wet season with station C (Yala Swamp) having the least value (1.51 Mg/l ± 0.57) and station A (Entry of River Yala to Dominion Farms) the highest (4.1 Mg/l ± 0.46). The values also varied significantly in the sampling sites (one-Way ANOVA, $F_{(5,41)} = 17.28$, $P < 0.0001$). In the dry season the water of River Yala before getting to Dominion farms (station A) had the highest mean 6.09 Mg/l ± 1.08 and lowest values were recorded at Yala Swamp (station C) with a mean of 3.10 Mg/l ± 0.83. The values also varied significantly across the stations (one-Way ANOVA, $F_{(5,41)} = 17.28$, $P < 0.0001$). Duncan Multiple Range Test further established there were no significant difference in mean DO values between station A in the dry season and station A in the wet season. This was similar to stations B, D and F both in the dry and wet seasons. However, there were significant difference in mean DO values between station C in the dry and wet season similar to station E (Table 4.8). In the two seasons there were significant differences in DO (Student's t-test p =0.0007).

The levels of DO were higher in the dry season than the wet season (table 4.4) and the mean values were significantly different (students t-test p=0.0007). This could be according to Krishnamurthy, (1990) increase in temperature and duration of bright sunlight which has an influence on the percentage of soluble gases (Oxygen and carbon (IV) oxide). During dry season the intense sunlight seem to accelerate photosynthesis by phytoplankton, utilizing CO_2 and giving off oxygen. This finally increases the DO levels. The correlation of DO with water body gives direct and indirect information e.g. bacterial activity, photosynthesis, availability of nutrients, stratification e.t.c. (Premlata Vikal, 2009). In both seasons the levels of DO are lowest in Station C ie 3.1±0.8 Mg/l and 1.5±0.6 Mg/l in the dry and wet seasons respectively. This could be because according to Raburu and Okeyo, (2002), low dissolved oxygen levels could be attributed to reduced water speed or lack of turbulent water movements that could increase the oxygenation. Station C is dominated by papyrus reeds which reduces the water speed and turbulence.
Similarly in both seasons the level of DO increased from Yala swamp (station C) to the exit of Yala Swamp to Lake Sare (station D) e.g. from 1.51±0.57 Mg/l in wet season to 2.63 ± 0.70 Mg/l and from 3.10 ±0.83 Mg/l in dry season to 5.21±0.51 Mg/l. The exit of Yala Swamp to Lake Sare (station D) also contains papyrus reeds but receives waters that have been filtered in Yala swamp (station C). Wetland plants are reported to transfer photosynthetic oxygen to the rhizosphere thus boosting the oxygen concentration in the water column. This could be the reason for the increase in DO values in the two Stations i.e. D and E.

According to Ndubi *et al*. (2015) during the wet season increased water volume could result in lower water temperature and increased DO values a situation that could increase photosynthesis. However, this is not the case from the results obtained in this study where DO values in the dry season are higher than in the wet season hence they disagree (table 4.8). This could be because according to Wetzel, (2001), dissolved oxygen is depleted through chemical oxidation and respiration by aquatic animals and microorganisms especially during decomposition of plant biomass and other organic materials. The quantities of these materials i.e. plant biomass and organic materials are higher in the wet season. The same sentiments are held by Raburu and Okeyo, (2002) that the decomposition of organic substances from the industries and urban centers contributes to the low levels of dissolved oxygen in the water The recommended DO value allowed for domestic water is 6 Mg/l (WHO, 1995) hence all the water in this study did not meet this criterion except at station A (entry of River Yala to Dominion Farms) in the dry season. The seasons had an effect on the levels of DO as indicated by the t-test (Student's t-test p =0.0007).

4.2.9. Turbidity Levels

Data obtained from analysis of turbidity values are represented in Figure 4.5 below.

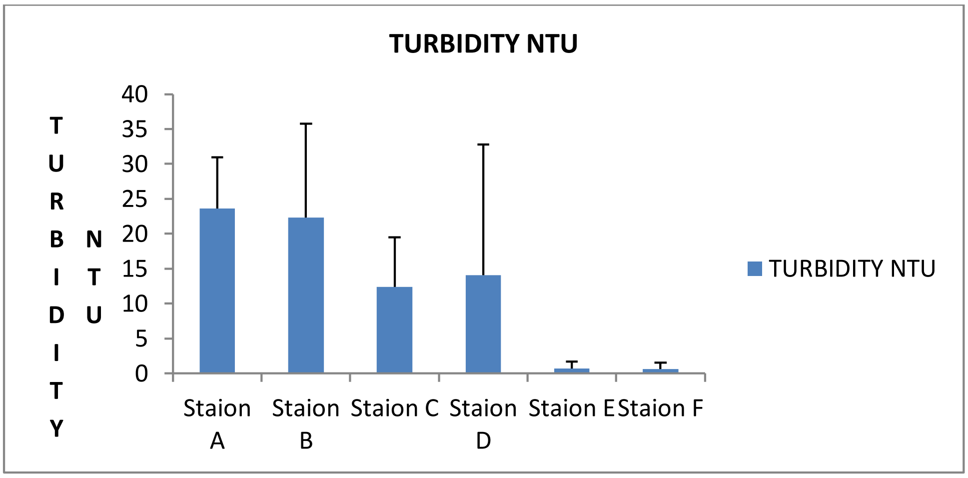


Figure 4.5. Turbidity values in the various stations.

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

Turbidity values varied in the various sampling stations (one-Way ANOVA, $F_{(5,35)} = 41.00014$, $P < 0.0001$). Duncan Multiple Range Test (DMRT) further established that mean turbidity levels for station A (entrance of River Yala to Dominion farms) was significantly different from all other stations and it had the highest mean value 23.64±7.34 NTU. There was a significant difference in mean turbidity values between stations B and C and stations D and E (Figure 4.5). However there were no significant differences in turbidity values between stations C and D and between stations E and F that were lowest.

Turbidity is a measure of the degree to which water losses its transparency due to presence of suspended particulates and the more the TSS the murkier it seems and the higher the turbidity (Amoako *et al*., 2011). In station A, the levels were the highest 23.64±7.34 NTU due to the fact that the waters were in motion with turbulence which increases resuspension of sediments in the water column. This is in agreement with Blackwell *et al*., (2012) that states that during high water flows, water velocities are faster which can stir up and resuspend materials from the River bed causing higher turbidities. Also there are chances that turbidity is high due to the immense agricultural activities taking place in the catchment area that contribute to erosion, storm water runoff and industrial discharges. In station B (exit of River Yala from Dominion Farms) the motion is less making some of the materials to settle but turbidity is still high since waste materials from Dominion farms are added to the water column. In station C (Yala Swamp) turbidity reduces due to the presence of the reeds that increase the residence time and retention of suspended organic materials in their root mass. This also applies to station D (exit of Yala Swamp to Lake Sare). In station E (Lake Sare) and station F (entrance of Lake Sare to Lake Victoria) the turbidity levels are least since most of the materials settle and turbidity was lowest.

According to Amoako *et al*, (2011), a wetland with high vegetation will correspond to low flow rate and low turbidity value. The same opinion is also expressed by Ndubi *et al*., 2015 that a wetland with high vegetation density will correspond to low flow rate and low turbidity values. This further explains the decrease in turbidity values as the water passes through the papyrus reeds in station C and D to get to stations E and finally F (Figure 4.5).

Turbidity for drinking water should not be more than 5 NTU or ideally below 1 NTU (Mackay *et al*., 2006). This implies that the water in all the stations studied were unfit for human consumption except at Lake Sare (station E) and the entrance of Lake Sare to Lake Victoria (station F).

4.2.10. Seasonal variation of turbidity Levels.

Data obtained from analysis of turbidity values in the dry and wet season are represented in table 4.5 below.

Table 4.6. Turbidity values in the Dry and Wet seasons.

Stations	Turbidity in Dry season (NTU)	Turbidity in Wet season (NTU)
A	28.8 ± 1.3^{AB}	18.5 ± 3.4^{A}
B	31.8 ± 3.5^{A}	12.8 ± 0.3^{B}
C	17.4 ± 4.1^{C}	7.3 ± 4.5^{C}
D	27.9 ± 2.9^{B}	0.8 ± 0.5^{D}
E	1.4 ± 0.1^{D}	0.01 ± 0.01^{D}
F	1.3 ± 0.5^{D}	0.01 ± 0.04^{D}
Mean	**18.1±2.1**	**6.57±1.46**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

In the wet season turbidity levels were generally low with the highest mean value recorded at station A (18.5 ± 3.4 NTU) and lowest in station E and F (0.01 ± 0.01 NTU), while during the dry season turbidity levels were higher; with station B recording the highest mean value (31.81 NTU ± 3.15) while station F the lowest (1.29 ± 0.47 NTU) (Table 4.10). There were significant variations in turbidity levels across stations in both the wet (one-Way ANOVA, $F_{(5,35)} = 69.02$, $P < 0.0001$) and dry season (one-Way ANOVA, $F_{(5,35)} = 179.4$, $P < 0.0001$). Duncan Multiple Range Test (DMRT) further established that there were significant differences in turbidity levels at stations B in the dry season and B in the wet season. This was similar to stations D in the dry and in the wet season (Table 4.5). In the remaining stations i.e. A, C, E and F, there was no significant difference in mean turbidity values in the dry and wet seasons. There were significant differences in turbidity levels in the two seasons (Student's T-test P =0.0379).

Turbidity levels were high in the dry season than wet seasons but they reduced from the entry of River Yala to Dominion Farms (station A) to the mouth of Lake Sare to Lake Victoria (station F). This observation in decrease in turbidity from stations A to F in both seasons could also be due to sedimentation as River Yala passes through the wetland which concentrates the ability of wetland to retain sediments. This is consistent with the findings of Mitch and Gosselink, (1993) that the most important role wetlands is that they increase the residence time of water, which means that they reduce the velocity and thereby increase the sedimentation of particles and associated pollutants .At station A the turbidity levels were higher than in any other station in both seasons (Table 4.10) could be because according to Raburu and Okeyo, (2002), high turbidity in the sub catchments is a direct consequence of poor agricultural practices and lack of buffer zone along the River.

Station A and B had relatively high turbidity levels in both seasons could be because as River Yala flows it could be carrying sediments and other particles from runoff. The same opinion is echoed by Akoto *et al*. (2008), that high turbidity could be associated with sediments resulting from soil erosion from farming activities and urban runoff pollution. The other reason could be that the water was in motion with turbulence which increases the amount of suspended materials.

According to Blackwell *et al*., (2012), during high flows, water velocities are faster which can stir up and suspend materials from the river bed causing higher turbidities. In this study turbidity levels are lower in the wet season than the dry season contradicting this statement could be because the area is known to do irrigation using water from weirs and when opened the water velocity becomes much higher which increase turbidity. The high turbidity in the dry season in the study area could also be because most agricultural activities like clearing and ploughing of land in preparation for planting happen at that time which leads to production of a lot of suspended soil and dust in water. This could further be due to low water volume during the dry season compared to the wet season where dilution effect takes place as reported by Blackwell *et al*., (2012). Some solids also dissociate as pH decreases during the dry season. According to Willar *et al*.

(1992), turbidity is caused by the presence of suspended matter in liquid. This explains why it is high in the dry season. The papyrus reeds could also be playing a role in reducing turbidity in the wet season. Additionally, wetlands are expected to have high water flow rates and have an increase in turbidity values during rainy seasons compared to dry seasons as observed by Laskowski, (2002), which makes rainfall amounts an instrument in regulating physical parameters of a wetland ecosystem. But as mentioned earlier this is not the case in this study since other factors come in. A study by Shadrack *et al*, (2015) in Nyando and Nzoia wetlands, there was a remarkable seasonal variation in turbidity values with rainy seasons recording the highest values in all turbidities measured. This also contradicts the findings of this study. The seasons played a role on the turbidity levels as indicated by the T-test (Student's T-test P =0.0379).

4.2.11. Biological Oxygen Demand

Data obtained from analysis of BOD values are represented in Figure 4.6 below.

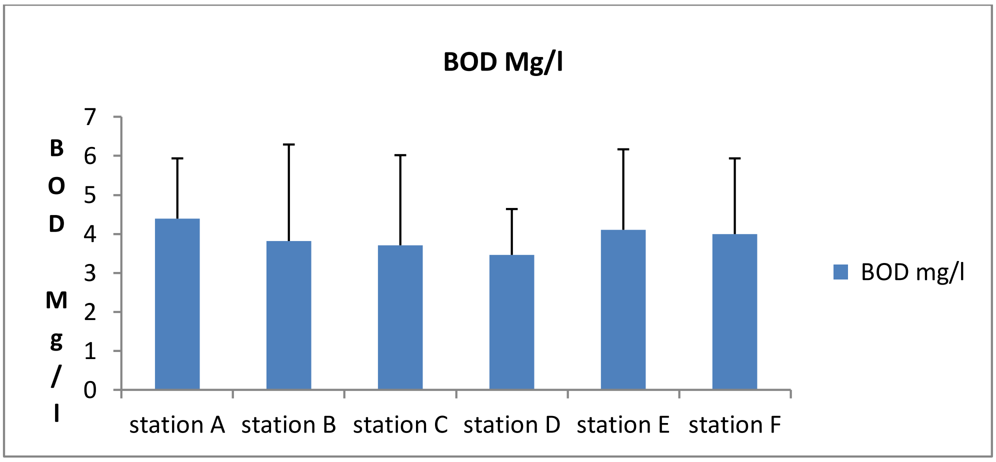


Figure 4.6. BOD values in the various stations.

*Values represent means ±Sd of triplicate analysis.

Note: A=Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The BOD values did not vary significantly between the different sampling sites (one-Way ANOVA, $F_{(5, 23)} = 1.349287$, P = 0.289087). The highest mean BOD value was recorded in station A (4.39 ± 1.54 Mg/l) and the lowest mean BOD value recorded at station D (3.71 ±2.32 Mg/l). DMRT also established that the BOD values did not vary significantly in all the stations (Figure 4.7).

BOD is a measure of the amount of oxygen removed from aquatic environments by aerobic micro-organisms for their metabolic requirements during the breakdown of organic matter (UNEP, 2006). In this study the highest BOD values 4.39±1.54 Mg/l was obtained in station A (River Yala before getting to Dominion farms) Figure 4.6. According to Adenkunle (2008), highest BOD could be due to a high influx of organic material resulting from rain water runoff and animal wastes as they drank water. This could explain the high BOD values at station A as animals from the community around the study area could be seen taking water and probably they would excrete their wastes in the process that would consequently increase BOD levels.

This is an indication of pollution which suggests that River Yala has other sources of pollutants and not just Dominion farms. The average BOD levels for the study area is 3.91± 0.32 Mg/l which further indicates that the area is polluted since according to Sekemo *et al*. (2011), unpolluted waters typically have BOD values of 2 Mg/L O2 or less, whereas those receiving wastewaters may have values up to 10 Mg/l or more, particularly near to the point of wastewater discharge.

4.2.12 Seasonal variation in Biological Oxygen Demand

Data obtained from analysis of BOD values in the dry and wet season are represented in table 4.6 below.

Table 4.6. BOD levels in the Dry and Wet seasons.

Stations	BOD in the Dry season (Mg/l)	BOD in the Wet season (Mg/l)
A	5.49 ± 0.15^{A}	3.30 ± 0.76^{A}
B	5.56 ± 0.09^{A}	2.70 ± 0.84^{A}
C	5.34 ± 0.09^{A}	2.08 ± 0.17^{A}
D	4.29 ± 0.10^{B}	2.63 ± 0.54^{A}
E	5.57 ± 0.12^{A}	2.58 ± 0.68^{A}
F	5.37 ± 0.04^{A}	2.63 ± 0.54^{A}
Mean	**5.27±0.09**	**2.65±0.59**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

Biological oxygen demand levels varied across different stations in the dry season (one-Way ANOVA, $F_{(5,23)} = 90.17$, $P < 0.0001$), In the wet season BOD values did not vary across the different stations (one-Way ANOVA, $F_{(5,23)} = 2.39$, $P = 0.0787$). The BOD levels were low in almost all the stations during the wet season, with the highest value recorded was at station A (3.30 ± 0.76 Mg/l) and lowest at station C (2.08 ± 0.17 Mg/l). In the dry season the BOD values were higher compared to the wet season, with Lake Sare (station C) recording the highest value of 5.57 ± 0.12 Mg/l) and the exit of Yala swamp to Lake Sare (station D) the lowest (4.29 Mg/l ± 0.1) (Table 4.12). DMRT further established that there were significant differences in mean BOD values in stations B in the dry season and station B in the wet season. This was similar to station D and E in the dry and wet season. On the contrary there was no significant difference in mean BOD values in A, C and F in the dry and wet seasons (Table 4.6). However there were significant differences in BOD levels in the dry and wet seasons (Student's t-test P =0.02013)

In the dry season the exit of River Yala from Dominion farms (station B) had a high BOD value 5.56±0.09 Mg/l (Table 4.6). This station receives a lot of pollutants from Dominion farms and according to Adekunle, (2008) high BOD values could possibly be due to a high influx of organic material resulting from runoff and animal wastes. A study by Waziri and Ogugbuaja, (2010) at River Yobe Nigeria had BOD values averaging to 2.77 Mg/l which are close to the findings in this study i.e. 2.55±0.59 Mg/l in the wet season.

High BOD values indicate decline in DO since oxygen is being consumed by the bacteria for respiration leading to inability of other aquatic organisms to survive. Additionally, during the dry seasons, the water volume reduces which carries a low concentration of oxygen. Studies have shown that constructed wetland with similar conditions like Yala Swamp can reduce the concentrations of suspended solids, BOD, nitrogen, phosphorus and coliform bacteria often by 98% (LVEMP 2001). In the dry season there was a drastic drop in the BOD levels from Yala Swamp (station C, 5.34±0.09 Mg/l) to the exit of Yala Swamp to Lake Sare (station D, 4.29±0.1 Mg/l). This could be because the accumulated wastes within the papyrus reeds encourage high microbial activities to take place. These activities break down pollutants from Dominion Farms and organic substances which utilize most of the oxygen leading to systems with high BOD to have low dissolved oxygen concentrations. In this study the stations with high BOD values had low DO values e.g. in the exit of River Yala from Dominion farms (station B) and Yala swamp (station C) in the dry season had DO values of (4.2 Mg/l and 3.1 Mg/l) and high BOD values of (5.56 Mg/l and 5.34 Mg/l respectively). Recommended standard by WHO for BOD should be 1 to 2 Mg/l (WHO, 1995). This shows that all the stations in this study area did not meet the right BOD standards.

The high levels of BOD in the dry season could be explained by Allan, (2004) who noted that nutrient enrichment in streams and Rivers as a result of land use change accelerates litter breakdown rates by bacteria and fungi which eventually increases the BOD levels. Most of these activities like land preparation, planting, and addition of fertilizers take place in the dry season in this study area which justifies the findings of this study.

4.2.13. Total Suspended Solids

Data obtained from analysis of TSS values are represented in Figure 4.7 below.

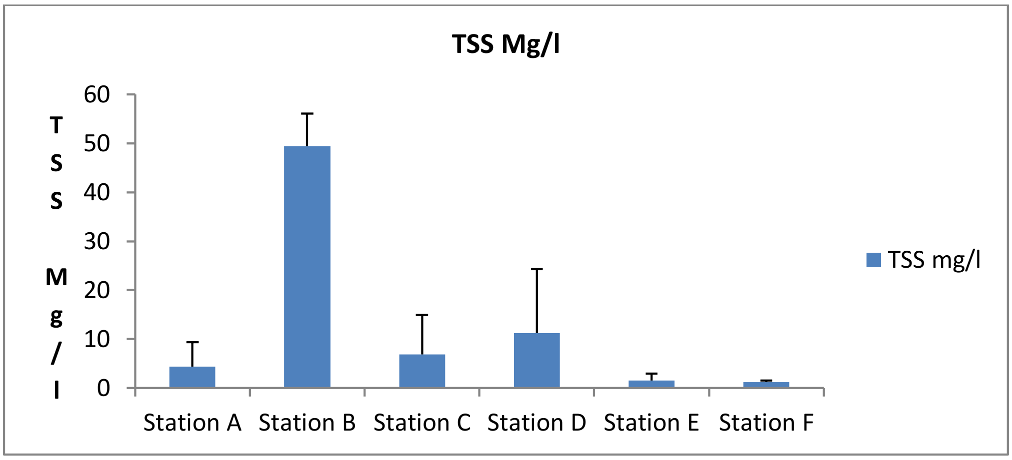


Figure 4.7. TSS levels in the various stations.

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The values of TSS varied among the sampling sites (one-Way ANOVA, $F_{(5,23)} = 542.901$, $P < 0.0001$). The highest mean TSS value 49.18±2.58 Mg/l was recorded at the exit of River Yala from Dominion farms (station B) and the least value 1.20±0.09 Mg/l recorded at the exit of Lake Sare to Lake Victoria (station F). DMRT further established that the mean TSS level in station B was significantly different from any other station. It also established that mean TSS varied significantly between stations B and C, C and D and D and E but there were no significant differences in stations A, C, E and F.

The high TSS levels in River Yala after leaving Dominion farms (station B) could be because of the many activities like farming and pollutants introduced into the waters as River flows in Dominion Farms which include materials like fertilizers, herbicides, fish feeds or runoff of loose soils from cultivated lands. As reported by Palmata (2009), high TSS can result in high sediment supply, discoloration and unclear water appearance. This is exactly how the waters at the exit of River Yala from Dominion farms (station B) appeared. These materials then move to the papyrus reeds (Station C), where they settle and some are broken down by bacteria such that by the time the water gets to Lake Sare (station E) the TSS level is very low as indicated in the figure 4.7.

The high TSS levels could also be caused by coagulation of pollutants and chemicals from Dominion Farms due to chemical reactions. According to Ajao (1990) effluents can introduce some reactions which precipitate more solid in solution leading to high total suspended solids which can decrease downstream due to natural filtration. This could also explain the reduction in the TSS levels from station C to D, E and F. The high TSS levels within the papyrus plants in stations C and D (6.87±7.99 Mg/l and 11.21±13.05 Mg/l respectively) could be because the pollutants and other materials are trapped within the roots of the papyrus plants which increase their levels due to accumulation. Afterwards the TSS levels reduce drastically in station E and F (1.52±1.37 Mg/l and 1.20±.29 Mg/l respectively) which is attributed to the papyrus reeds. The slow motion of the water also encourages settling of sediments which further reduce TSS. The mass of water at stations E and F is also big which can also reduce TSS values by dilution effect.

4.2.14. Seasonal variation of TSS levels.

Data obtained from analysis of TSS values in the dry and wet season are represented in table 4.7 below.

Table 4.7. TSS levels in the Dry and Wet seasons.

Stations	TSS in the Dry season (Mg/l)	TSS in the Wet season (Mg/l)
A	0.71 ± 0.10^{D}	7.89 ± 2.59^{D}
B	2.86 ± 0.18^{A}	96.0 ± 4.24^{A}
C	1.21 ± 0.07^{C}	12.53 ± 1.84^{C}
D	1.98 ± 0.04^{B}	20.44 ± 2.20^{B}
E	0.53 ± 0.09^{D}	2.49 ± 0.35^{E}
F	1.05 ± 0.18^{C}	1.41 ± 0.17^{F}
Mean	**1.39±0.11**	**23.46±1.89**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

There were significant variations in total suspended solids levels across stations in the wet season (one-Way ANOVA, $F_{(5,23)} = 755.11$, $P < 0.0001$). The highest value 96.0±4.24 Mg/l recorded at the exit of Yala from Dominion Farms (station B) and the lowest value 1.41±0.17 Mg/l recorded at the exit of Lake Sare to Lake Victoria (station F). In the dry season the variations in values of TSS in the sampling sites were also significant (one-Way ANOVA, $F_{(5,23)} = 205.7$, $P < 0.0001$). The values were much lower compared to those recorded in the wet season, with the exit of River Yala from Dominion farms (station B) having the highest value of 2.86 Mg/l ± 0.18 and the lowest value 0.53 ± 0.09 Mg/l recorded at Lake Sare (station E) Table 4.7. DMRT established that there were significant difference in mean TSS values between station A in the dry season and station A in the wet season. This was similar to station B, C, D and F in the dry and wet season except between station E in the dry season and E in the wet season where there was no significant difference (Table 4.7). There were no significant differences in TSS levels in the two seasons (Students T-test P =0.17422).

In the study the values of TSS were higher in the wet season than in the dry season. This could be because in the dry season there is a lot of sedimentation as the materials settle while in the wet season other natural processes like erosion, wind and flooding occur which spread the materials as a natural part of the environment as reported by Jessica, (2013). The role of the papyrus in reducing the levels of TSS is quite evident from the results as the levels reduce drastically as the waters pass through the swamp since the materials are trapped by the papyrus roots, some are utilized by the reeds and some just settle. Eventually the water that leaves the reeds is clearer with very low TSS. Studies by Oketch, (2002), at Chemelil constructed wetland in Kisumu and splash constructed wetland in Nairobi revealed drastic reduction in TSS levels i.e. from 1.10Mg/l to 0.04 Mg/l and from 195.4 Mg/l to 4.7 Mg/l respectively. This also applies to this study whereby in both seasons the level of TSS drops as the waters pass through the papyrus plants.

4.2.15. Total dissolved solids

Data obtained from analysis of TDS values are represented in figure 4.8 below.

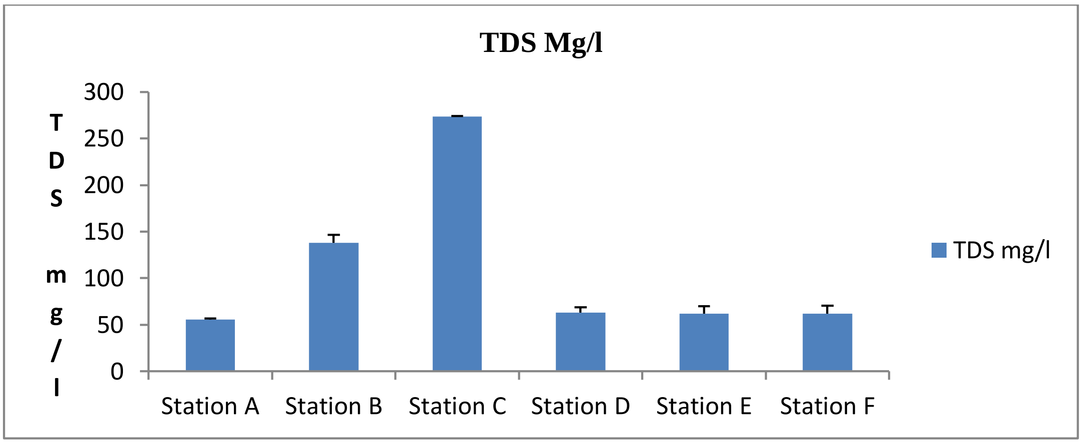


Figure 4.8. TDS levels in the various stations.

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The TDS values varied between the sampling sites (one-Way ANOVA, $F_{(5,41)} = 1589.277$, $P < 0.0001$). The highest mean value 273.58 ± 0.36 Mg/l was recorded at Yala Swamp (station C) and the lowest value 55.83 ± 0.81 Mg/l recorded at the entry of River Yala to Dominion farms (station A). Duncan Multiple Range Test further established that mean TDS value in station C was significantly different from any other station in the study area. There were significant differences in the mean TDS values between stations A and B and B and C while there was no significant difference in mean TDS values in stations A, D, E and F (Figure 4.8).

TDS is a measure of the presence of dissolved salts. In this study the highest levels were recorded in Yala Swamp (station C). The high levels of TDS especially at station C could be because most of the pollutants introduced in River Yala from Dominion farms have been broken down by bacteria into a dissolved state increasing amount of ions in water and also accumulated in the swamp. Most of these dissolved pollutants are absorbed and utilized by the papyrus reeds which leads to a reduction in the levels as the water moves to

Lake Sare as indicated in figure 4.8. According to Raburu and Okeyo, (2002), the occurrence of low TDS, could be ascribed to the provision of adequate vegetation cover around the farms that reduces the soil erosion within these sub-catchments. This is consistent with the findings of this study especially in station D that is occupied by numerous papyrus plants.

A study by Safari *et al*. (2012) in Nyaruzinga wetland Uganda had TDS values ranging from 40.98 to 545.63 Mg/l. These results are higher than the findings of this study and could be because there are more agricultural activities in the wetland than in Yala Swamp.

4.2.16. Seasonal variation in TDS levels.

Data obtained from analysis of TDS values in the dry and wet season are represented in table 4.8 below.

Table 4.8. TDS levels in the Dry and Wet seasons.

Stations	TDS in the Dry season (Mg/l)	TDS in the Wet season (Mg/l)
A	56.4 ± 1.05^{C}	55.25 ± 1.68^{C}
B	75.69 ± 3.41^{B}	199.96 ± 26.13^{B}
C	273.33 ± 8.96^{A}	273.83 ± 8.91^{A}
D	59.18 ± 3.11^{C}	67.37 ± 1.71^{C}
E	56.09 ± 0.32^{C}	67.39 ± 1.50^{C}
F	56.07 ± 0.33^{C}	67.88 ± 0.51^{C}
Mean	**96.13±2.86**	**121.95±6.74**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria

In the wet season, Total dissolved solids (TDS) levels varied significantly across different sampling stations (one-Way ANOVA, $F_{(5,41)} = 463.3$, $P < 0.0001$). The highest value 273.83±8.91 Mg/l was recorded at Yala Swamp (station C) while the least value 55.25± 1.68 Mg/l was recorded at entry of River Yala to Dominion farms (station A). In the dry season, TDS values were relatively lower but also varied significantly (one-Way ANOVA, $F_{(5,41)} = 3099.5$, $P < 0.0001$). The highest (273.33 ± 8.96Mg/l) was also recorded in Yala Swamp (station C) and the lowest value 56.07±0.33 recorded at the entry of Lake Sare to Lake Victoria (station F) Table 4.8. Duncan Multiple Range Test there was no significant difference in mean TDS values between all the stations in the dry and all the stations in the wet season (Table 4.8). There were no significant differences in TSS levels in the two seasons (Students T-test P =0.1875)

In this study the values of TDS are higher in the wet season than in the dry season probably because a lot of agricultural activities takes place in the wet season including addition of fertilizers, use of herbicides to control weeds, use of lime to correct acidity and even the washing away of fish feeds by excess rain water.

According to Raburu and Okeyo, (2002), non-point sources such as nutrients, pesticides, heavy metals and sediments are transported from land by atmospheric, surface water and ground water pathways. Such chemicals and organic materials could increase the TDS levels.

The low TDS recorded afterwards (in stations D, E and F) table 4.8, could be due to settling of silt and dissolved salts as reported by Moshood, (2008) that the settling of silt and dissolved salts in water bodies tend to lower TDS levels. Similarly, according to Markantonatos *et al.*, (1995) high levels of TDS are generally recorded in effluent discharge points and reduce downstream due to the Rivers self-cleansing capacity.

The wet season had high TDS values compared to the dry season in all the stations (table 4.8). This could be because according to Mwangi *et al*. (2012), in the wet season TDS increase due to runoffs from sediments and catchment watersheds that occurs when it rains. In both seasons the TDS levels are highest at station C (Yala Swamp). This could be because the water in station C come from station B which contains a lot of wastes, contaminants and agro chemicals from Dominion Farms. According to Raburu and Okeyo (2002), elevated levels of TDS can be closely linked to the industrial effluent from the factories and agrochemicals. The levels later reduce as the water pass through the papyrus reeds in station D and the reducing trend goes on until it is least at stations E and F (Table 4.8). This could be because some of the dissolved solids are utilized by the papyrus plants. It can also be attributed to dilution effect. The TDS values were within allowable limits for drinking water as they were not exceeding above 500 Mg/l (WHO.1995).

4.3 Nutrients

4.3.1. Nitrates in water and sediments.

Data obtained from analysis of nitrate values in water and sediments are represented in table 4.9 below.

Table 4.9. Nitrate levels in water and sediments in the various sampling stations.

Stations	Nitrates in water (Mg/l)	Nitrates in sediments (Mg/l)
A	1.86 ± 0.02^{B}	1.40 ± 0.64^{D}
B	1.82 ± 0.06^{B}	1.74 ± 0.04^{A}
C	1.74 ± 0.05^{C}	1.64 ± 0.13^{B}
D	1.67 ± 0.01^{D}	1.67 ± 0.06^{B}
E	1.97 ± 0.07^{A}	1.62 ± 0.15^{B}
F	1.66 ± 0.09^{D}	1.58 ± 0.04^{C}
MEAN	**1.79±0.05**	**1.61±0.18**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

Nitrate values in water varied in the various stations (one-Way ANOVA, $F_{(5, 23)} = 10.16071$, $P = 0.000249$). The highest mean Nitrate value (1.97 ± 0.07 Mg/l) was recorded in Lake Sare (station E) and the lowest value (1.66 ± 0.09 Mg/l) recorded at the exit of Lake Sare to Lake Victoria (station F) (Table 4.9). Duncan Multiple Range Test further established that mean nitrate level in station C was significantly different from any other station in the study area. There were significant differences in the mean nitrate values between stations C and D and between stations E and F while there were no significant differences between stations A and B and between stations D and F (Table 4.9).

Nitrate values in sediments varied in the various stations (one-Way ANOVA, $F_{(5, 23)} = 3.287412$, $P = 0.02777$). The highest mean Nitrate value 1.74 ± 0.04 Mg/l recorded in the exit of River Yala from Dominion farms (station B) and the lowest value 1.40 ± 0.64 Mg/l recorded at the entry of River Yala to Dominion farms (station A) (Table 4.9). Duncan Multiple Range Test further established that the mean Nitrate level in sediments in station B was significantly different from any other station in the study area. It also established that there was a significant difference in mean nitrate levels between stations A and B and between stations E and F while there were no significant differences in stations C, D and E.

In this study it can be noted that the levels of nitrates are higher in River Yala both before and after draining to Dominion farms than within the papyrus reeds i.e. 1.86±0.02 Mg/l in station A, 1.82 ±0.06 in station B and 1.74±0.05 in station C (Table 4.9). This could be because as water moves there is turbulence and agitation that releases the nitrates trapped in the sediments which mix in the water column. According to Boqiagn *et al*. (2004), after degradation of organic matter, the nutrient is separated out and comes into the pure water where because of wave and wind forces the sediments are re-suspended. The nutrient in pure water then leaks into the super adjacent waters accordingly. This also explains the high mean nitrate levels in water in Lake Sare (station E) 1.8 Mg/l when the water has just left Yala Swamp (Table 4.9). Generally acceptable ranges of total Nitrates are 2 to 6 Mg/l (Brian *et al*., 2001). This indicates that the levels in this study area are within acceptable range. The high levels of nitrates in station A could also be attributed to livestock wastes as they would occasionally come to drink water and in the process release their wastes. This was not possible in the other stations as they were protected by papyrus plants. This is consistent with findings of Schepers and Fransis (1982) who reported that livestock wastes deposited in or near rivers or entrained or dissolved in runoff often contributed to Nitrogen, Phosphorus and other nutrients in streams. In this study the stations with the highest DO levels also had the highest levels of nitrates like at River Yala before draining in Dominion farms (station A) (table 4.4 and 4.9).

According to Boquiagn *et al*. (2004), the content of dissolved oxygen (DO) at the water sediment interface is the main factor that affects the degradation of nitrate and its outcome. This explains the high levels of nitrates in this station A and low levels within the papyrus plants, station C and exit of Yala Swamp to Lake Sare, station D, where DO is low.

4.3.2 Seasonal variation of Nitrate levels in water and sediments

Data obtained from analysis of nitrate values in water and sediments in the dry and wet season are represented in table 4.10 below.

Table 4.10. Nitrate levels in water and sediments during the dry and wet seasons

	Nitrates in water (Mg/l)		Nitrates in sediments (Mg/l)	
Sampling sites	**Dry season**	**Wet season**	**Dry season**	**Wet season**
A	1.6 ± 0.01^{B}	2.2 ± 0.1^{A}	1.4 ± 0.1^{B}	1.4 ± 0.4^{B}
B	1.6 ± 0.01^{B}	2.1 ± 0.02^{A}	1.5 ± 0.3^{A}	2.01 ± 0.1^{A}
C	1.4 ± 0.01^{C}	2.1 ± 0.1^{A}	1.3 ± 0.2^{B}	2.04 ± 0.1^{A}
D	1.4 ± 0.02^{C}	1.9 ± 0.2^{A}	1.1 ± 0.1^{B}	2.2 ± 0.5^{A}
E	1.8 ± 0.02^{A}	2.1 ± 0.2^{A}	1.6 ± 0.1^{A}	1.7 ± 0.2^{B}
F	1.4 ± 0.03^{C}	1.9 ± 0.2^{A}	1.1 ± 0.1^{B}	2.0 ± 0.04^{A}
MEAN	**1.5±0.02**	**2.1±0.2**	**1.3±0.15**	**1.89±0.22**

***Means with different superscripts in the same column are significantly different at P<0.05. (Data analyzed by Duncan's Multiple Range Test).

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria

Nitrate levels in water did not show significant variation during the wet season across the different stations (one-Way ANOVA, $F_{(5, 23)} = 2.01$, P = 0.1264. The highest value 2.2 ± 0.1 Mg/l was recorded at the entry of River Yala to Dominion farms (station A) and lowest value1.90 ± 0.2 Mg/l recorded at the exit of Yala swamp to Lake Sare (station D) and at the entry point of Lake Sare to Lake Victoria (station F).

The nitrate levels varied in the dry season across the different stations (one-Way ANOVA, $F_{(5, 23)} = 335.0$, $P < 0.0001$). Nitrate values in water in the dry season were much lower than those recorded in the wet season with the highest mean 1.8 ±0.02 Mg/l recorded at Lake Sare (station E) and the lowest value 1.4±0.01 Mg/l recorded at Yala Swamp (station C), (Table 4.10). DMRT further established that there were significant differences in mean Nitrate values in water between all the stations in the dry and wet seasons except between station E in the dry season and E in the wet season (Table 4.10). There were significant differences in the level nitrates in sediments in the two seasons. (Students t-test, P =0.000249).

Nitrate levels in sediments varied across different stations in the wet season (one-Way ANOVA, $F_{(5, 23)} = 8.44$, P = 0.0003). The exit of Yala Swamp to Lake Sare (station D) recorded the highest value of nitrates in sediments (2.20 ± 0.5 Mg/l) while the entrance of River Yala to Dominion farms (station A) recorded the lowest nitrate value in sediments (1.40 Mg/l ± 0.40). In the dry season the nitrate values in sediments also varied (one-Way ANOVA, $F_{(5, 23)} = 13.24$, $P < 0.0001$). The highest mean value recorded for nitrates in sediments 1.60 ± 0.1 Mg/l was at Lake Sare (station E) while the lowest value recorded 1.1 ± 0.10 Mg/l was at the exit of Yala Swamp to Lake Sare (station D) and at the entry of lake Sare to Lake Victoria (Station F) (Table 4.10). DMRT established that there was a significant difference in mean nitrate values in sediments between stations A in the dry season and station A in the wet season. This was similar to station B in the dry season and station B in the wet season. However, there was no significant difference in mean nitrate levels between the remaining stations in the dry and wet season. There were significant differences in the level nitrates in sediments in the two seasons. (Students t-test, P =0.02498).

From the study the levels of Nitrates in water were higher in the wet season than in the dry season. This could be because most agricultural activities take place in the catchment area during the wet season like planting, addition of fertilizers or herbicides, liming among others, which increase the level of nitrates in the runoff. In the dry season such activities are less and the station within the papyrus plants (station C) had the least Nitrate levels (1.4±0.01 Mg/l) since the papyrus reeds and other plants utilize most of the nitrates in the waters to make proteins.

According to Markantonatos *et al.* (1995) and Moreau *et al.* (1998) seasonality in the concentration of nutrients, particularly in agricultural areas is common with peaks being recorded during high flow periods. This explains the high levels of nitrates in water in the wet season. High flows usually occur when fields lack vegetation cover and nitrate-nitrogen for instance gets easily leached from the soil. Inorganic nitrogen forms are subject to biological transformations that increase with increasing temperature (Davies and Keller, 1983). Seasonality in nutrient levels can be attributed to the deposition in the sediments during low flow periods and resuspension and transportation during high flow periods. This explains the low nitrate levels in sediments during the dry season and high levels during the wet season.

According to Sundaravadivel, (2001), nitrogen in wetlands can also be removed by nutrient uptake of plants. The plants uptake nitrogen in the form of ammonium or nitrate, which is then stored in the plant in the organic form. This explains why in the dry season both in water and sediments the levels of nitrates reduced significantly in the waters within the papyrus plants in stations C and D then afterwards the levels increase in station E that lacks the papyrus plants (table 4.10). The levels thereafter increase in station F that is also surrounded by papyrus plants depicting that the reeds use up the nitrates for their growth and development. In the wet season the trend is similar in water but not in sediments and could be because during such seasons the high volume of water may transport nutrients from other areas due to run off and settle in sediments leading to the higher levels recorded.

According to Tanner, (2011) and Kadlec, (2012), wetlands have been demonstrated to be an effective means to attenuate nitrogen derived from diffuse water pollution by plant and periphyton uptake and microbial denitrification. From studies papyrus seems to promote greater nitrogen removal efficiencies through nitrification and denitrification rates of bacterial associated with its roots as reported by Morgan *et al*., (2008). Denitrification is an anoxic biological process which involves the reduction of nitrate to nitrite to molecular nitrogen (Gonzalez *et al.*,2011). The energy required for this reduction comes from inorganic or organic compounds oxidation. Optimum pH range for denitrification is reported to be between 7.0 and 8.5 (Kadlec *et al*., 2000; Britton, 1999; Metcalf and Eddy, 2003; Gerald, 2002) and it is highly temperature dependent with reaction rates significantly reduced at temperatures below 5 ^{0}C. In this study the pH values range between 7.3 to 8.1 and temperatures range between 23.60 to 29.05 ^{0}C which justifies the fact that denitrification is taking place.

In some wetlands, studies have shown that denitrification is the dominant nitrate removal mechanism (Kadlec, (2012), Davidsson, (2000) and Matheson *et al.* (2002). However, microbial activity, which controls denitrification rates, can be reduced at low temperatures Xu *et al.* (2016). This is consistent with the findings of this study where the levels of nitrates are higher in the wet season than the dry season both in water and sediments since as explained denitrification rates are low at low temperatures and so more nitrates become available. Similarly, according to Kadlec, (2012), in line with these seasonal differences in wetlands, nitrogen removal performance is widely reported with reduced rates measured at colder temperatures.
The high levels of nitrates in the rainy season in water is in agreement with Wolfhard and Reinhard, (1998) who concluded that nitrates are usually built up during dry seasons then the initial rains flush out deposited nitrate from near surface soils and nitrate level reduces drastically in sediments and increases in water as rainy season progresses.

4.3.3. Phosphates in water and sediments.

Data obtained from analysis of phosphate values in water and sediments are represented in table 4.11 below.

Table 4.11. Phosphate levels in water and sediments.

Stations	Phosphates in water (Mg/l)	Phosphates in sediments (Mg/l)
A	0.07 ± 0.01^{AB}	0.08 ± 0.01^{AB}
B	0.31 ± 0.05^{A}	0.12 ± 0.05^{A}
C	0.03 ± 0.07^{B}	0.03 ± 0.03^{B}
D	0.38 ± 0.51^{A}	0.16 ± 0.01^{A}
E	0.02 ± 0.06^{B}	0.02 ± 0.01^{B}
F	0.02 ± 0.01^{B}	0.06 ± 0.01^{B}
MEAN	**0.14±0.11**	**0.08±0.02**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

Phosphate values in water varied significantly in the various stations (one-Way ANOVA, $F_{(5, 23)} = 21.77999$, $P < 0.0001$). The highest mean phosphate value 0.38 ± 0.51 Mg/l was recorded in the exit of Yala swamp to

Lake Sare (station D) and the lowest value 0.02 ± 0.01 Mg/l was recorded at the exit of Lake Sare to Lake Victoria (station F). Duncan Multiple Range Test further established that there were significant differences in the mean phosphate values in stations B and C, B and E and B and F while there were no significant differences in mean phosphate values in stations C, E and F. Station A was not significantly different from all other stations. (Table 4.11).

Phosphate values in sediments varied significantly in the various stations (one-Way ANOVA, $F_{(5, 23)}$ = 13.77161, $P < 0.0001$). The highest mean phosphate value in sediments 0.16 ± 0.01 Mg/l recorded in the exit of Yala swamp to Lake Sare (station D) and the lowest value 0.02 ± 0.01 Mg/l recorded at Lake Sare (station E). Duncan Multiple Range Test further established that there were significant differences in the mean phosphate values in stations B and C and C and D while there were no significant differences in stations B and D and in stations C, E and F. Station A was not significantly different from all other stations. (Table 4.11).

The levels of phosphates were generally low both in water and sediments in the study area but despite that they surpassed the permissible levels in drinking water since according to US public Health standards the permissible level for phosphates in drinking water is 0.1 Mg/l (Di, 2002). This indicates that it is not fit for human consumption. The drastic drop in the levels on phosphates from stations B to C both in water and sediments (table 4.11) could be because adsorption of phosphorus was taking place within the papyrus reeds. According to Verhoeven (1999), adsorption of phosphorus is the most important phosphorus removal process in the wetlands. Adsorption of phosphorus occurs due to reactions with iron, calcium and magnesium present in sediments to form stable complexes. Similarly this opinion is also consistent Sundaravadivel, (2001) that decomposition of litter (dead plants) and organic matter in the wetland also takes up phosphorus. This process results in storage of phosphorus in the organic matter which will be released eventually. Growing plants take up nutrients like phosphorus, thereby reducing levels in the wetland.

The highest levels of phosphate were observed at station D both in water and sediments and this could be because according to White *et al*. (2004) and Corstanje *et al*. (2006) vegetation can act as short-term phosphorus storage, which can rapidly release 35 to 75% of the total plant-associated phosphorus during senescence, potentially increasing the water phosphorus concentrations. The area is dominated by papyrus plants which make up the high vegetation density.

The levels of phosphates were lower in sediments could be because according to Håkanson and Jansson (1996), large amounts of phosphates entering water bodies eventually settle down in sediments. Later, Kuo (1996) noted that, once the phosphates reach the bottom of a water body, physiochemical and biological processes in sediments act in concert and regulate phosphate solubility, which in turn affects surface water. This eventually increases its concentration in water.

According to Welch, (1980), a water body is considered as eutrophic if total phosphate value ranged between 20- 30 Mg/l. The value in this study fluctuates between 0.02 to 0.4 Mg/l (Table 4.19), which is much below this level which indicates that it is not eutrophic. In both water and sediments the phosphate levels reduce drastically from station D to E (Table 4.11). This could be because some of the phosphates are utilized by the papyrus plants in station D for their growth and development leading to the declining levels in station E.

4.3.4 Seasonal variation of Phosphate levels in water and sediments

Data obtained from analysis of phosphate values in water and sediments in the dry and wet season are represented in table 4.12 below.

Table 4.12. Phosphate levels in water and sediments in the Dry and Wet seasons.

	Phosphates in water (Mg/l)		Phosphates in sediments (Mg/l)	
Sampling sites	**Dry season**	**Wet season**	**Dry season**	**Wet season**
A	$0.10{\pm}0.01^{C}$	$0.1{\pm}0.03^{A}$	$0.09{\pm}0.01^{B}$	$0.1{\pm}0.03^{B}$
B	$0.58{\pm}0.10^{A}$	$0.1{\pm}0.03^{A}$	$0.05{\pm}0.02^{C}$	$0.2{\pm}0.13^{A}$
C	$0.04{\pm}0.01^{D}$	$0.04{\pm}0.01^{AB}$	$0.03{\pm}0.01^{CD}$	$0.04{\pm}0.01^{B}$
D	$0.29{\pm}0.01^{B}$	$0.03{\pm}0.02^{B}$	$0.27{\pm}0.02^{A}$	$0.04{\pm}0.01^{B}$
E	$0.02{\pm}0.01^{D}$	$0.02{\pm}0.001^{B}$	$0.02{\pm}0.01^{D}$	$0.02{\pm}0.01^{A}$
F	$0.01{\pm}0.01^{D}$	$0.02{\pm}0.002^{B}$	$0.09{\pm}0.01^{B}$	$0.03{\pm}0.01^{AB}$
MEAN	**0.17±0.01**	**0.05±0.01**	**0.09±0.01**	**0.07±0.03**

*Means with different superscripts in the same column are significantly different at P<0.05. (Data analyzed by Duncan's Multiple Range Test).

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria

There were significant differences in mean phosphate levels in water in the various stations in the dry season (one-Way ANOVA, $F_{(5, 23)} = 71.57$, $P < 0.0001$). In the wet season there were no significant variation in mean phosphate values in water across the different stations (one-Way ANOVA, $F_{(5, 23)} = 2.32$, $P = 0.0855$). DMRT also established that there were significant differences in mean phosphate values between the stations in the dry season and in the wet season except between station B in the dry and B in the wet season and between station D in the dry and wet season (Table 4.12). There were no significant differences in phosphate levels in water in both seasons (Students t-test, p =0.1772).

In sediments, Phosphate levels varied significantly across stations in the wet season (one-Way ANOVA, $F_{(5,23)} = 5.11$, $P < 0.0043$). In the dry season the values also varied significantly (one-Way ANOVA, $F_{(5,23)} = 164.06$, $P < 0.0001$). DMRT established that there were significant differences in mean phosphate value between the stations in the dry and wet season except between station A in the dry and wet season and station F in the dry and wet season (Table 4.12). There were also no significant differences in phosphate levels in water in both seasons (Students t-test, p =0.60674).

According to Gatcher *et al*, (1988), the sufficient supply of oxygen in favor of oxidation of elements in water e.g. Fe, Mn e.t.c. enhances their absorption at sediment water interphase and finally retards the release of phosphates to overlaying water. This explains the low mean phosphate levels especially in the wet seasons (Table 4.12) since the swamp is well oxygenated especially during this season with DO levels ranging from 3.10 to 6.09 Mg/l. During the dry season the mean levels of phosphates in sediments are higher than during the wet season as indicated in table 4.20. This is so because according to Odada *et al*., (2004), the largest contribution of nutrients emanates from River flow and run-off, which constitute more than 50% with atmospheric contribution making 40%. This means that direct land activities mainly farming which mostly takes place in the dry season could be responsible for high nutrient load which includes phosphates into the lake. Most run off take place during the rainy season and most papyrus reeds which create a buffering capacity have been destroyed in Yala Swamp to give room for farming.

Similarly, the study by Nnaji *et al*. (2011) in River Galma, Nigeria had high phosphate values of 4.96 Mg/l in water and 7.55 Mg/l in sediments probably due to high agricultural activities but the area lacks papyrus plants to help in remediating their levels. In this study levels are quite low which could be because of the presence of papyrus plants that reduce their levels after utilizing them. This is evident as the levels reduce from the exit of River Yala from Dominion farms (station B) to the exit of Lake Sare to Lake Victoria (station F) especially in the dry season (Table 4.12).

Phosphates also exist as orthophosphates which when applied to agricultural cultivated land as fertilizers may be carried into surface waters with storm runoff (Franson, 1995). This explains the higher levels of phosphates in water than in sediments in both seasons. In this study seasons did not affect the levels of phosphates in water and sediments (Students t-test, p = 0.177234 and p =0.60674 respectively).

4.4. Heavy metals in water and sediments during wet and dry seasons

4.4.1. Lead levels in water and sediments

Data obtained from analysis of lead values in water and sediments are represented in table 4.13 below

Table 4.13. Lead levels in water and sediments.

Stations	Lead in water (Mg/l)	Lead in sediments (Mg/l)
A	$2.67{\pm}0.06^{B}$	$2.65{\pm}0.03^{B}$
B	$4.25{\pm}0.02^{A}$	$1.98{\pm}0.03^{C}$
C	$1.63{\pm}0.10^{C}$	$3.30{\pm}0.08^{A}$
D	$1.65{\pm}0.04^{C}$	$3.12{\pm}0.19^{A}$
E	$2.37{\pm}0.22^{B}$	$2.45{\pm}0.15^{B}$
F	$1.51{\pm}0.02^{C}$	$2.14{\pm}0.06^{B}$
MEAN	**2.34±0.08**	**2.61±0.09**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

Lead levels in water varied significantly in the various stations (one-Way ANOVA, $F_{(5, 17)} = 29.92468$, $P < 0.0001$). The highest value 4.25 ± 0.02 Mg/l recorded in the exit of River Yala as it leaves Dominion farms (station B) and the lowest value 1.51 ± 0.02 Mg/l recorded at the exit of Lake Sare to Lake Victoria (station F). Duncan Multiple Range Test established that the mean lead values in station B was the highest and was significantly different from any other stations in the study area. It further established that there were significant differences in mean lead values between stations A and B, B and C and between stations D and E, while there were no significant differences in stations C, D and F and between station A and E (Table 4.13) above.

Lead levels in sediments also varied significantly (one-Way ANOVA, $F_{(5, 17)} = 69.03234$, $P < 0.0001$). The highest mean lead value 3.30 ± 0.08 was recorded at Yala Swamp (station C) and the lowest value 1.98 ± 0.03 recorded at the exit of River Yala as it leaves Dominion farms (station B). DMRT established that mean lead value in sediments in station B was significantly different from any other station in the study area. It also established that there were significant differences in mean lead values between stations A and B, B and C and D and E while there were no significant differences in stations A, E and F and between stations C and D (Table 4.13).

The levels of lead in water were highest in River Yala after leaving Dominion Farms station B (4.25±0.02 Mg/l). This could be because the station is a source of most pollutants since the waters come directly from Dominion farms. As mentioned earlier the Dominion Farms has a rice milling industry, fish rearing farms among whose effluents are discharged directly in the waters. The fertilizers, pesticides, herbicides, fish feeds and other chemicals from the farm could contain some traces of lead hence its high levels in this water.

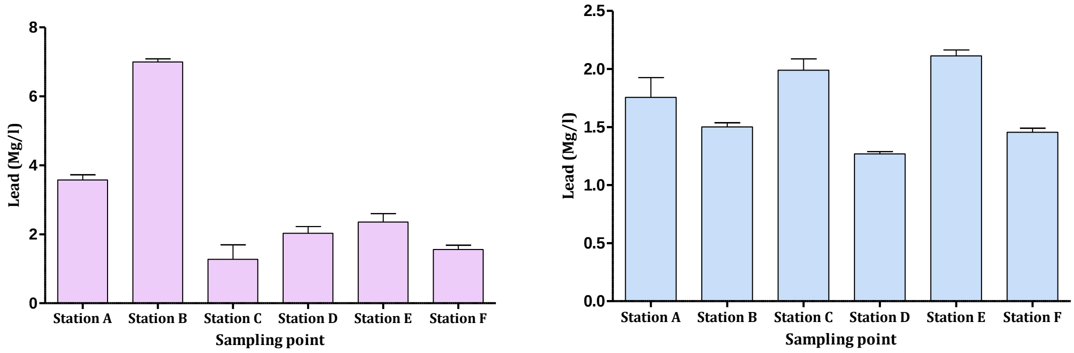
At the same station in sediments the levels of lead are lowest (table 4.13). This could be because according to Kirmani *et al*. (2011), mobility of lead is greater in sandy soils which tend to lack organic matter than organic matter soils. At station B the soils have a high level of organic matter due to many pollutants deposited in it that undergo decomposition. Afterwards the levels of lead decrease gradually from station B to F (Table 4.21) above. This could be attributed to dilution effect from runoff as well as the absorption by plants and sediments in the River Yala (Kithiia, 2006; Kar *et al*., 2008).

The Pb levels in sediments were generally higher than in water (Table 4.21). According to Obasohan, (2008) and Kar *et al*. (2008), the presence of lead and other heavy metals in sediments could be attributed to discharge of industrial effluents and municipal wastes, geology of River bed and catchment area. In stations C and D the levels in sediments were exceedingly high 3.30±0.08 Mg/l and 3.12±0.19 Mg/l respectively (Table 4.13). This could be because in these stations there is the presence of papyrus plants that reduce speed of flow of water hence the lead in water settle in the sediments and some are trapped by the roots of the papyrus plants. According to Oztürk *et al*. (2009), sediments are important sinks for various pollutants such as pesticides and heavy metals and play significant role in remobilization of contaminants in aquatic systems under favorable conditions. In a study by Muwanga and Barifaigo, (2006) in Thruston Bay a wetland in Tanzania the levels of lead in water samples ranged from 0.01 to 0.26 Mg/l. This values are quite low compared to the ones in this study could be because it less polluted. A similar study done in Yala swamp by Ogoyi *et al.,* 2009 obtained lead values in water ranging from 0.01 to 1.622 Mg/l which are also lower than the values in this study and it could be that the water samples were taken in areas not affected by contaminants from Dominion Farms.

According to USEPA, (2010), the recommended maximum contaminant level (MCL) for lead is 0.0015 Mg/l hence the area has surpassed this level (Table 4.13). The agency has classified lead as being potentially hazardous and toxic to most forms of life. It has been found to be responsible for chronic neurological disorders in fetuses and children especially when it greater than 0.1 Mg/l as is the case in this study where the mean is 2.34±0.08 Mg/l and 2.61±0.09 Mg/l in water and sediments respectively (Table 4.13).

4.4.2. Seasonal variation of lead levels in water and sediments

Data obtained from analysis of lead values in water and sediments in the dry and wet season are represented in Figure 4.9 below.



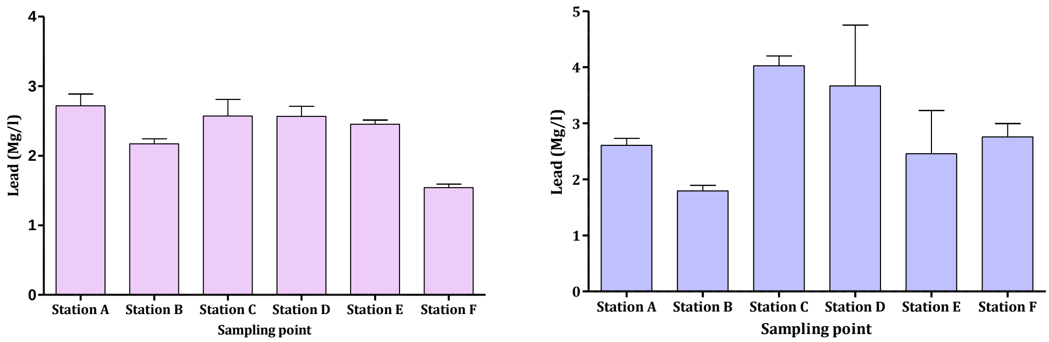
Wet season   Dry season

Figure 4.9. **Lead levels in water in the Wet and Dry seasons.**

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The levels of lead in water varied significantly in the dry season (one-Way ANOVA, $F_{(5,17)} = 39.92$, $P < 0.0001$). The levels of lead in water were generally higher in the wet season than in the dry season. In the wet season, the values also varied significantly (one-Way ANOVA, $F_{(5,\ 17)} = 174.18$, $P < 0.0001$). The highest lead level in water was 7.0±0.04 Mg/l recorded at the exit of River Yala from Dominion farms (station B), while the lowest was 1.3±0.2 Mg/l recorded within the papyrus reeds (station C) (Figure 4.9). DMRT established that there were significant differences in mean lead values between all the stations in the dry season and in the wet season except between stations A in the dry and wet season. There were no significant differences in the mean levels of lead in water in the two seasons (Students T-test P=0.216)



Wet season   Dry season

Figure 4.10. **Lead levels in sediments in the Wet and Dry seasons**

Considering sediments, there were significant differences in lead levels in sediments during the wet season (one-Way ANOVA, $F_{(5,17)} = 174.18$, $P < 0.0001$) and the dry season (one-Way ANOVA, $F_{(5,17)} = 39.92$, P <

0.0001) Lead levels were higher in the dry season than in the wet season (Table 4.22). The highest level (4.0±0.7 Mg/l) in the dry season was recorded in Yala Swamp (station C) and lowest value (1.8±0.04 Mg/l) recorded at the exit of River Yala from Dominion farms (station B). During the wet season, lead levels were highest at the entry of River Yala to Dominion farms (station A) 2.72±0.07 Mg/l and lowest value 1.5±0.02 Mg/l recorded at the exit Lake Sare to Lake Victoria (station F) Figure 12. DMRT established that the mean lead values in sediments varied significantly between stations A in the dry season and A in the wet season. This was similar to station F in the dry season and F in the wet season. In the remaining stations there were no significant differences between the wet and dry seasons (Figure 4.10). There were also no significant differences in mean sediment values in the two seasons (Students T-test P =0.1526)

From the study the levels of lead in water were higher in the wet season than in the dry season (Figure 4.9). This could be because according to Larsmann and Nambisan, (1983) increased precipitation which lowers water pH and alkalinity switches on the process of dissolution of metallic compounds from sediment compartment to aquatic column resulting in increase of dissolved heavy metals and decrease of biologically available heavy metals during the dry season. Similarly, according to Kiithia, (2006) the concentration of heavy metals has been found to decrease down the River due to dilution effect as the water volume increases. The high water volume in the wet season seemed to reduce lead levels. Chronic low level intakes of heavy metals have adverse effects on human beings and other animals due to the fact that there is no effective mechanism for their elimination from the body (Bahemuka and Mubofu, 1999). Metals such as lead, mercury, cadmium and copper are cumulative poisons. These metals cause environmental hazards and are reported to be exceptionally toxic (Ellen *et al*., 1990). For this reason, the adjacent factories such as Dominion group of companies need to be thoroughly investigated and caution taken.

4.4.3. Copper levels in water and sediments

Data obtained from analysis of copper values in water and sediments are represented in table 4.14 below.

Table 4.14. Copper levels in water and sediments

Stations	**Copper in water (Mg/l)**	**Copper in sediments (Mg/l)**
A	0.03 ± 0.01^{D}	0.76 ± 0.01^{B}
B	0.35 ± 0.01^{A}	0.50 ± 0.01^{C}
C	0.24 ± 0.03^{B}	0.91 ± 0.01^{A}
D	0.19 ± 0.01^{C}	0.65 ± 0.26^{B}
E	0.36 ± 0.01^{A}	0.27 ± 0.03^{D}
F	0.23 ± 0.01^{B}	0.36 ± 0.02^{D}
MEAN	**0.23±0.01**	**0.58±0.02**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan’s Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The levels of copper in water varied significantly in the various stations (one-Way ANOVA, $F_{(5,17)}$ = 89.7437, P < 0.001). The highest value 0.36 ± 0.01 Mg/l recorded in Lake Sare (station E) and the lowest value 0.03 ± 0.01 Mg/l recorded at the entry of River Yala to Dominion Farms (station A). Duncan Multiple Range Test established that station A was significantly different from any other station. It also established that there were significant differences in the mean copper values in all the stations except between stations B and E and between stations C and F (Table 4.14).

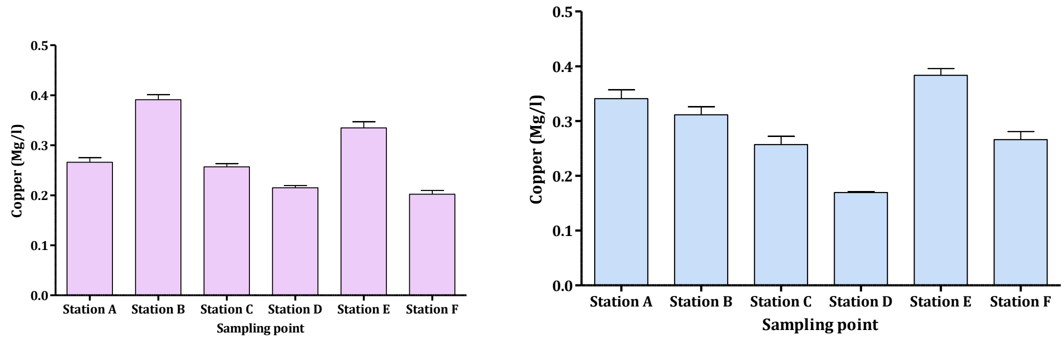
Copper levels in sediments also varied significantly (one-Way ANOVA, $F_{(5, 17)}$ = 10.4647, P < 0.0001). The highest value 0.91 ± 0.01Mg/l was recorded at Yala Swamp (station C) and the lowest value 0.27± 0.03Mg/l recorded at Lake Sare (station E). DMRT established that station C was significantly different from any other station. It further established that there were significant differences in mean copper values in sediments between stations A and B, B and C, C and D, and D and E while there were no significant differences between station A and D and E and F. (Table 4.14).

Although copper toxicity in humans is rare, aquatic organisms are potentially at risk from Cu exposures (Adriano, 2001). Given that areas showing high Cu concentrations are in Yala swamp, mitigation measures are required to reduce Cu inflow into lake Sare and later Lake Victoria. The Cu analyses in the present study are within acceptable range given that the average Cu content in soils/sediments is considered to be about 3 Mg/l (USEPA, 1986). The levels of copper in water were an average of 0.23±0.01Mg/l and 0.58±0.02 Mg/l in sediments which is below the maximum limits hence safe. In water Cu has been noted to be exceedingly toxic to Aquatic biota in contrast to low toxicity in mammalian consumers of water. The greater sensitivity of most Aquatic biota could be as a result of high surface to volume ratios of algae and highly permeable gill to surface area in various fish species that facilitates rapid uptake of large amounts of copper (Vulkan *et al* .,2000). In a study by Fredrick *et al*., (2011) in Lake Victoria catchment where Yala swamp is included, the values of copper ranged from 0.001 to 0.014 Mg/l. These values are very low compared to the values obtained in this study (Table 4.14). This could be because the areas affected by contaminants from Dominion Farms were not sampled as in the case of this study.

Although copper is an essential element for all life, at high concentrations it is potentially toxic to soil microorganisms and higher plants (Vulkan *et al*., 2000). From the study the levels of copper are higher in sediments than in water (Table 4.14) and these mean levels are highest in stations C and D that are dominated by papyrus plants. This could be because they are being absorbed and some retained around the root region on the papyrus plants leading to the high levels within the Swamp. According to Eimers *et al*., 2001 sediments associated with heavy metals pose a direct risk to deposit feeding and detrital benthic organisms and may also represent long term sources of contamination to higher trophic levels. For this reason, continual assessment of sediments is very essential.

4.4.4 Seasonal variation of copper levels in water.

Data obtained from analysis of copper values in water and sediments in the dry and wet season are represented in Figure 4.11 below.



Wet season Dry season

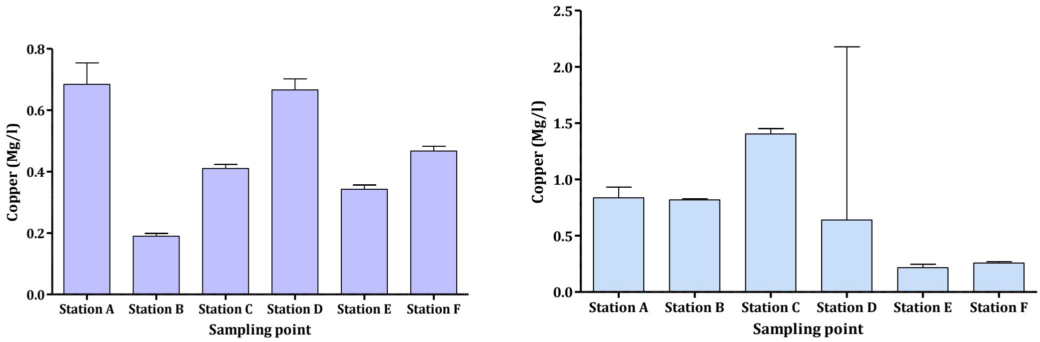
Figure 4.11. Copper levels in water in the wet and dry seasons

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria

Copper levels in water varied significantly across the different stations during both the dry (one-Way ANOVA, $F_{(5,17)} = 574.92$, $P < 0.0001$) and wet (one-Way ANOVA, $F_{(5,17)} = 291.4$, $P < 0.001$) seasons. DMRT further established that the mean copper levels in water did not vary significantly between stations in the dry season and the wet season except at station F where they varied significantly (Figure 4.11). There was no significant difference in the mean levels of copper in water in the two seasons (Student T-test $P = 0.70$)

4.4.5 Seasonal variation of copper levels in sediments.



Wet season Dry season

Figure 4.12. Copper levels in sediments in the wet and dry seasons

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria

Copper levels in sediments varied significantly across the different stations during both the wet (one-Way ANOVA, $F_{(5,17)}$ = 590.4, P < 0.0001) and dry one-Way ANOVA, $F_{(5,17)}$ = 8.98, P < 0.001) seasons. In sediments the copper levels were higher than in water. The highest value was recorded in Yala Swamp (station C) in the dry season 1.40 ± 0.02 Mg/l while the least value (0.20 ± 0.01 Mg/l) at Lake Sare in the same season (Figure 4.12). DMRT further established that there were significant differences in mean copper levels between the stations in the dry and wet seasons except between station E in the dry and wet season (Figure 4.12). There were no significant differences in the mean levels of copper in sediments in the two seasons (Student T-test P =0.28).

From the results the levels of copper were higher in sediment in the dry season than the wet season. This is consistent with the results obtained by Abdullahi *et al.* (2015) in their study in Tungan Kawo dam in Nigeria. According to them this could be due to high anthropogenic input of these metals in the dry season and also due to the low water level in the same season compared to wet season. According to Abdullahi *et al.* (2015), copper has a high complexing tendency for organic matter. It is in the organically bound form that copper is most likely deposited at the sediment phase. This is also true in relation to Yala swamp which is believed to have a high organic matter content due to filtration and adsorption by the papyrus reeds. This is explained by Mitch and Gosselink, (1993) that plants in wetlands increase the residence time of water, reduce velocity and increase sedimentation of particles associated with pollutants which eventually increase organic matter content in such sediments.

Additionally, several studies have found out that increased temperature mostly in the dry season resulted in a higher maximum sorption of heavy metals by minerals (Echeveria *et al.*,2005). This explains the higher levels of Copper in sediments in the dry season than wet season. Although he goes on to say that on the other hand temperature may also affect the bacterial activities, DO, oxidation rate, reduction rate and molecules diffusion rate which might pose contrasting impact on metal release. Thus the impact of temperature on heavy metal release is complex and uncertain.

4.4.4. Zinc levels in water and sediments.

Data obtained from analysis of zinc values in water and sediments are represented in table 4.15 below.

Table 4.15. Zinc levels in water and sediments

Stations	Zinc levels in water (Mg/l)	Zinc levels in sediments (Mg/l)
A	0.42 ± 0.01^{B}	1.14 ± 0.03^{C}
B	0.28 ± 0.01^{E}	0.79 ± 0.11^{E}
C	0.32 ± 0.01^{D}	1.23 ± 0.08^{B}
D	0.37 ± 0.01^{C}	1.09 ± 0.09^{D}
E	0.55 ± 0.01^{A}	1.09 ± 0.08^{D}
F	0.23 ± 0.01^{F}	1.99 ± 0.03^{A}
MEAN	**0.36±0.01**	**1.07±0.07**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range

Test.*Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.*

The levels of Zinc in water varied significantly in the various stations (one-Way ANOVA, $F_{(5,17)}$ = 1652.604, $P < 0.001$) DMRT further established that there were statistically significant differences in the mean zinc values in stations in all the stations with the highest value 0.55 ± 0.01 Mg/l recorded in Lake Sare (station E) and the lowest value 0.23 ± 0.01 Mg/l recorded at the entry of Lake Sare to Lake Victoria (station F) (Table 4.15).

Zinc levels in sediments also varied significantly (one-Way ANOVA, $F_{(5, 17)}$ = 24.80323, $P < 0.0001$).The highest value 1.99 ± 0.03 was recorded at the entrance of Lake Sare to Lake Victoria (station F) and the lowest value 0.79± 0.11 recorded at the exit of River Yala from Dominion farms (station of B). DMRT also established significant differences in mean Zinc values in all the stations except between stations D and E.

Zn is an essential macronutrient for plants but is phytotoxic when in excess. According to Vymazal *et al*. (2007), zinc is essential for plant growth and metabolism. Phytotoxicity may cause decreased crop yield and quality and likelihood of Zn transfer into the food chain (Adriano, 2001). In this study the average levels of zinc in water was 0.36±0.01 Mg/l which is below the recommended level of 0.5 Mg/l (USEPA, 1986) hence safe. On the contrary the concentrations of zinc were higher in sediments than in water and could be because according to Barron, (1995) aquatic sediments act as a source and a sink for pollutants whereby contaminants can accumulate to sedimental concentrations that can exceed water concentrations. Additionally, sediments also had high concentrations of Zn and could be because the factories upstream dealing in sorts of Zn bi-products seems to be releasing them into the effluent which find their way into the swamp like the rice milling industry and animal feeds industry. At station F the level of zinc was significantly high in sediments (1.99±0.03 Mg/l) and could be because the area is full of activities including car washing, laundry washing and subsistence farming that involve the use of chemicals some of which may contain high zinc levels which later accumulate in the sediments.

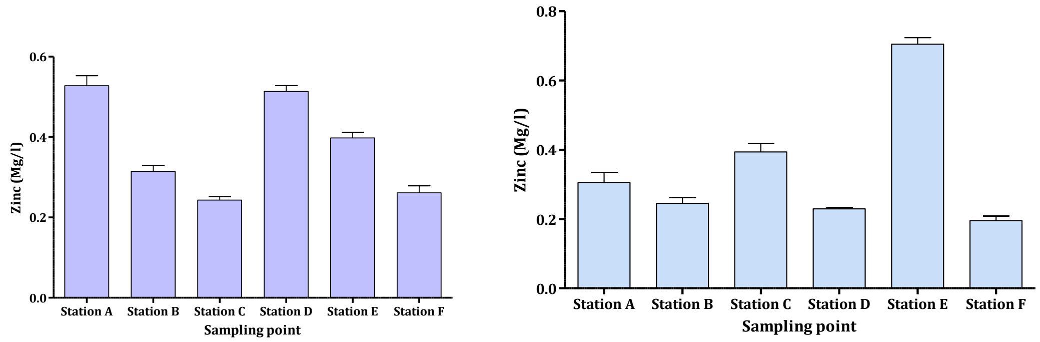
According to Rajappa *et al*. (2010), zinc shows fairly low concentrations in water samples due to its restricted mobility from place to place. In Lakes and Rivers some zinc settles to the bottom in association with heavier particles. This further explains the high levels of Zinc in sediments than in water. Rajkovic *et al*. (2008) asserted that elevated levels of zinc are toxic to some aquatic life. It has the potential to biaccumulate in the food chain. Zinc is also an important mineral limiting absorption of cadmium in both plants and animals. In studies on hard red spring wheat by Green *et al*., (2003), zinc soil amendments reduced translocation of cadmium from roots to shoots of plants. This antagonism is explained by the similarity in chemical properties of cadmium and zinc confirmed mainly by their structural similarity. Both are members of the same group (group 12) of the periodic table with similar number of valence electrons. However due to decreasing reactivity with increase in atomic mass, (atomic mass 65.39 amu) in more reactive than cadmium (atomic mass 112.41 amu) and the electrons required for the sequensation and transport of cadmium are inhibited in the presence of zinc. This explains why the levels of cadmium in this study were below detectable levels in most of the stations and none was detected in the tissues of papyrus plants.

A study by Nirmal *et al*. (2008) in Pariyej reservoir in India that focused on assessment of heavy metal accumulation in certain aquatic macrophytes used as biomonitors, in water and sediments, Zn was the most abundant in sediments (2114.82 p.p.m.) and water (160.70 p.p.m.), followed by Cu with a concentration of 105.78 p.p.m. in the sediments and 19.67 p.p.m. in the water. This results are too high compared to the results obtained in this study and could be because the region had higher levels of polution. The only similarity is that in this study the levels of zinc were also higher in sediments. Similarly, Lovett-Doust *et al*.

(1994) reported that the accumulation levels of pollutants in aquatic ecosystems might be higher in sediments than in plants.

4.4.5. Seasonal variation of Zinc in water and sediments

Data obtained from analysis of zinc values in water and sediments in the dry and wet season are represented in figure 4.13 below.



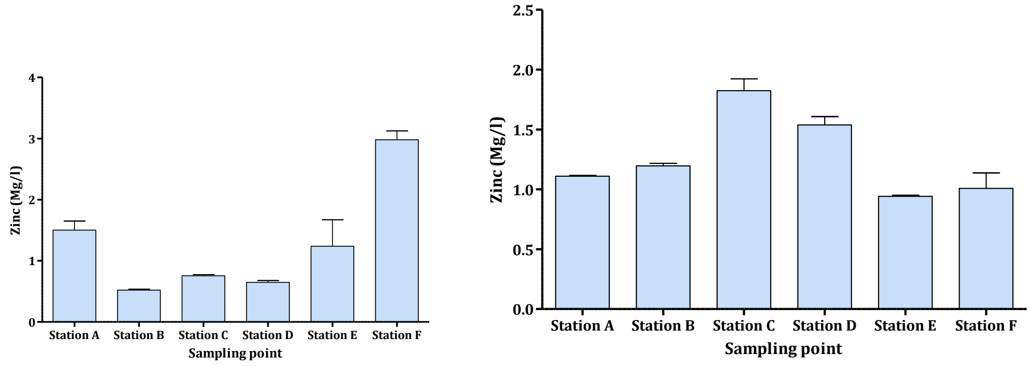
Wet season Dry season

Figure 4.13. Levels of zinc in water in the wet and dry season

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

Zinc levels in water were almost similar in both seasons with the highest value recorded at station E (Lake Sare in the dry season) 0.70 ± 0.01 Mg/l and least at station F (exit of Lake Sare to Lake Victoria) still in the dry season 0.20 ±0.01 Mg/l (Figure 15). Zinc levels in water varied significantly across the different stations during both the wet (one-Way ANOVA, $F_{(5,17)}$ = 1063.0, P < 0.0001) and dry (one-Way ANOVA, $F_{(5,17)}$ = 1745.91, P < 0.0001) seasons. DMRT further established that there were significant differences in mean zinc values between all the stations in the dry and wet seasons except between station B in the dry and wet season and station E in the dry and wet season (Figure 4.13).



Wet season Dry season

Figure 4.14. Levels of zinc in sediments in the wet and dry seasons

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

The levels of zinc in sediments were generally higher in the wet season than in the dry season. The highest value recorded was at station F (2.98 ±0.06 Mg/l) in the wet season and least value at station at station B (0.50 ±0.01 Mg/l) in the same season. Zinc levels in sediments varied significantly across the different stations during both the wet (one-Way ANOVA, $F_{(5,17)} = 403.5$, $P < 0.0001$) and dry (one-Way ANOVA, $F_{(5,17)} = 413.22$, $P < 0.0001$) seasons. DMRT further established that mean zinc levels at all stations varied significantly with each other during the dry season and wet season. There were no significant differences in the mean levels of zinc in water and sediments in both seasons (Student T-test P = 0.7495 and P =0.9927 respectively.

From the findings the levels of Zinc in sediments and in water were within a close range in both seasons (Figure 4.13 and 4.14). According to Payan *et al*. (2012), the release of trace heavy metals from contaminated sediments may increase their concentrations in overlaying water to undesirable levels at a local scale that affect the environment and ecosystem health due to its characteristics of persistence and toxicity.

Also from the findings the levels of zinc were highest in stations C and D in the dry season. This are regions that were dominated by papyrus reeds and the soils were majorly clay soil with a high content of organic matter. According to Prabu (2009), the concentration of heavy metals is dependent on clay content because the clay size particles have a large number of ionic binding sites due to higher amount of surface area. This results in immobilization of heavy metals ant there is little leaching through the soil profile. Immobilization can increase the concentration of heavy metals and toxicity of soil .Similarly the levels of zinc in sediments are very high at station F in the wet season (Figure 4.14). This station is characterized with a lot of activities including the watering of animals that release their wastes in the area, subsistence farming by many farmers who use both organic and inorganic fertilizers and general use of the water for washing and cleaning by the residents. Such activities increase the organic matter content of the sediments and according to Asada *et al*., (2010), the application of compost manure not only results in increase in zinc accumulation in soil but also causes an increase in zinc mobility and enhances zinc leaching.

4.4.6. Iron levels in water and sediments.

Data obtained from analysis of iron values in water and sediments are represented in table 4.16 below

Table 4.16. Iron levels in water and sediments.

Stations	Iron in water (Mg/l)	Iron in sediments (Mg/l)
A	11.81±0.13^{C}	64.61±0.13^{A}
B	12.63±0.10^{B}	69.49±0.65^{A}
C	5.24±0.70^{E}	42.57±0.88^{B}
D	4.27±0.09^{E}	46.30±0.81^{B}
E	8.07±0.52^{D}	42.15±0.64^{B}
F	32.27±0.99^{A}	35.74±0.66^{C}
MEAN	**12.38±0.42**	**50.14±0.62**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus reeds, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria

The levels of Iron in water varied significantly in the various stations (one-Way ANOVA, $F_{(5,17)} = 1716.305$, $P < 0.001$). The highest value 32.27 ± 0.99 Mg/l recorded at the entrance of Lake Sare to Lake Victoria (station F) and the lowest value 4.27 ± 0.09 Mg/l recorded at the exit of Yala Swamp to Lake Sare (station D). Duncan Multiple Range Test further established that there were significant differences in the mean iron values between stations A and B, B and C, D and E and E and F while there was no significant difference between stations C and D. (Table 4.27).

Iron levels in sediments also varied significantly (one-Way ANOVA, $F_{(5, 17)} = 800.8252$, $P < 0.0001$). The highest value 69.49 ± 0.65 was recorded at the exit of River Yala from Dominion farms (station B) and the lowest value 35.74 ±0.66 recorded at the entrance of Lake Sare to Lake Victoria (station of F). DMRT also established significant differences in mean iron values between stations B and C and E and F while there was no significant difference between stations A and B and among stations C, D and E.

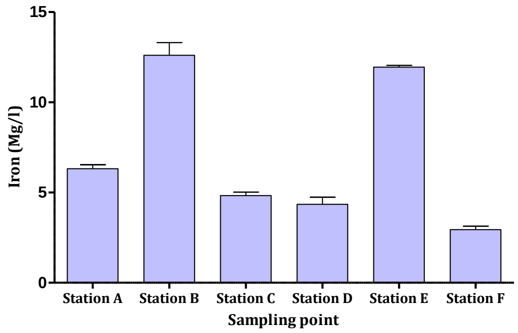
The mean iron values were above the maximum contaminant level (MCL) of <0.3 mg/l according to USEPA, (2010). This is unacceptable which indicate that the study area is highly contaminated with Fe. The insoluble Fe is reduced to soluble Fe^{2+} in water by bacteria which explains the increased levels of iron after passing through station C and D where bacterial activities are believed to be high (table 4.16). The high levels of iron at station F (exit of Lake Sare to Lake Victoria) could be because of the bridge in the station which is in a bad state with a lot of rusting of metallic parts under it. Additionally, at this station many residents wash their vehicles, motorbikes, bicycles, utensils some of which may introduce some iron from the rusted parts in the area that further increase its levels.

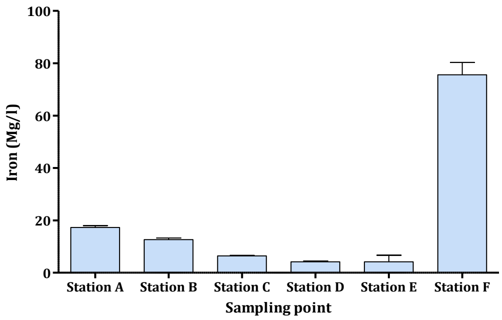
According to Ndimele and Komolu, (2012) the concentration of Fe to an extent is usually determined by the nature of soils along the River course which is eventually leached into the River system and its sediments.

The high level of Fe in the area may be attributed to discharge of Fe laden effluent together with corroded iron pipes, containers and scrapes into the water body and lithilogical or crustal origin (Osakwe and Clarke, 2013). The region is also surround by very few reeds hence the iron is not absorbed like what is happening in station C and D that are dominated by the papyrus plants. Additionally, iron is generally the most abundant metal in all of the reservoirs because it is one of the most common elements in the earth's crust, Usero *et al*. (2003).

4.4.7. Seasonal variation of iron levels in water and sediments

Data obtained from analysis of iron values in water and sediments in the dry and wet season are represented in Figure 4.15 below.





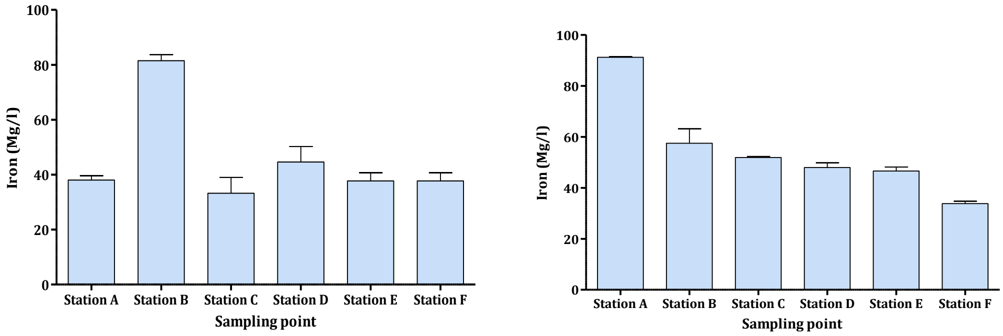
Wet season Dry season

Figure 4.15. Iron levels in water in the wet and dry seasons.

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

Iron levels in water varied significantly across stations both during the wet (one-Way ANOVA, $F_{(5,17)}$ = 2364.6, P < 0.0001) and dry (one-Way ANOVA, $F_{(5,17)}$ = 2872.23, P < 0.0001) seasons. In water, iron levels were highest at the entrance of Lake Sare to Lake Victoria (station F) 75.6 ± 1.91 Mg/l and least at Lake Sare (station E) 4.2 ± 1.0 Mg/l during the dry season while in the wet season, the highest value was recorded at River Yala as it exits Dominion Farms (station B) 81.5 ± 0.9 Mg/l and least at Yala swamp (station C) 33.4 ±2.3 Mg/l. DMRT further showed that iron levels in water during the dry season were significantly different from those in the wet season except in station C where they were not significantly different (Figure 4.15).



Wet season Dry season

Figure 4.16. Iron levels in sediments in the wet and dry seasons

*Values represent means ±Sd of triplicate analysis.

Note: A = Entry of River Yala to Dominion farms, B = River Yala as it leaves Dominion farms, C =within papyrus plants, D = Exit of Yala Swamp to Lake Sare, E = middle of Lake Sare, F =Entry point of Lake Sare to Lake Victoria.

Iron level in sediments varied significantly across the stations both during the wet (one-Way ANOVA, $F_{(5,17)} = 397.9$, $P < 0.0001$) and dry (one-Way ANOVA, $F_{(5,17)} = 1073.42$, $P < 0.0001$) seasons. In sediments iron levels were very high. The highest value was recorded at the entrance of River Yala to Dominion Farms (station A) 91.20 ± 0.10 Mg/l and least at the entrance of Lake Sare to Lake Victoria (station F) 33.80 ± 0.40 Mg/l during the dry season while in the wet season, the highest iron level was recorded at exit of River Yala from Dominion farms (station B) 12.6±0.29 Mg/l and least the exit of Lake Sare to Lake Victoria (station F) 2.95 ± 0.08 Mg/l. DMRT further established that there were significant difference in mean iron levels between the dry and wet seasons in all the stations except in station D and F (Figure 4.16). There were no significant differences in the iron levels in water and sediments in both seasons (Students T-test P = 0.3398 and P= 0.4152 respectively).

In terms of seasons the levels of iron were very high in the wet season in water than in the dry season. This could be because according to Laksmann and Nambisan, (1983), the lowering of water pH and alkalinity due to increased precipitation switches the process of dissolution of metallic compounds from sediment compartment to aquatic column resulting in increase in dissolved heavy metals. In the dry season the levels of heavy metals were very high in sediments than in water this could be because according to Nussey *et al*. (2001) a higher temperature could also lead to a higher metabolic rates which would induce more feeding and in turn result in increased metal concentration if the metals are taken back in the food chain. Additionally according to Oguzie and Izeubigie, (2009) weathering of rocks and a variety of anthropogenic activities that are affected by seasons increase the concentration of these heavy metals.

4.5. Heavy metals in papyrus tissues (roots, leaves and flowers)

4.5.1. Levels of lead in papyrus reeds tissues

Papyrus reeds were found in Yala Swamp (stations C) and entry of River Yala to Lake Sare (station D) only. Data obtained from analysis of lead values in papyrus tissues i.e. roots, flowers and leaves are represented in table 4.17 below.

Table 4.17. Lead levels in papyrus tissues.

Plant part	Lead (Mg/l) in station C	Lead (Mg/l) in station D
Roots	1.61 ± 0.04^{B}	2.19 ± 0.06^{A}
Flowers	1.72 ± 0.12^{A}	1.97 ± 0.19^{B}
Leaves	1.74 ± 0.19^{A}	2.04 ± 0.01^{A}
Mean	**1.69±0.12**	**2.07±0.09**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analyzed by Duncan's Multiple Range Test.

Note: Station C =within papyrus plants and station D = Exit of Yala swamp to Lake Sare

The highest lead values were recorded in roots at exit of Yala Swamp to Lake Sare (station D), 2.19 ± 0.06 Mg/l and least value in roots at Yala Swamp (station C, 1.61 ± 0.04 Mg/l) Table 4.17. A significant difference was observed in the values of lead in the plant parts in both stations (one-Way ANOVA, $F_{(1,5)} = 24.2757$, P =0.007). DMRT further established that the mean lead levels varied significantly between roots and flowers in station C but not between flowers and leaves. While in station D mean lead values varied significantly between roots and flowers but not between flowers and leaves.

In the study papyrus plants extract heavy metals from the waters and sediments as evident from the levels determined in the stems, flowers and roots. They help to reduce the levels of these heavy metals in the waters and sediments as evident from the study where their levels reduce after passing through the papyrus plants. Sekemo *et al*. (2011) established that papyrus plants play an important role in metal retention. Plants take up nutrients as a requirement for their growth and these nutrients accumulate in the plant parts which present an opportunity to remove excess nutrients from wetlands systems through harvesting the aerial plant phytomass (Kansiime, 2007).

A study by Home and Mithigo, (2010), in constructed wetlands Nairobi, Papyrus plants had the highest Lead uptake with an initial concentration of 0.0005p.p.m. while in the final concentration in the plant material was 0.1342 p.p.m. (>260 times). The order of lead absorption by the macrophytes was: Papyrus spp>Typha spp>Polygonum spp. These levels are quite low in comparison to the levels obtained in this study which were quite high in the tissues of papyrus. The study though indicates the effectiveness of papyrus in removing lead from water and sediments which is in agreement with this study. Although Pb is expected to have low phytotoxicity because of its strong affinity to organic matter, when environmental conditions change e.g. change in pH, it may become mobile and may go into the food chain.

In the study papyrus plants were found to accumulate more lead in roots than in shoots in station D (table 4.17). Similar results were reported by Odong *et al*. (2013) in Uganda. According to Kidd *et al.* (2009) metals absorbed or adsorbed by roots are often bound by cell wall material or other macromolecules to prevent them from being translocated to sensitive plant parts. This explains the high concentration of lead in roots in station D. Similarly, Patra *et al*. (2004) reported that lead is easily taken up by plants from the soil and accumulate in roots while only a small fraction is translocated upwards towards the shoots.

At times the roots were seen to have a lower concentration of lead than the shoots and this was attributed to a biological factor that stems contain vascular bundles xylem and phloem that are essential in translocation. According to Odong *et al*. (2013), when these elements are transported and reach the shoots they are subjected to other processes like transpiration which takes away the water leaving higher concentrations of solids in shoots. This explains the high concentration of lead in stems in station C (table 4.17.). Additionally, according to JingLi *et al*. (2015), the concentration of lead could be higher in leaves, potentially because the capacity of roots can become exhausted due to a high concentration of lead in wastewater.

Seasonal variation of lead in papyrus plants tissues

Data obtained from analysis of lead values in papyrus tissues in the dry and wet seasons i.e. roots, flowers and leaves are represented in table 4.18 below.

Table 4.18. Lead levels in papyrus tissues in the wet and dry seasons.

	Lead in Station C (Mg/l)		**Lead in Station D (Mg/l)**	
Plant part	**Wet season**	**Dry season**	**Wet season**	**Dry season**
Roots	1.66 ± 0.01^{A}	1.49 ± 0.1^{B}	1.91 ± 0.05^{B}	2.52 ± 0.18^{A}
Flowers	1.49 ± 0.05^{B}	1.99 ± 0.02^{A}	2.43 ± 0.03^{A}	1.66 ± 0.04^{B}
Leaves	1.23 ± 0.01^{B}	2.22 ± 0.23^{A}	2.51 ± 0.05^{A}	1.42 ± 0.41^{B}
Mean	**1.46±0.02**	**1.9±0.12**	**2.28±0.04**	**1.87±0.21**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analyzed by Duncan's Multiple Range Test.

Note: Station C = within papyrus plants and station D = Exit of Yala Swamp to Lake Sare.

In the papyrus plants the highest values were recorded in roots in the dry season 2.52 ± 0.18 and least in leaves in the wet season 1.23 ± 0.01 Mg/l. A significant difference was observed in the values of lead in the plant parts in both seasons (one-Way ANOVA, $F_{(5,17)} = 15.7116$, $P < 0.001$) for dry season and (one-Way ANOVA, $F_{(5,17)} = 120.6016$, $P < 0.001$) for wet season. DMRT established that the mean lead values in station C varied in all the papyrus tissues between the dry and wet season (Table 4.18). The same situation was exhibited in station D where the mean lead values also varied in the papyrus tissues between the wet and dry season.

Seasons play a role in the manner in which heavy metals are absorbed by the papyrus plants as indicated in table 4.18. In station C the absorption levels were higher in the dry season than the wet season could be because according to Hooda and Alloway, (1993); Macek *et al*. (1994); Baghour *et al*. (2001) and Albrecht *et al.* (2002), terrestrial plants grown at high root temperatures find higher uptakes of Zn, Pb, and Cd than is the case with plants grown at low root temperatures. The high root temperatures are possible during the dry season. Therefore, a general increase of metal uptake with increasing temperature seems likely. The situation is slightly different with station D where the levels of heavy metals in the papyrus plants are higher in the wet season than the dry season. In the same station the levels of lead are higher in leaves in the wet season 2.51±0.05 Mg/l than the dry season (1.42±0.41 Mg/l). This could be that the leaves in station D were older than the leaves in station C since according to Cheng (2003) older leaves accumulate more heavy metals than younger leaves. The high levels of lead in roots in station D both in the wet (1.91±0.05 Mg/l) and dry seasons (2.52±0.18 Mg/l) could also be because the papyrus plants were older hence developing more lateral roots and according to Cheng (2003) lateral roots accumulate more heavy metals than the main roots.

4.5.2. Copper levels in papyrus plants tissues

Data obtained from analysis of copper values in papyrus tissues ie roots, flowers and leaves are represented in table 4.19 below.

Table 4.19. Copper levels in papyrus tissues.

Plant part	Copper (Mg/l) in Station C	Copper (Mg/l) in Station D
Roots	0.63 ± 0.02^{A}	0.41 ± 0.01^{A}
Flowers	0.11 ± 0.01^{B}	0.23 ± 0.01^{B}
Leaves	0.15 ± 0.01^{B}	0.38 ± 0.01^{A}
Mean	**0.29±0.01**	**0.34±0.01**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: Station C =within papyrus reeds and station D = Exit of Yala Swamp to Lake Sare.

In the papyrus plants the highest copper values were recorded in roots in station C (0.63±0.02 Mg/l) and the least value (0.11±0.01Mg/l) was recorded in the same station in flowers. The values varied in the various parts of the papyrus tissues (one-Way ANOVA, $F_{(1,5)} = 0.06055$, P =0.1877). DMRT established that mean values of copper varied significantly between those in roots and flowers in station C while they did not vary significantly between the Flowers and leaves (Table 4.19). In station D the mean copper values in roots and flowers also varied significantly while there was no significant difference between the values in roots and leaves.

The levels of copper were high in the roots than in leaves and stems and least in the flowers as indicated in table 4.19. This could be according to Dunbabin and Bowmer, (1992) under contaminated conditions, the greater proportion of heavy metals taken up by plants is retained in the roots with metal concentrations decreasing in the following order: roots > rhizomes > non-green leaves > green leaves. Papyrus has a large root system with rhizomes and fibrous roots that is capable of filtering a variety of contaminants. This is so because according to Kansime and Nalebengu 1999, Okurut 2004 and Kyambadde *et al*., 2004, the below ground biomass provide attachment sites for proliferation of bacterial biomass that act on wastes.

The roots and rhizomes influence the waste water residence time, trapping and settling of suspended particles, increased surface area for pollutant adsorption, uptake and assimilation in plant tissues and provision of oxygen for organic and inorganic oxidation in rhizosphere. In a study by Nabulo *et al.* (2008) in Lake Victoria basin considering trace metal accumulation in different sites, it was observed that *Cyperus papyrus* accumulated the highest trace metal concentrations from the study sites. The highest levels of trace metal accumulation at all the sites were observed in roots and followed the order of root > rhizome > leaves, respectively. This agrees with the findings of this study. Hence, the below ground parts of *C. papyrus* effectively accumulated trace metal pollutants from soil, with the lowest concentrations transported to the leaves.

Seasonal variation of copper in papyrus plant tissues

Data obtained from analysis of copper values in papyrus tissues ie roots, flowers and leaves in the dry and wet seasons are represented in table 4.20 below.

Table 4.20. Copper levels in papyrus tissues in the wet and dry seasons.

	Copper in Station C (Mg/l)		**Copper in station D (Mg/l)**	
Plant part	**Wet season**	**Dry season**	**Wet season**	**Dry season**
Roots	0.57 ± 0.03^{A}	0.70 ± 0.01^{A}	0.17 ± 0.00^{B}	0.66 ± 0.02^{A}
Flowers	0.06 ± 0.01^{B}	0.25 ± 0.03^{B}	0.33 ± 0.01^{A}	0.45 ± 0.01^{B}
Leaves	0.09 ± 0.01^{B}	0.13 ± 0.01^{B}	0.15 ± 0.01^{B}	0.33 ± 0.01^{B}
Mean	**0.24±0.01**	**0.36±0.01**	**0.22±0.01**	**0.48±0.01**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: Station C =within papyrus reeds and station D = Exit of Yala Swamp to Lake Sare.

In the wet season the mean copper levels in papyrus tissues varied significantly in the roots, flowers and leaves (one-Way ANOVA, $F_{(5,17)} = 488.1271$, $P < 0.001$). In the dry season copper levels in papyrus tissues also varied significantly one-Way ANOVA, $F_{(5,17)} = 1174.763$, $P < 0.001$). DMRT also established that there were no significant differences in mean copper levels in the roots, leaves and flowers between the dry and wet seasons in station C. In station D they varied significantly in roots and flowers between the dry and wet seasons but not in stems. The values in the dry season were generally higher than those in the wet season. (Table 4.20).

From the results it is evident that the levels of copper accumulated in the tissues of papyrus plants were higher in the dry season than the wet season both in stations C and D as indicated in table 4.20. This could be because temperature increases both metabolism according to Marschner, (1995) and Nilsen and Orcutt, (1996) and protein synthesis according to Nilsen and Orcutt, 1996, and this may result in higher metal uptake at additional uptake sites on membranes or an increased release of molecules facilitating metal uptake. Additionally, according to Fritioff *et al.* (2004) in their study on the Influence of temperature and salinity on heavy metal uptake by submersed plants in wetland and treated ponds in Sweden found out that metal concentrations and accumulations increased with increasing water temperature for Cu, Zn, and Cd in Elodea and for Cu, Zn, Cd, and Pb in Potamogeton. Their explanation for this is was that increased temperature will increase the biomass and thus the absorption area of the plant; this, in turn, will increase the metal uptake. Higher temperatures are known to increase growth rates by increasing the rate of photosynthesis in plants which supports this statement.

4.5.3. Zinc levels in papyrus plants tissues

Data obtained from analysis of zinc values in papyrus tissues i.e. roots, flowers and leaves are represented in table 4.21 below.

Table 4.21. Zinc levels in papyrus tissues.

Plant part	Zinc (Mg/l) in Station C	Zinc (Mg/l) in Station D
Roots	0.79 ± 0.17^{A}	0.49 ± 0.20^{B}
Flowers	0.60 ± 0.01^{B}	0.81 ± 0.01^{A}
Leaves	0.81 ± 0.01^{A}	0.81 ± 0.04^{A}
Mean	**0.73±0.06**	**0.70±0.08**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: Station C =within papyrus plants and station D = Exit of Yala Swamp to Lake Sare.

In the papyrus plants zinc levels were highest in the stems in both stations (0.81±0.01 Mg/l) and least in roots in station D (0.49±0.20 Mg/l). There were no significant difference observed in the values of zinc in the plant parts in the two stations (one-Way ANOVA, $F_{(1,5)} = 0.05676$, $P = 0.823396$). DMRT established that there was a significant difference in the mean zinc values between the roots and flowers in station C while there was no significant difference between the roots and stems. In station D a significant difference was observed in the mean zinc values between roots and flowers while there was no significant difference between the flowers and leaves (Table 4.21).

The presence of zinc in papyrus tissues as seen in table 4.34 can be explained by Mcgrath *et al*. (1997), that when plants absorb the heavy metal, zinc is transformed from the insoluble to the soluble Zn2+ state. Simultaneously, it also activates the insoluble state in the water, which could increase the ability of aquatic plants to absorb zinc.

In this study zinc levels were detected in high levels in stems than root in both stations C and D.

This is similar to observations made by Mugisha *et al*., (2007) who established that photosynthetic organs of papyrus (culms and umbel) generally had a higher nutrient than other organs (roots and rhizomes) at the Navikubo and Kirinya wetlands at the shores of Lake Victoria in Uganda. This is also true according to Kyambadde *et al*., (2005) who reported that higher amounts of nutrients are sequestered in papyrus stems and flowers compared to roots and rhizomes portion.

Seasonal variation of zinc in papyrus tissues

Data obtained from analysis of zinc values in papyrus tissues i.e. roots, flowers and leaves in the dry and wet seasons are represented in table 4.22 below.

Table 4.22. Zinc levels in papyrus tissues in the wet and dry seasons

	Zinc in station C		Zinc in station D	
Plant part	**Wet season**	**Dry season**	**Wet season**	**Dry season**
Roots	0.87±0.01^{A}	0.93±0.01^{A}	0.50±0.01^{A}	0.72±0.00^{B}
Flowers	0.20±0.01^{C}	1.00±0.03^{A}	0.54±0.01^{A}	0.97±0.01^{A}
Leaves	0.76±0.01^{B}	0.86±0.01^{A}	0.64±0.01^{A}	0.98±0.01^{A}
Mean	**0.91±0.01**	**0.93±0.01**	**0.56±0.01**	**0.89±0.01**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analyzed by Duncan's Multiple Range Test.

Note: Station C =within papyrus plants and station D = Exit of Yala Swamp to Lake Sare.

Considering seasons there was a significant difference in mean zinc value in papyrus tissues in the wet season (one-Way ANOVA, $F_{(5,17)} = 4701.425$, $P < 0.0001$). This was similar to the dry season where the mean zinc values in the papyrus tissues also varied significantly (one-Way ANOVA, $F_{(5,17)} = 179.9015$, $P < 0.0001$). DMRT further established that there was no significant difference in mean zinc values in roots and flowers between the dry and wet seasons in station C except in the flowers. In station D there was also no significant difference in mean zinc values in the flowers and leaves in the dry and wet seasons except in the roots (Table 4.22).

The levels of zinc were higher in the papyrus tissues in the dry season than the wet season as indicated in table 4.22. This is similar to the findings of Fritioff *et al.* (2004) that increase in temperature increases heavy metal uptake in plants which increases their concentration in their tissues. In station C (Yala Swamp), the highest concentration of zinc is obtained in the roots both in the dry and wet seasons (table 4.22). This could be according to Blake, *et al*., (1987), zinc has the tendency to remain concentrated in the root tissues.

In a study conducted by Jing Li, (2015) in China on heavy metals absorption by macrophytes, the roots accumulated significantly higher concentrations of zinc, whereas the leaves had lower concentrations of zinc than did the stems. The roots have been known as good absorptive sponge for heavy metals in soil and water. Similar findings have been reported by various authors for heavy metal uptake in water (Yadav 2011, Sun *et al.,* 2013, Rai *et al*., 1995 and Sahu *et al*., 2007). A possible reason is that the roots are the primary site of metal uptake.

4.5.4. Iron levels in papyrus plants tissues

Data obtained from analysis of iron values in papyrus tissues i.e roots, flowers and leaves are represented in table 4.23 below.

Table 4.23. Iron levels in papyrus tissues.

Plant part	Iron (Mg/l) in station C	Iron (Mg/l) in station D
Roots	32.36 ± 0.11^{A}	38.38 ± 0.52^{A}
Flowers	32.93 ± 0.20^{A}	13.74 ± 0.03^{B}
Leaves	13.04 ± 0.14^{B}	16.89 ± 0.11^{B}
Mean	**26.11±0.15**	**23.0±0.22**

*Values represent means ±Sd of triplicate analysis. *Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analyzed by Duncan's Multiple Range Test.

Note: Station C =within papyrus reeds and station D = Exit of Yala Swamp to Lake Sare.

In the papyrus plants the mean iron levels did not vary significantly in stations C and D (one-Way ANOVA, $F_{(1,5)} = 0.094003$, $P = 0.77445$). The highest value was recorded in roots in station D (38.38±0.52 Mg/l) and the least value recorded in stems in station C (13.04±0.14 Mg/l). DMRT established that in station C the mean iron values did not vary significantly between roots and flowers but they varied significantly between flowers and leaves. In station D the mean iron values varied significantly between roots and flowers but not between flowers and leaves (Table 4.23).

The levels of iron are highest in flowers in station C (32.93±0.20 Mg/l) which could be explained by Woraman *et al*.,(2010) that plants take up heavy metals from substrate and accumulate them in their biomass. Some heavy metals are translocated to stems leaves and flowers and in this study more iron were translocated to the flowers. From the same results the levels of iron are very high in roots in both stations

(32.36±0.11Mg/l and 38.38±0.52 Mg/l respectively). According to Cheng, (2003) relatively larger portions of heavy metals are stored in roots of plants compared to above ground biomass.

In a study by Emmy *et al*., 2014, batch experiments were conducted to evaluate the influence of four aquatic macrophytes *(Cyperus papyrus*, *Typha latifolia*, *Cyperus alternifolius* and *Phragmites mauritianus*) towards phytoremediation of agrochemicals from simulated wastewater in Arusha, Tanzania. The highest removal capability was observed in planted batch reactor with *Cyperu papyrus* and *Typha latifolia*, where the initial concentration of iron (3.515 p.p.m.) dropped to 0.077 (±0.021). These observations revealed that *Cyperus papyrus* has the capability influencing the magnitude of Fe removal from polluted water. In this study the levels of Fe in the earlier results reduce gradually from station A to E especially during the dry season which agrees with Emmy *et al*., 2014. According to Kaldec *et al,* (2000), macrophytes can play an important role in metal removal through adsorption and uptake by plants. The high levels of iron in the papyrus tissues as indicated in table 4.23 could be because Fe is an important metal in both plants and animals especially in cellular processes hence it is absorbed in large quantities.

Seasonal variation of iron levels in papyrus tissues

Data obtained from analysis of iron values in papyrus tissues i.e. roots, flowers and leaves in the dry and wet seasons are represented in table 4.24 below

Table 4.24. Iron values in papyrus tissues in the wet and dry seasons.

	Iron in Station C		**Iron in Station D**	
Plant part	Wet season	Dry season	Wet season	Dry season
Roots	46.89 ± 0.1^{A}	17.8 ± 0.1^{B}	30.66 ± 0.95^{A}	45.97 ± 0.66^{A}
Flowers	7.68 ± 0.31^{C}	18.39 ± 0.20^{B}	17.82 ± 0.13^{B}	15.96 ± 0.35^{B}
Leaves	21.33 ± 0.40^{B}	44.54 ± 0.46^{A}	14.93 ± 0.09^{B}	12.54 ± 0.08^{B}
Mean	**25.30±0.27**	**26.91±0.25**	**21.14±0.39**	**24.82±0.36**

*Values represent means ±Sd of triplicate analysis.*Means with different superscripts in the same column are significantly different at $p < 0.05$. (Data analysed by Duncan's Multiple Range Test.

Note: Station C =within papyrus plants and station D = Exit of Yala Swamp to Lake Sare.

Considering seasons the mean iron levels in papyrus tissues varied significantly in the wet season (one-Way ANOVA, $F_{(5,17)} = 2889.129$, $P < 0.0001$). The values also varied significantly in the dry season (one-Way ANOVA, $F_{(5,17)} = 4910.573$, $P < 0.0001$). DMRT established that the mean iron levels varied significantly in all the plant parts in the dry and wet seasons in station C. In station D there was no significant difference in all the plant parts between the dry and wet seasons (Table 4.24).

The levels of iron were higher in the papyrus tissues in the dry season than the wet season as indicated in table 4.37. This is similar to the findings of Fritioff *et al.* (2004) that increase in temperature increases heavy metal uptake in plants which increases their concentration in their tissues. Higher temperatures are also known to increase growth rates which may increase the plant biomass and according to Ekvall and Greger, (2003), a plant of relatively high biomass may have a greater metal uptake capacity; this results from lower metal concentration in its tissue because of a growth rate that exceeds its uptake rate.

Additionally, according to Rai *et al.* (1995) the enrichment mechanism of heavy metals in plant tissues may also be related to the surface area of the plant exposed to water, in that a higher surface area: volume ratio would enable higher uptake of heavy metals. In this study quantity of papyrus reeds in the swamp were very high which depicts a high surface area exposed for heavy metal absorption.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of findings

The physicochemical parameters like Temperature, Turbidity, pH, Biological oxygen Demand (BOD), Electrical Conductivity (EC), Dissolved Oxygen (DO), Total Dissolved solids and Temperature varied significantly in the various sampling stations. The activities in the study area like farming which involves the use of fertilizers, herbicides, pesticides among other chemicals and season's played a role in determining the levels of these parameters. Sites with papyrus reeds (Station C and D) recorded highest concentration of the physico-chemical parameters which later improved in sites without the reeds both in wet and dry seasons. These findings consecrate the importance of papyrus reeds in controlling the levels of physicochemical parameters.

The study established that there were significant differences in nutrient levels at sites within the swamps and Lake Sare both in wet and dry seasons. Highest nutrient levels (phosphates and nitrates) were recorded at sites with papyrus reeds (within Yala Swamp) and lowest in sites without reeds (at the entry of the River Yala and towards Lake Sare). The levels of nitrates and phosphates reduced significantly after passing through the reeds in Yala Swamp but increases towards Lake Sare during dry and wet seasons.

Generally, the heavy metal contents were lower at the entry sites A and B (River Yala before draining and after draining Dominion farms), as compared to site C and D (water from Yala Swamp and the exit of Yala Swamp to lake Sare surrounded by papyrus reeds) and lowest at the exit E and F (mid and exit of lake Sare to lake Victoria).This was attributed to introduction of pollutants from Dominion farms whose levels reduce after these water passes through the papyrus reeds. The levels of these heavy metals also varied significantly across the sampling sites.

The papyrus reeds were present in stations C (Yala Swamp) and station D (entry of River Yala to Lake Sare) and some heavy metals (lead, copper, zinc and iron) were obtained in their tissues. This is attributed to the fact that they absorb and adsorb these heavy metals in their tissues leading to reduction in their levels in the study area both in the dry and wet seasons.

5.2. Conclusions

The papyrus plants showed the capacity of adsorbing and absorbing pollutants as evident from the reduction of levels physicochemical parameters nutrients from station B believed to be the source of pollutants through stations C and D dominated by papyrus plants and finally reduce to standard levels in station E and F.

The papyrus also showed different capacities for heavy metal uptake and its use for phytoremediation has numerous economic and ecological benefits, including low cost, high efficiency, energy savings, and prevention of secondary pollution. This indicates the potential use of papyrus in biomonitoring of environmental contamination with heavy metals.

5.3. Recommendations

Nutrient loading from other non point sources should be explored to prevent water quality degradation and include other nutrients like sulphates and chlorides since they have similar sources like nitrates and phosphates.

Since there was a considerable level of heavy metals studied in water and soil a research should be carried out in food crops to determine whether similar levels are reflected in food stuffs from the study area.

Control measures should be adapted to reduce the amount of pollutants discharged into the swamp to tackle heavy metal pollution. Controlled use of agricultural chemicals and encouragement of use of organic farming are suggested to avoid further deterioration of water quality of the swamp.

5.3. Suggestions for Further Research

A regular monitoring program of physicochemical parameters should be carried out in order to help in detecting other sources of pollution. Other parameters like COD, salinity and hardness which were not looked at in the current study should also be looked at.

A further study should be done to include metals like arsenic, mercury and magnesium to determine their contamination levels. This is because their anthropogenic origin includes acaricides and pesticides which are also used in farming done in the study area.

REFERENCES

Abbasi, S. A., Abbasi, N. and Soni, R. (1998). Heavy metals in the environment. 1s Ed., Mittal Publications, pp. 657 -709.

Abdul Syukor Bid Abd Razak (2013). Special issue for international conference of Advanced Materials Engineering and Technology (ICAMET).Bandung Indonesia.Advances in Environmental Biology 9(12).pp 3808-3814.

Abila, R. (2002). Utilization and economic valuation of the Yala swamp wetland, Kenya. In Gawler, M. (ed.) 2002. Strategies for wise use of Wetlands: Best Practices in Participatory Management. Proceedings of a Workshop held at the 2nd International Conference on Wetlands and Development (November 1998, Dakar, Senegal). Wetlands International IUCN, WWF Publication No. 56, Wageningen, the Netherlands.

Abila, R.O. (2003). A Socio - Economic Study of the Yala Swamp Fisheries.Paper presented at ECOTOOLS Scientific Workshop on Yala Swamp. Switel Hotel, Bondo, Kenya. 9th10thDecember, 2003.

Abira, M.A. (2007). A pilot constructed treatment wetland for pulp and paper mill wastewater: performance, processes and implications for the Nzoia river, Kenya. PhD Thesis, UNESCO-IHE, Delft, Netherlands.

Abdullahi M.S.,Uzairu A.,Okunula O.J.,Balarabu M.L.(2005).Distribution pattern in sediment of Tungan Kawo Dam Kontagora,Naigeria.*American Jornal of chemistry*.ISSN:2165-8749.5(4):96-114.

Abunje, l. (2003). The distribution and status of Ethiopian wetlands: an overview. P. 12-18 in Proceedings of a conference on *Wetlands of Ethiopia*. Adebe, Y.B., and K. Geheb (eds.). International Union for Conservation of Nature and Natural Resources, Nairobi, Kenya.

Adams, B. J. and Papa, F. (2000).Urban storm water management planning with analytical probabilistic models, Wiley, Toronto, Ont., Canada.

Adenkunle A.S. (2008). Impacts of Industrial Effluent on Quality of Well Water within Asa Dam Industrial Estate,Ilorin, Nigeria, *Nature and Science*., 6(3), 1-5.

Adeyemo, O. K., Adedokun, O. A., Yusuf, R. K. and Adeleye, E. A. (2008). Seasonal changes in physico-chemical parameters and nutrient load of river sediment in Ibadan city, Nigeria. Global NEST Journal 10(3): 326 – 336

Adriano, D.C. (2001). Trace elements in terrestrial environments: Biochemistry, bioavailabilty and risks of metals. Springer Verlag. 867 pp.

Adler, T. (1996). Botanical cleanup crews. Sci. News. 150:42-43. Aksoy, A., Demirezen, D. and Duman, F. (2005). Bioaccumulation, detection and analyses of heavy metal pollution in sultan marsh and its environment. *Springer: water, air, and soil pollution, 164,* 241–255.

Ahern, M. D and Morris, S. (1998**).** Accumulation of lead and its effects on sodium balance in the freshwater Crayfish, *Cherax destructor*. *The Journal of Experimental Zoolog;* **281:**270–279.

Akoto, O., Bruce T. and Darko G. (2008). Heavy metals pollution profiles in streams serving the Owabi reservoir. *African Journal of Environmental Science and Technology*, 11: 354-359.

Aksoy, A., Demirezen, D. and Duman, F. (2005). Bioaccumulation, detection and analyses of heavy metal pollution in sultan marsh and its environment. *Springer: water, air, and soil pollution, 164,* 241–255.

Alabaster, J. S and Lioyds, R. (1982). Water quality criteria for fresh water fish. Second edition,Butterworths publication, London.pp:361.

Allan, J.D.(2004). Landscapes and Riverscapes: The influence of land use on stream ecosystems. *Annual Review of Ecology,* 88, 1030-1040.

Albrecht, A., Schultze, U., Liedgens, M., Flu¨ hler, H., and Frossard, E., (2002). Incorporating soil structure and root distribution into plant uptake models for radionuclides: toward a more physically based transfer model. Journal of Environmental Radioactivity 59 (3), 329– 350.

Aloo, P.A. (2003). Biological diversity of the Yala swamp lakes, with special emphasis on fish species composition in relation to changes in the Lake Victoria Basin (Kenya).Threats and conservation measures. . *Biodiversity and conservation*.**12**:905-920.

Alkarkhi, F., Ismail, N and Easa, A. M. (2008). Assessment of arsenic and heavy metal contents in cockles (Anadara granosa) using multivariate statistical techniques. *Journal of hazardous materials,* Vol. 150, No. 3, pp 783-789, ISSN 0304-3894

Alvarez, P.J.J and Illman, W.A. (2006). Bioremediation and natural attenuation: process Fundamentals and mathematical models, John Wiley & Sons, ISBN-13 978-0-471-65043-0, New Jersey.

Amoako J., Ansa-Asare O.D., Karikari A.Y and Dartey, G. (2011). Levels of polycyclic aromatic hydrocarbons (PAHs) in the Densu River Basin of Ghana. Environmental Monitoring and Assessment 174:471-480.

An, S., H. Li, B., Guan, C., Zhou, Z., Wang, Z., Deng, Y., Zhi, C., Xu, S., Fang, J., Jiang, H., Li. (2007). China’s Natural Wetlands: Past Problems, Current Stats, and Future. Challenges. *Ambio*. 36: 335-342.

Anil, K.D. (1994). Environmental Chemistry. New international (P) limited 3rd Edition. New Delhi 237-247.

Anyona, D. N., Dida, G. O., Abuom,P. O., Onyuka, J. O., Matano, A. S., Kanangire, C. K., Ofulla, A. V. O. (2014). Influence of anthropogenic activities on microbial and nutrient levels along the Mara River tributaries, Kenya. *Eurasia journal Biosciences* 8: 1-11.

Anyona, G.O. (1997). An Investigation into some Water quality problems of Lake Kanyaboli in Kenya: M Sc Thesis University of Nairobi.

APHA, (2005). Standard methods for the examination of water and waste water. American public health.21st Edition.1-55pp.

Armstrong J and Armstrong W. (1988). Phragmites australis a preliminary study of soil oxidizing sites and internal gas transport pathways. *New Phytologist*; 108:373–82.

Asada, K., Toyota, K., Nishimura, T., Ikeda, J. and Hori, K. (2010). Accumulation and mobility of zinc in soil amended with different levels of pig-manure composite. *Journal of Environmental Science and Health*, **45**:285-292.

Aslam, M. M., Hassan, S and Baig, M. A. (2010). Removal of Metals from the Refinery Wastewater through Vertical Flow Constructed Wetlands, *International Journal of Agriculture & Biology* Vol. **12**(5), 2010,Faisalabad, Pakistan.

Asuquo J.E. and Etim E.E.(2012). Physicochemical and Bacteriological Studies of Selected . . Borehole Water in Uyo Metropolis in Akwa Ibom State, *Int. J. of Modern Chem.*2(1) 7-. 14.

Avenant-Oldewage, A. and Marx, H. M. (2000). Bioaccumulation of chromium,copper and iron in the organs and tissues of *Claria gariepinus* in the Olifants River, Kruger National Park *Water SA*; **26**: 5

Azza, N. G. T., Kansiime, F., Nalubega, M., and Denny, P. (2000). Differential permeability of and *Miscanthidium* root mats in Nakivubo swamp, Uganda. *Aquatic Botany*, 67: 169-178.

Bahemuka, T.E. and Mubofu, E.B. (1999). Heavy metals in edible green vegetables grown along the sites of the Sinza and Msimbazi rivers in Dares Salaam, Tanzania. *Food Chemistry*, 66 (1), 63-66.

Bañuelos, G.S.,Ajwa H.A.,Mackey B.,Wu L.L.,Cook. C., Akohoue S and Zambrzuski S. (1997). Evaluation of different plant species used for phytoremediation of high soil selenium. J.Environ. Qual. 26(3):639- 646.

Bañuelos, G.S.,Shannon, M.C., Ajwa, H., Draper, J.H., Jordahl, J., and Licht. L. (1999). Phytoextraction and accumulation of boron and selenium by poplar (Populus) hybrid clones. Int.J. Phytoremediation. 1(1):81-96

Begum,A.,Harikrishna S.,Khan L.(2009).Analysis of Heavy metals in water,sediments and Fish samples of Madirala Lakes of Bagalore, Karnataka: International Jounal of ChemTech research.Vol(2),p.245-249.

Berman, E. (1986). Toxic heavy metals and their analysis, Lewis publishers INC.121 South main street,Chelsea,Michigan,525-530.

Blackwell, M., Hogan D., and Malty, E. (2012) . Agriculture, hydrology and water quality. CAB international, London.

Blake, G., Gagnaire, M. J.,Kilrassian, B and Morand, P.(1987). Distribution and accumulation of zinc in *Typha latifolia*. In:Proc. Seminar aquatic plants for water treatment and resource recovery, Orlando, Florida, USA.

Blignaut, J and Van Heerden J. (2009). The impact of water scarcity on economic development initiatives. *Water SA* **35** (4) 415-420.

Boyd, C.E and Tucker, K. (1992). Water quality and pond soil analysis for aquaculture. Alabana Agricultural Experiment station. Auburn university.pp.73.

Boonyapookana B.,Parkpian P.,Techapinyawat S., Delaune R.D., and Jugsujinda .A. (2005). Phytoaccumulation of lead by Sunflower (Helianthus annus), Tobacco (*Nicotiana tabacum*), and Vetiver (*Vetiveria zizanioides*). J. Environ. Science Health. 40: 117-137.

Bosire, G.O (2014). Rehabilitation and Phytoremediation-of Heavy Metal Polluted Riverine Wetlands using Bamboo Phytoextraction in Kibera, Kenya:http://irlibrary.ku.ac.ke .Date accessed 11/03/2014.

Brian, J.,Boma.,P.,Chris Wilson.,and Ontermaa.E.A. (2001).Understanding water quality parameters for citrus irrigation and drainage systems. University of Florida. Gainnesville.FL.32611.

Brix, H. (1997). Do macrophytes play a role in constructed treatment wetlands?*Water science and technology*, Vol. 35, No. 5, pp 11-18, ISSN 0273-1223

Brix H. (1994).Functions of macrophytes in constructed wetland. Water Sci Technol;29(4):71–8.

Bruce, E. P. (2001). Ground water use. Phytoremediation of contaminated soil and ground water at Harzadous waste sites .US.EAP.Office of solid wastes and emergency response.

Busulwa, H.S. and Bailey, R.G. (2004). Aspects of the physicochemical environment of the . Rwenzori rivers, Uganda‖. *African Journal of Ecology* 42:87–92.

Carpenter, S.R. (1998). Non point pollution of surface waters with Phosphorus and Nitrogen, Ecological application, Vol 8, 3, pp.559-568.

Chapman,L.J.,Chapman,C.A and Crisma ,T.L. (1998). Limnology observation of papyrus swamp in Uganda;implications for fish fauna structure and diversity.26:1821-1826.

Chapman, M and Kimistach, V. (1992). A guide to use of biota, sediments and water in environmental monitoring.

Cheng S. (2003). Review Articles: Heavy Metals in Plants and Phytoremediation .International Journal of Enviromental Science and pollution research.10(5):335-340.

Crafter .S.A., and Njuguna, S.G. (1992).Wetlands of Kenya.*Proceedings of the KWWG Seminar on Wetlands in Kenya.*National Museums of Kenya. Nairobi Kenya3-5 July 1991.

Craig S.T. and Louis R.A.(2008). Managing High pH in Freshwater Ponds. Southern Regional . Aquaculture Centre, Publication No., 4604.

Claudia, B., Michela, S., Riccardo, P., Andrea, E.,Marco, P.,and Mario, M. (2008). Seasonal variations of Cu, Zn, Ni and Cr concentration in Papyrus *cyperus* in a constructed wetland of North Italy, *Desalination*, **246** pg. 35–44.

Cornish, J.E., Goldberg W.C., Levine.R.S., and Benemann.J.R. (1995). Phytoremediation of soils contaminated with toxic elements and radionuclides. pp. 55-63. In R.E. Hinchee, J.L. Means, and D.R. Burris (eds.), Bioremediation of Inorganics. Battelle Press, Columbus, OH.

Corstanje, R., Reddy.K.R and Portier K.M.. (2006). *Typha latifolia* and *Cladium jamaicense* litter decay in response to exogenous nutrient enrichment. *Aquatic Botany*. 84:70–78.

Cunningham, S.D., Berti.W.R and Huang. J.W. (1995). Phytoremediation of contaminated soils.Trends Biotechnology. 13:393-397.

Davidsson, T.E. and Stahl, M. (2000). The influence of organic carbon on nitrogen transformations in five wetland soils. Soil Sci. Soc. Am. J., 64, 1129–1136.

Davies, O. A. and Abowei, J. F. N. (2009). Sediment quality of lower reaches of Okpoka Creek, Niger Delta, Nigeria. European Journal of Scientific Research 26(3): 437 – 442 .

Davis, J.S. and Keller, H.M., (1993). Dissolved Loads in Streams and Rivers - Discharge and Seasonally Related Variations. *In*. B.W. Webb ed. *Dissolved Loads of Rivers and Surface Water Quantity/Quality Relationships.* IAHs Publication No. 141, International Association of Hydrobiological Sciences, Washington.

Dhirendra, M. J., Alok K., Namita A. (2009). Studies on Physicochemical Parameters to Assess the Water Quality of River Ganga for Drinking Purpose in Haridwar District. Vol.2, No.1, pp. 195-203 ISSN: 0974-1496.

Di ,H.S and Cameron,K.C. (2002). Nitrate loading in temperate agro ecosystems, souces and mitigation strategies .Nutrient cycling in agro ecosystems,vol 64,3,pp.237-256.

Dida, G. O., Gelder, F. B., Anyona, D. N., Abuom, P. O., Onyuka, J. O., Matano, A-S., Adoka, S. O., Kanangire, C. K., Owuor, P. O., Ouma, C., and Ofulla, A. V. O. (2015). Presence and distribution of mosquito larvae predators and factors influencing their abundance along the Mara River, Kenya and Tanzania. Springer Plus.4:136. doi:10.1186/s40064-015-0905-y.

Dunbabin, J. S and Bowmer, K. H., (1992). Potential use of constructed wetlands for treatment of industrial wastewaters containing metals. *Science of Total Environment.,* 3, 151-168.

Dushenkov, V., Nanda Kumar,P.B.A., Motto.H., and Raskin.I. (1995). Rhizofiltration: The use of plants to remove heavy metals from aqueous streams. *Environmental journal of Science and Technology*. 29:1239- 1245.

Dushenkov, S.D., Vasudev, Y.,Kapulnik, D., Gleba, D., Fleisher, K.C. Ting., and Ensley.B. (1997). Removal of uranium from water using terrestrial plants. *Environmental journal of Science and Technology*. 31(12):3468-3474.

Echeveria J.C.,Zarranz I.J.,Estella J., and Garrito J.J (2005).Simultaneous effect of pH,Temperature,ionic strength and initial concentration on retention of lead on illite.*Applied clay science*.30(2) pp103-115.

Eimers, R.D., Evans,R.D., and Welbourn,P.M. (2001).Cadmium accumulation in fresh water isopod *Asellus vacoriteai*:the relative importance of solute and particulate sources at trace concentrations.Environ,polute.,111:247-258.

Ellen, G., Van loon, J.W. and Tolsma, K. (1990). Heavy metals in vegetables grown in the Netherlands and in domestic and imported fruits. *Z Lebensm Unters Forsch,* 190, 34-39.

Ellery, W.N.,Ellery ,K.,Rodgers,K.H., and McCarthy,T.S. (1995). The role Cyperus papyrus in channel blockage and abandonment in the NorthEastern Okavango delta,Bostwana. *African journal of ecology*, 33:25-49.

Ekmekci Y., Tanyolac D and Ayhan B, (2009). A crop tolerating oxidative stress induced by excess lead: maize. Acta Physiol Plant 31:319-330.

Eloy Bécares, (2006). Limnology of natural systems for wastewater treatment in Mansilla de las Mulas.*Limnetica*, **25**(1-2):143-154. The ecology of the Iberian inland waters, (León, Spain).

Ensley, B.D. (2000). Rationable for use of phytoremediation, In: *Phytoremediation of toxic metals*, Raskin, L. & Ensley, R.D. (Ed.), 3-11, John Wiley & Sons, ISBN 0-471-19254-6, New York.

Ekvall, L and Greger, M., (2003). Effects of environmental biomass producing factors on cadmium uptake in two Swedish ecotypes of Pinus sylvestris. *Environmental Pollution* 121, 401– 411.

Ezekiel Okemwa. (2006). Community Workshops Report On Dominion Farms Project Yala Swamp, Kenya.

FAO, (1993).Guidelines for land use planning. Soil resources, management and conservation. FAO Development series No. 1.

Farr, G. (2004). Why heavy metals are a hazard to your health.

Fisher, T. R., Gustafson A. B., Radcliffe, G. M., and Haas, L. (2001). Effects of atmospheric nitrogen deposition on algal assemblages in Chesapeake Bay.Final Report.Chesapeake Bay Program Office.

Franson, M.H. (1995). Standard methods for examination of water and waste water.(Andrew.D.E .,Lenoo,S.C.,Arnold ,E.G eds)19th Edition American public health ass. Washington 936. 450,1021-1032.

Fredrick, J.M., Fredrick L.M., and Raphael Kapiyo. (2011). Environmental Quality and Fish communities in selected catchments of Lake Victoria. *The open Environmental Engineering, Journal,*4,54-65

Fritioff, A and Greger, M. (2003). Aquatic and terrestrial plant species with potential to remove heavy metals from stormwater. *International Journal Phytoremediation*. 5: 211-224.

Fritioff, A., Kautsky.L., and Greger. M., (2004). Influence of temperature and salinity on heavy metal uptake by submersed plants. Department of Botany, Stockholm University, S-106 91 Stockholm, Sweden Environmental Pollution.133 (2005) 265–274.

Fo¨ rstner, U., (1979). Metal transfer between solid and aqueous phases. In: Fo¨ rstner, U., Wittman, G.T.W. (Eds.), Metal Pollution in the Aquatic Environment. Springer-Verlag, Berlin, pp. 197–270.

Gichuki, F. N. (2003). A review of Wetland Research in Lake Victoria basin, Kenya: Analysis and Synthesis Report SIDA-SAREC. Nairobi.

Gichana Z. M., Njiru M., Raburu P. O., Masese F. O. (2014). Effects Of Human Activities On Microbial Water Quality In Nyangores Stream, Mara River Basin. *international journal of scientific & technology research* vol.3.ISSN. 2277-8616.

Gichuki, J., Maithya, J., and Masai D., M. (2005). Wetland research in the lake Victoria Basin,Kenya ; a report.

Ghosh, M., and Singh, S. P. (2005). A review on phytoremediation of heavy metals and utilization of its by products. *Applied and ecology and environmental research*, 3 (1): 1-18.

Green.E.C., Chaney .L.R and Bouwkamp .J.(2003). Interactions Between Cadmium Uptake and Phytotoxic Levels of Zinc in Hard Red Spring Wheat. *Journal of Plant Nutrition* 26(2):417-430.

Government of Kenya. (1987). Yala swamp reclamation and development project: Inception Report.The Government of Kenya and the Government of Netherlands.Lake Basin Development Authority.

Goering,P.L.,Waalkenes M.P., and klaason C.D.(1994).Toxicology of metals.In: Zinc supplimen supplement overdose can have toxic effects. (R. Hess,.nm and Schmidt ed.) Journal of pediatric Haematology/Oncology,24:528-584.

Gonzalez B.G., Ricardo,B.C.,Flor,C.L., and Fransisco,J.C.(2011).denitrification applied to waste water treatment: processes, regulation and ecological aspects. Nora Science publishers. Inc.Nicolo Seraglio, Raul Puopolo.

Hagan, G. P., Ofosu, F. G., Hayford, E. K., Osae, E. K., and Oduro ‐ Afriyie, K. (2011). Heavy metal contamination and physico - chemical assessment of the Densu River basin in Ghana. *Research Journal of Environmental and Earth Sciences*; **3(4):**385-392.

Håkanson, L, and Jansson, M. (1996) *Principles of Lake Sedimentology*.: Springer- Verlag. Berlin, Gemany

Hess,R and Schmid.B. (2002). Zinc supplement overdose can have toxic effects. Journal of pediatric Haematology/Oncology,24:582-584.

Hooda.P.S.,Edwards, A.C.,Anderson, H.A.,and Miller,A. (2000). Areview of water quality concerns in livestock farming areas. *The science of total environment*, 250,143-167.

Hooda, P.S., and Alloway, B.J., (1993). Effects of time and temperature on the bioavailability of Cd and Pb from sludge-amended soils. *Journal of Soil Science,* 44 (1), 97–110.

Iqbal P.J., Pandit A.K. and Javeed J.A. (2006). Impact of Sewage Waste from Settlements on. Physico- Chemical Characteristics of Dal Lake, Kashmir, *journal of research and development*, 6**,** 81- 85.

Jessica B.(2013). Development of a Field Test for Total Suspended Solid Analysis. Theses Dissertation. Department of Civil Engineering, University of Nebraska- Lincoln.

Jing Li, Haixin Yu and Yaning Luan (2015). Meta-Analysis of the Copper, Zinc, and Cadmium Absorption Capacities of Aquatic Plants in Heavy Metal-PollutedWater.International journal of Enviromental Research and Public Health.

Jones and S.W. Humphries, (2002). Impacts of the C4 sedge *Cyperus papyrus L.* on carbon and water fluxes in an African wetland. Hydrobiologia, 488: 107-113.

Jones, M.B. (1983). Papyrus a new fuel for the third world .New scientist.11:418-421.

Johns .M.B., Kansiime F., and Saunders M.J. (2018).The potential use of papyrus (*Cyperus* *papyrus.L)* Wetland as a source of biomass energy for sub-saharan Africa. GCB.Bioenergy.10 (1):4-11

Jones, (1988). Photosynthetic responses of C3 and C4 wetland species in a tropical swamp. Ecology 76: 253-262.

Jones,M.B and Muthuri, F.M. (1997). Standing biomass and carbon distribution in papyrus (*Cyperus papyrus*)swamp on lake Naivasha.Kenya.Jornal of ecology .13:347-356.

Jordao, C., Pereira, M., and Pereira, J. (2002). Metal contamination of river waters and sediments from effluents of kaolin processing in Brazil.*Water, Air, & Soil Pollution,*Vol. 140, No. 1, pp 119-138, ISSN 0049-6979.

Joseph Kyambadde., Frank Kansiime .,Lena Gumaelius and Gunnel Dalhammar, (2003). A comparative study of *Cyperus papyrus* and *Miscanthidium violaceum* -Based constructed wetlands for waste water treatment in a tropical climate.Department of Biotechnology ,Royal institute of Technology,Albanova University center.S-1061.Stockholm Sweden.

Kabata-Pendias.A and Pendias. H. (2001). Trace elements in soils and plants. CRC Press, London.

Karkhanis M., Jadia C.D., and Fulekar M.H. (2005). Rhizofilteration of metals from coal ash leachate. *Asian Journal of Water, Environment and Pollution*, 3(1): 91-94.

Kaldec, R.H. (2000). The inadequacy of first order treatement wetlands models.*ecological engineering* 12:13-25.

Kadlec, R.H. (2012). Constructed marshes for nitrate removal. Critical Review in Environmental Science and Technolog, 42, 934–1005.

Kadlec, R. H and Brix, H. (1995). Wetlands systems in water pollution control. *Jounal of Water Science and Technology, 32: (3).*

Kadlec, R.H. And Knight, R.L. (Eds.) (1996) Treatment Wetlands.Lewis Publishers, Boca Raton.pp 893 -890.

Kadlec, R. H., Knight, R. L., Vymazal, J., Brix, H., Cooper, P. and Haberl, R. (2002).Constructed wetlands for pollution control: Processes, performance, design and operation. IWA specialist group on use of Report, No.8. London. UK: IWA publishing, p156.

Kamal, M., Ghaly, A. E., Mahmoud, N., and Côté, R. (2004). Phytoaccumulation of heavy metals by aquatic plants. *Environment International* . 29: 1029-1039.

Kansiime, F. and M. Nalubega, (1999). Wastewater treatment by a natural wetland: the Nakivubo swamp Uganda - processes and implications. UNESCO-IHE, Delft, Netherlands.

Kansiime, F., E. Kateyo, H. Oryem-Origa and P. Mucunguzi, (2007). Nutrient status and retention in pristine and disturbed wetlands in Uganda: management implications. Wetlands Ecology and Management, 15: 453-467.

Keith Wiebe and Noel Collehen. (2006) (eds).Agricultural resources and environmental indicators.Nova publishers.

KEBBS (1996). Kenya Bureau of Standards .Government printer Nairobi .KS 05-459:part 1 pg 6. ICS 13:06020.

Khayatzadeh J and Abbasi E. (2010).Effects of Heavy metals on Aquatic animals .1st International Applied Geological congress.Islamic azad University,Iran.

Kibichii, S., Shivoga, W.A., Muchiri, M and Miller, S.N. (2007). Macroinvertebrate assemblages along a land-use gradient in the upper River Njoro watershed of Lake Nakuru drainage basin, Kenya‖ Lakes and Reservoirs: Research and Management 12,107-117.

Kidd, P., Barceló, J., Bernal, M.P., Navari-Izzo, F., Poschenrieder, C., Shilev, S., Clemente, R., and Monterroso, C. (2009). Trace Element Behaviour at the Root–Soil Interface: Implication in Phytoremediation. Environ. Exp. Bot, 67, 243–259.

Kirmani, M. Z., Mohiuddin, S., Naz, F., Naqvi, I. I. and Zahir, E. (2011).Determination of some toxic and essential trace metals in some medicinal and edible plants of Karachi city. *Journal of Basic and Applied Sciences,***7**:89-95.

Kithiia, S.M.(2006). The effects of land use types on hydrology and water quality of upper Athi River basi; Kenya.University of Nairobi.

Kiwango Y.A. and Wolanski, (2008). Papyrus wetlands, nutrients balance, fisheries collapse, food security and Lake Victoria level decline.

Krishnamurthy. R. (1990). Hydro-biological studies of Wohar reservoir Aurangabad (Maharashtra State) India, *Journal of Environmental Biology*, 11(3), 335-343.

Kuo, S. (1996). Phosphorus. In J. Bartels (ed.). *Methods of soil analysis*: *Chemical methods* (Part 3, pp. 869-919). Winsconsin, WI: Soil Science Society of America, Madison Inc.

KWF, (2006). Kenya Wetlands Forum.Rapid Assesment of the Yala swamp wetlands. East African Wildlife Society. Nairobi.

Kumar, P.B.A. N ., Dushenkov, V., Motto,H., and Raskin.I. (1995). Phytoextraction: The use of plants to remove heavy metals from soils. Environ. Sci. Technol. 29(5):1232-1238.

Kuzovkina Y.A., Knee M., and Quigley M.F.(2004). Cadmium and copper uptake and translocation in five Willow (*Salix* L.) species, Int. J. Phytoremediation. 6: 269-287.

Kyambadde, J., Kansiime, K., Gumaelius, K., Dalhammar, L. and, Dalhammar, G. (2004). A comparative study of Cyperus papyrus and Miscanthidium violaceum-based constructed wetlands for wastewater treatment in a tropical climate. Water Research, **38**, 475-485.

Kyambadde, F. Kansiime and G. Dalhammar, (2005). Nitrogen and phosphorus removal in substrate-free pilot constructed wetlands with horizontal surface flow in Uganda. Water Air and Soil Pollution, 165: 37-59.

Laar, C., Fianko, J. R., Akiti, T. T., Osei, J., Brimah, A. K., Osae, S. and Bam, E.K. (2011). Determination of trace elements in the Sakumono Wetland sediments *Research Journal of Environmental and Earth Sciences*; 3(4): 417-421.

Lakmann, P.T and Nambisan P.N.K.(1983).Seasonal variations in trace metal contents in bivale Mollusks,Villorita cyprinoids,Meretrix costa and Perna virdis.India J.Mar.sci.,12:100-103.

Laskowski, D.A. (2002). Physical and chemical properties of pyrethroids. Rev Environ Contam Toxicol 174: 49-170.

Lobanga K.P., Vanzyl J.E and Ilemobade A.A. (2009). The extent of non-compliant plumbing components used in South Africa. Water SA35 (2) 175-182.

LVEMP, (2001).Use of constructed wetlands in the tertiary treatment of industrial wastewater .News bulletin ,vol.2.No.1.

LVEMP, (2002). Lake Victoria Environmental Management Project phase 1, water quality an ecosystem management component, preliminary findings of study conducted on lake Victoria.

LVEMP, (2003). Lake Victoria Environmental Management Project phase 1,Revised Draft Scientific stocking report progress during LVEMP 1 and challenges for future .World bank.

Lytle, C. M., Lytle, F. W., Yang, N., Qion, J. H., Hansen, D., Zayed, A., and Terry, N. (1998). Reduction of Cr (VI) to CR (III) by wetland plants: Potential for *in situ* heavy metal detoxification. Environ. Sci. Technol. 32: 3087–3093.

Macek, T., Kotrba, P., Suchova, M., Skacel, F., Demnerova, K., and Ruml, T.(1994). Accumulation of cadmium by hairy-root cultures of Solanum nigrum. Biotechnology Letters 16 (6), 621–624.

Madigan T.M. and Martinko M.J.(2006). Environmental Effects on Microbial Growth, In : Brock Biology of Microorganisms 11th Edition., Pearson Prentice Hall.

Mamba.B.B, Krause.R.W, Matsebula.B and Haarhoff.J. (2009).Monitoring natural organic matter and disinfection byproducts at different stages in two South African water treatment plants.*Water SA* **35** (1) 121-127.

Majiwa ,J.G.,Magunda,M.M.,and Musitwa,F. (2001). Soil and Nutrient losses from major agricultural land practices in lake Victoria basin. Paper presented at regional scientific conference,Kisumu,Kenya.

Markantonates, P.G., Bocalis,N.C., and Angelidis,M.O. (1995). Pollution Control in the Catchment Basin of River Evrotas, Greece. *Water Science and Technology*, 32 (9-10): 247-255.

Mcgrath, S.P., Shen, Z.G., Zhao, F.J.(1997). Heavy Metal Uptake and Chemical Changes in the Rhizosphere of Thlaspi Caerulescens and Thlaspi Ochroleucum Grown in Contaminated Soils. Plant Soil, 188, 153–159

Matheson, F.E., Nguyen, M.L., Cooper, A.B., Burt, T.P., and Bull, D.C.(2002). Fate of 15N-nitrate in unplanted, planted and harvested riparian wetland soil microcosms. Ecol. Eng., 19, 249–264

Matsumura –Tundusi,T and Tundis J.G. (2005). Plankton richness in eutrophic reservoir (Barva Banita reservoir Brazil)Hydrologia 542:367-378.

Mavuti,K.M. (1989). An account of some important fresh water wetlands of Kenya in Crafter ,S.A,Njuguna .S.G., and Howard,G.W (eds).pp23-35 ICUN Conference proceedings on wetlands of Kenya.

Meagher, R.B., Rugh C.L., Kandasamy M.K., Gragson G., and N.J. Wang N.J. (2000). Engineered Phytoremediation of Mercury Pollution in Soil and Water Using Bacterial Genes. In N. Terry and G. Bañuelos (eds.). Phytoremediation of Contaminated Soil and Water.Lewis Publishers, Boca Raton, FL. pp. 201-219.

Metcalf and Eddy (2003). Wastewater Engineering: Treatment, Disposal and Reuse, 4th Edn, New York: McGraw- Hill.

McNeill, J., (2000). Nothing new under the sun: an environmental history of the twentieth century: Penguin Books, London, England.

Miguel,L;Jody,G;Canty,T.Jukka,P.L;Andwa.S and Alexander,K. (2002). The Gumeric Manual.

Mitsch ,W.J.,Gosselink,J.G., (1993). Wetlands 2nd Edition Van Nostrand Reinhold.115 fifth Avenue,Newyork,NY 10003,USA.

Mnaya, B., Asaeda T., Kiwango,Y., and E. Ayubu, (2007). Primary production in papyrus (*Cyperus papyrus* L.) of Rubondo Island, Lake Victoria, Tanzania. Wetlands Ecology and Management, 15: 269-275.

Mohan, B.S., and Hosetti, B .B. (1999). Aquatic plants for toxicity assessment, Environmental Research. 81: 259-274.

Moreau, S.G. Bertru and Buson. C.(1998). Seasonal and Spatial Trends in Nitrogen and Phosphorus Loads to the Upper Catchment of the River Valaine (Brittany): Relationships with Land Use. *Hydrobiologia* 373/374:247-258.

Moshood K.M. (2008).Assessment of the Water Quality of Oyun Reservoir, Offa, Nigeria, using Selected Physicochemical Parameters, *Turkish J. of Fisheries and Aquatic Sci.*, **8,** 309-319.

Mulongaibalu, M., Jean J. M. B., Muderhwa N., Mujugu E. K. (2014). Assessment of physicochemical parameters in relation with fish ecology in Ishasha River and Lake Edward, Albertine Rift Valley, East Africa. *International Journal of Current Microbiology,vol*, 3(6): 230-244.

Morgan,G;Xie,Q;Davins,M. (2000). Small catchments water quality aspects in Tunney H (eds).Quantification of phosphorus loss from soil to water.EPA,Waxford,24-37.

Morgan, J.A., J.F. Martin and V. Bouchard, (2008). Identifying plant species with root associated bacteria that promote nitrification and denitriefication in ecological treatment systems.Wetlands, 28: 220-231.

Mugisha, P., F. Kansiime, P. Mucunguzi and E. Kateyo, (2007). Wetland vegetation and nutrient retention in Nakivubo and Kirinya wetlands in the Lake Victoria basin of Uganda. Physics and Chemistry of the Earth, Parts A/B/C, 32: 1359-1365.

Mutembei, J.K .,Salim, A M ., Onditi, O.A ., Waudo, W ., Yusuf, A.O . (2014). Determination of Heavy Metals and Nutrients in Rivers Naka and Irigu, Chuka, (Kenya) Using Atomic Absorption Spectrometry and UV/Visible Spectrophotometry. *Journal of Applied Chemistry, vol.7, pp 82-88, ISSN: 2278-5736.*

Muthuri, F.M. and M.B. Jones, 1997. Nutrient distribution in a papyrus swamp: Lake Naivasha, Kenya. Aquatic Botany, 56: 35-50.

Muli, J.R. (1996). Environmental problems of Lake Victoria (East Africa): What the international community can do. *L. Res. Manag*. 2: 47-53.

Munzuroglu, O. and Geckil.H. (2002). Effects of metals on seed germination, root elongation, and coleoptile and hypocotyl growth in Triticum aestivum and Cucumis sativus, Arch. Environ.Contam.Toxicol. 43, 203-213.

Muwanga, A and Barifaijo, E. (2006).Impact of industrial activities on heavy metal loading and there physicochemical effects on wetlands of lake Victoria basin (Uganda). African Journal of Science and Technology.Vol 7(1),pp 51-63.

Mzimela, H.M., Wepener V.,and C.D.P. (2003). Seasonal variation of selected metals in sediments, water and tissues of the groovy mullet, Liza dumerelii (Muglidae) from the Mhlathuze Estuary, South Africa. Mar. Pollut. Bull. 46 659-676.

Mwangi J.K., Thiong'o G.T. and Gathenya J.M. (2012).Assessment of the Water Quality Status of Sasumua Watershed, Kenya, *Elearning. jkuat.ac.ke/journals*.

Nabulo,G., Oryem,H., Origa, G. Nasinyama,W (2008). Assessment of Zn, Cu, Pb and Ni contamination in wetland soils and plants in the Lake Victoria basin. Int. J. Environ. Sci. Tech., 5 (1), 65-74. ISSN: 1735-1472.

Nagendra K. C and Ram K.T. (2011). Effect of industrial effluents and wastes on physico-chemical parameters of river Rapti. *Advances in Applied Science Research*, 2 (5): 207-211.ISSN: 0976-8610.

NAS (1977). National Academy of Sciences ,drinking water and health Vol 2 Washington DC printing and publishing office,National Academy of Sciences.

Nasirwa ,O and Njoroge,P. (1997). Papyrus native birds in the fringing swamps of lake Victoria,western, Kenya.Research reports of the center of biodiversity, National museums of Kenya.Ornithology,28pp.

NEMC (1994). Report of National Environmental Management council and working group on monitoring of mercury and other heavy metals pollution in gold mining areas around Lake Victoria, Tanzania. Pp 69 -78 .

Ndeda, L. A and Manohar, S. (2014). Bio Concentration Factor and Translocation Ability of Heavy Metals within Different Habitats of Hydrophytes in Nairobi Dam, Kenya. *IOSR Journal of Environmental Science, Toxicology and Food Technology.*Vol 8.(5) P.2319-2402. ISSN: 2319-2399.

Ndimele P.E and Komulu-Johnson, C.A.(2012).Some aspects of the physiochemistry and heavy metal content of water sediments and cynothrissa,mento from Bandry crook,lagos,Nigeria. Trends in Applied sciences research.7:724-763.

Ndubi D. Oyaro N. Githae E and Afullo. A. (2015). Determination of Physico-Chemical Properties Of Sources of Water In Narok North Sub- County, Kenya. *Int. Res. J. Environment Sci.* Vol. 4(1), 47-51. ISSN 2319–1414.

Nichole,M and Mason,R.P.(2001).Concentration mercury, methylemercury,cadmium,lead,arsenic and Selenium in rain and stream water of two contrasting water shed in western maryland waters.Res.35,4039-4052.

Nilsen, E.T., Orcutt, D.M.(1996). Physiology of Plants under Stress Abiotic Factors. John Wiley and Sons, Inc., New York, United States of America.

Nyakang'o, J.B. and J.J.A. van Bruggen, (1999). Combination of a well-functioning constructed wetland with a pleasing landscape design in Nairobi, Kenya. Water and Technology, 40: 249-256.

Noraho, N and Gaur, J.P.(1995). Effect of cations, including heavy metals, on cadmium uptake by Lemna polyrhiza L. Biometals 8, 95–98

Obasohan,E.E. (2008). Heavy metals concentrations in the offal, gill, muscle and liver of a fresh water mud fish (Parachannaobscura) from Ogba River, Benin City, Nigeria. African Jounrnal of Biotechology.6:2620-2627.

Odada E. O., Olago, D. O., Kulindwa, K., Ntiba, M., and Wandiga, S., (2004). Mitigation of Environmental Problems in Lake Victoria, East Africa: Causal Chain and Policy. Options Analyses. *Ambio* Vol. 33 No. 1–2.

Odong R.,Kansiime,F.,Omara J.mand Kyambadde J. (2013). The potential of four tropical wetland plants for the treatment of abattoir effluent.*Intl.J.Environ.Technol.Manage*.16 (3):203-222.

Ogoyi, D.O., Chacha M., Ngolo, E.K., Wasonga, C.O., and Shiundu,P.M. (2009). Effects of heavy metal pollution, microalgae richness and diversity of Lake Victoria, in Lake Victoria research proceedings. ISSN 2078-5933, pp 193-210.

Ogundiran, Mathew, A and Fawole, Olatunde, O. (2014). Assessment of the Impacts of Industrial Effluent Discharges on the Water Quality of Asa River, Ilorin, Nigeria. *Journal of Environmental Science, Toxicology and Food Technology. Volume 8, PP 80-98, ISSN: 2319-2399.*

Oketch M.A. (2002). The potential role of constructed wetlands in protection and sustainable management of lake catchments in kenya.Department of environmental Scie`nce.Egerton University.

Okemwa, E.N. (1981). A preliminary survey of the fisheries and Limnology of lake Kanyaboli and Lake Sare in Western Kenya.Proceedings of the workshop of the Kenya Marine and Fisheries Research on ‘Aquatic Reserves of Kenya’.pp 192-211.

Okurut, T., Kansiime, F., Busulwa, H., Mwebembezi, L., Malinga, A and Barugahare, V. (2000). Lake Victoria Environmental Management Project, Wetlands Component, Buffering capacity of wetlands subcomponent: Buffering capacity of Kinawataka and Kisoma wetlands report; Ministry of Water, Lands and Environment.

Okurut, T. O., Rijs, G. B. J., and Van Bruggen, J. J. A. (1999). Design and performance of constructed wetlands in Uganda, planted with *Cyperus papyrus* and *Phragmites mauritianus*.

Okurut, T.O. (2000). A Pilot Study on Municipal Wastewater Treatment Using a Constructed Wetland in Uganda. PhD dissertation, UNESCO-IHE, Institute for Water Education, Delft,The Netherlands.*er Science and Technology* 40 (3): 265-271.

Ombaka O. and Gichumbi J.M. (2012). Investigation of Physico-chemical and Bacteriological Characterization of Water Samples from Irigu River, Meru South, Kenya, *International. Journal of Scientific and Engineering Research.*, 3(11)

Ongeri, D.M.K., Mburu,J.N., and Mburu ,J.K. (2008). Potential environmental problems of pesticide residues in coffee farming, (A review) Presented at a workshop on coffee farming and its future held at coffee research foundation Ruiru,Jomo Kenyatta Foundation,Kenya pp4.

Opiyo,S.V. (1991). Feeding ecology of *Oreonchromis esculentus* (Graham) (pisces:Ochlidae) in lake Kanyaboli,Kenya.M.Sc.Thesis,University of Nairobi,147 pp.

Osakwe ,S.A. and Perentiema.B.O.(2013).Evaluation of heavy metals in sediments of river Ethiope,delta state,Nigeria.IOSR. Journal of applied chemistry (IOSR-JAC).4(2)1-4.

Outridge, P. M. and Noller, B. N. (1991). Accumulation of toxic trace elements by freshwater vascular plants.*Reviews of Environmental Communication and Toxicology, 121*, 1-63.

Oztürk.M.,Özoen.G.,Minaroci.O and Minaroci.E. (2009). Determination of heavy metals in water and sediments of Avsar dam in Turkey.Iranian Journal of environmental health science and engineering.6:73-80.

Patil Kishor P. Patil vilas S, Nilesh Patil and Motiraya vijay, (2012) Adsorption of copper (Cu^{2+}) and zinc (Zn^{2+}) metals. Journal of Hazardous materials, B90, pp 205-216

Patra, M., Bhowmik, N., Bandopadhyay, B. and Sharma, A. (2004). Comparison of mercury, lead and arsenic with respect to genotoxic effects on plant systems and the development of genetic tolerance. *Environmental and Experimental Botany,* **52:**199-223.

Payan M.C.,Galan B.,Coz.A.,Vandecasteole J.C and Viguri J.R. (2012).Evaluation through column leaching tests of metal release from contaminated estuarine sediment subject to CO_2 leakages from carbon capture storage sites.*Envionmental pollution*.117(10).pp.174-184.

Perbangkhem, T. and Polprasert,C. (2010). Biomass production of papyrus (*Cyperus papyrus*) in constructed wetland treating low-strength domestic wastewater. *Bioresource Technology*, 101: 833-835.

Piedade, M.T.F and Long, S. P. (1991). The Productivity of the C_4 Grass *Echinochloa polystachya* on the Amazon Floodplain. Ecology, 72: 1456-1463

Popay, I, (2104). *Cyperus papyrus (*papyrus). Invasive species compendium,CABI Publishing,Wallingford,UK.

Prabu, P. C. (2009). Impact of heavy metal contamination of akaki river of Ethiopia on soil and metal toxicity on cultivated vegetable crops. *Electronic Journal of Environmental, Agricultural and Food Chemistry, **8**:*818-827.

Prasad, M.N.V. (2007). Aquatic plants for phytotechnology. In S.N.Singh and R.D.Tripathi (eds) Environmental Bioremediation technologies. Springer. Pp. 257-274.

Premlata V. (2009).Multivariant Analysis of Drinking Water Quality Parameters of Lake Pichhola in Udaipur, India,*Biol. Forum- An Int. J*., 1(2) 97-102.

Pullan, R.A. (1988). A survey of past and present wetlands of the western Algarve. Department of Geography, University of Liverpool, UK.

Raburu P. O.and Okeyo-Owuor J.B.(2002). Impact of agro-industrial activities on the water quality of River Nyando, Lake Victoria Basin, Kenya. Department of Fisheries and Aquatic Sciences, Moi University. Eldoret, Kenya.

Rai, U.N., Sinha, S., Tripathi, R.D., and Chandra, P. (1995). Wastewater Treatability Potential of some Aquatic Macrophytes: Removal of Heavy Metals. Ecol. Eng., 5, 5–12.

Ramdan, A. A. (2003). Heavy metal pollution and biomonitoring plants in Lake Manzala,Egypt. Pak. J. Biol. Sci, 6(13), 1108-1117.

Rajappa, B., Manjappa, S and Puttaiah, E. T. (2010**).** Monitoring of heavy metal concentration in groundwater of Hakinaka Taluk, India. *Contemporary Engineering Sciences*; **3(4)**:183- 190.

Raskin, I.,and Ensley, B.D. (2000). Phytoremediation of Toxic Metals: Using Plants to clean up the Environment, John Wiley and Sons, ISBN 0-471-19254-6, New York.

Ratajkiewicz (2007). An influence of quality of water on the selected properties of tank mixes. *Prog. Plant Prot.* **47** (1) 115- 118 (in Polish). URL:

Rajkovic, M. B., Lacnjevac, C. M., Ralevic, N. R., Stojanovic, M. D., Toskovic,D. V., Pantelic, G. K., Ristic, N. M and Jovanic, S. (2008). Identification of metals (heavy and radioactive) in drinking water by indirect analysis method based on scaletests. *Sensors*; **8**:2188-2207.

Razas S.T.,Zulfiqar Ali.,Zainab Irfan and Sidra Safdar.(2015). Soil and Water analysis for micronutrients in wetlands associated with grassland ecosystems. *Journal of animal and plant sciences* 25(4):1168-1175.

Rehman, A.,and Sohail Anjum, M. (2010). Cadmium Uptake by Yeast, Candida tropicalis,Isolated from Industrial Effluents and Its Potential Use in Wastewater Clean-Up Operations. *Water, Air, & Soil Pollution,* Vol. 205, No. 1, pp 149-159, ISSN 0049-6979

Rooney, P. (2013).*Cyperus papyrus L.*Infraspecies: A pilot monographic study of the infraspecies of *Cyperus papyrus L*. Prepared in assessment for the Msc .Plant Diversity at Reading university,2012-2013.Reading.UK.

Sahu, R.K., Naraian, R., and Chandra, V. (2007). Accumulation of Metals in Naturally Grown Weeds (Aquatic Macrophytes) Grown On an Industrial Effluent Channel. Clean Soil Air Water, 35, 261–265.

Samarokoon,C.C.,Weerasinge, P.A., and Weerekkody,W.A.P. (2006). Effect of Electrical conductivity (EC) of nutrient solution on nutrient uptake growth and yield of leaf lettuce (*Lanctuca Sativa*) in stationary culture.

Salt, D.E., M., Blaylock, P.B.A. Nanda Kumar, V., Dushenkov, B.D., Ensley, I. Chet.,and Raskin.I. (1995). Phytoremediation: A novel strategy for the removal of toxic metals from the environment using plants. Biotechnol. 13:468-474.

Safari D., Mulongo G., Byarugaba D., and Tumwesigye W. (2012). Impact of Human Activities on the Quality of Water in Nyaruzinga Wetland of Bushenyi District – Uganda. *Int. Res. J. Environment Sci.* Vol. 1(4)1-6. ISSN 2319–1414.

Saunders, M. Jones and F. Kansiime, (2007). Carbon and water cycles in tropical papyrus wetlands. Wetlands Ecology and Management, 15: 489-498.

Sekomo, C.B. (2012). Development of a low-cost alternative for metal removal from textile wastewater.PhD Thesis.UNESCO-IHE Institute for Water Education. Delft, The Netherlands.

Serag, M.S. (2003). Ecology and biomass production of *Cyperus papyrus* L. on the Nile bank at Damietta, Egypt. Mediterranean Ecology, 4: 15-24.

Shadrack, M., Charles, N., Kamau, G., Gilbert ,O., and Phanice W.(2015). Physical Parameters of Tropical Wetlands in Lake Victoria Basin: A Case Study of Kigwal/Kimondi, Nyando and Nzoia Wetlands. *J Environ Anal Toxicol* 5: 254.

Sharpley,A.N.,Foy,B., and Withers,P. (2000). Practical and innovative measures for the control of Agriculture phosphate losses to water;an overview.journal of environmental quality;29,1-9.

Sharma P and Dubey R.S. (2005). Lead toxicity in plants. Braz J Plant Physiol 17:35-52

Schnoor, J.L. (1997). Phytoremediation, Technology Evaluation Report TE-98-01, GWRTAC,Pennsylvania.

Scherem ,P.A., Mirambo,A.M., Lemmen.,J.H., and Katima ,F.J. (2001). Assesment of pollution sources and socio economic circumstances related to the eutrophication of lake Victoria. Paper presented at LVEMP Conference Kisumu.

Schmidt Ulrich, (2003). Enhancing Phytoextraction: The Effect of Chemical Soil Manipulation on Mobility, Plant Accumulation, and Leaching of Heavy Metals.*Journal of Environmental Quality*. 32:1939-1954.

Schuyt, K., and Brander, L. (2004). The Economic Values of the World's Wetlands, Gland/Amsterdam, WWF.

Seif ,R and Waskom,K. (2008). Nutrients in the Nations water. Identifying problems and progress.96-981.

Sekomo.B, C., Uwamariya V., Birori M., Nkundimana E., and Nkuranga J. B.(2011). Water Quality Monitoring in Rwanda. A report by National University of Rwanda

Sidney, W. (1984). Official methods of analysis, 14th Ed.A.O.A.C.Inc.,Washington DC; pp.38-48.

Simonit ,S and Perrings,C. (2004). An intergrated watershed approach to fisheries managemet in Lake Victoria .IN EC RTD INCO-DEV programme.(2004).Tools for wetland ecoststem resource management in Eastern Africa.pp229-249.

Skoog,A.D., Holler, J.F.and Crouch,S. (2007). Principles of instrumental analysis 6th ed,Thomson Books.Cole ; pp.238-246.

Smith, R.A., Alexander, R.B., and Lanfear, K.J., (1993). Stream Water Quality in the Conterminous United States – Status and Trends of Selected Indicators During the 1980's.*In:* National Water Summary, 1990-91, U.S. Geological Water-Supply Paper 2400:111-140.

Southern Cooperative Series Bulletin, (2000). Methods of phosphorus analysis for soil sediments residuals and waters. *Throckmorton plant science Ctr*.Kansas State University.Manhattan ISBN: 1-58161-396-2.

Sun, H., Wang, Z., Gao, P., and Liu, P. (2013). Selection of Aquatic Plants for Phytoremediation of Heavy Metal in Electroplate Wastewater. Acta Physiologica. Plant, 35, 355–364.

Sundaravadivel., M. and Vigneswara.,S. (2001). Constructed Wetlands for Wastewater treatment**.** *Critical Reviews in Environmental Science and Technology*, 31(4):351–409

Suresh, B.,and Ravishankar, G.A. (2004). Phytoremediation.A novel and promising approach for environmental clean-up.*Critical reviews in biotechnology*, 24, 2-3, 97-124. ISSN:1549-7801.

Tanner, C. and Sukias, J.(2011). Multiyear nutrient removal performance of three constructed wetlands intercepting tile drain flows from grazed pastures. J. Environ. Qual., 40, 620–633.

Terer, T., Triest.L., and Muthama Muasya, A. (2012). Effects of harvesting *Cyperus Papyrus* in undisturbed wetland, Lake Naivasha, Kenya. Hydrobiologia, 680: 135-148.

Theophile F.,Victor F.N., Jonas Y.P.,Vincent M.A., Dekoum,M.L., and Amongou. (2005). Macrophyte diversity in polluted and non polluted wetlands in Cameroon.Cameroon Journal of experimental biology vol.01.pp 26-33.

Thenya, T. (2006). Analysis of macrophyte biomass productivity, utilization and impacts onvarious eco-types of Yala swamp, Lake Victoria basin, Kenya.Ecology and development series No. 48, 2006.

Tiner, R.W. (1984). Wetlands of the United States: Current status and Trends, US fish and Wildlife Service, Washington, D.C.

Tucker, R.K. and Shaw, J.A. (2000). Phytoremediation and public acceptance, *Phytoremediation* of Toxic Metals: Using Plants to Clean up the Environment, Raskin, L.& Ensley, R.D. (Ed.), 33-49, John Wiley & Sons, ISBN 0.

Tunney,H.,Copulter,B.,Darly,K.,Kurtz,L.,Coxon,C.,Jeffrey,D.,Mills,P.,Kelly,G and Morgan,G. (2000). Quantification of phosphorus loss from soil to water,EPA,Waxford.

UNEP (United Nation Environment Programme) (1999). Global Environmental Outlook 2000. London, Earthscan Publications.

USEPA, (1986). Quality Criteria for Water. Office of Water Regulations and Standards.Washington, D.C. EPA/440/5-86-001.

US EPA (1996). Overview of the storm water management program. Washington (DC): US EPA Office of Water. EPA 833-R-96-008.42 p.

USEPA, (1998). U.S. Environmental Protection Agency. Guidelines for Ecological Risk Assesment.Federal register 63(93)(26846-26924).Washington D.C.

USEPA (U.S.Environmental Protection Agency) (2002).Methods of evaluating wetlands conditions: Introduction to wetland biological assessment.Office of water .US.Environmental Protection Agency .Washington.DC.EPA-822-R-02-014.

UNEP, 2000. Global Environmental Outlook 2000. UNEP, Nairobi.

Usero, J., Izquierdo.C.,and Morillo,J.(2003).Heavy metals in fish (*Solea vulgaris, Anguilla anguilla and Liza aurata)* from salt marshes on the southern Atlantic Coast of Spain.*Environ.int*.,1069:1-8.

Vaughan G. (2011). Cyperus Papyrus L.In:Brink,M;Achigan-Dako,E.G.PROTA (Plant Resource Of Tropical Africa),Wagoningen, Netherlands.

Verhoeven, J.T. and Meuleman, F.M. (1999). Wetlands for wastewater treatment: Opportunities and limitations. *Ecological engineering*. 12, 5-12

Vymazal, J., Vehla, J., Kr Pfelová, L., and Chrastny, V. (2007). Trace Metals in Phragmites australis and Phalaris Arundinacea Growing in Constructed and Natural Wetlands. Sci. Total Environ., 380, 154–162.

Vymazal and Kröpfelová, L. (2009). Removal of organics in constructed wetlands with horizontal sub-surface flow: A review of the field experience. Science of the Total Environment, 407: 3911-3922.

Vymazal, J., Brix H., Cooper ,P.F., Green, M.B., and Herbel R., (1998). Constructed wetlands for wastewater treatment in Europe. Leiden, The Netherlands: Backhuys Publishers.

Wang, T.C., Weissman J.C., Ramesh G., Varadarajan R., and Benemann J.R.(1996). Parameters for removal of toxic heavy metals by water milfoil (Myriophyllum spicatum). Bull. Environ. Contam.Toxicol. 57:779-786.

Waziri,M and Ogugbuaja,V.O. (2010). Interrelationships between physicochemical water pollution indicators: A case study of River Yobe-Nigeria. American Journal of Scientific and Industrial Research. ISSN: 2153-649.

Welsh, R. P. and Denny, P. (1980). The uptake of lead and copper by submerged aquatic macrophytes in two English lakes. *Journal of Ecology*; **68:** 443 - 455.

Wetzel, R.G. (2001). Limnology,3rd edition. Academic press: London UK.

White, J.R., Reddy,K.R. and Moustafa.M.Z. (2004). Influence of hydrology and vegetation on phosphorus retention in Everglades Stormwater treatment wetlands. *Hydrol. Processes* 18:343–355.

Willard,H.,Merrit,Jr.L.L.,Dean ,J.A and Settle,F. (1992). Instrumental methods of Analysis .Van Nonstrand.Co.Newyork.7th Ed.World .

WHO (World Health Organization) (1995). Guidelines for Drinking Water Quality. World Health Organization,Geneva

WHO (World Health Organization) (1998).Guidelines for drinking water quality. International programme on chemical safety.(UNEP,ILO.WHO).vol 1.

WHO (World Health Organization) (2000).Global Water Supply and Sanitation Assessment 2000 Report. World Health Organization,Geneva. URL

WHO (World Health Organisation) (2004).Guidelines for drinking water quality,3rd edn.World Health Organisation,Geneva.

Woranam, N., Natthawoot P., Kannika S., Orapan M., and Wattchara N. (2010).Advances in Phytoremedaion Research:A case study of Gynura Pseudochina (L.)DC.,Advanced Knowledge Application in Practice ,Igor Feustner (Ed).ISBN:978-953-307-141-1,InTech.

Woodworth, J.C. and Pascoe V. (1982). Cadminium toxicity to rainbow trout,*Salmo garrdneri* Richardson .A of eggs and alevins.J.Fish.Biol.,21:47-57.

Woźnica Z. and Waniorek W. (2008). Importance of water conditioners for glyphosate efficacy.*Prog. Plant Prot.* **48** (1) 329-335 (in Polish). URL:

Xu, J.H., He, S.B.,Wu, S.Q., Huang, J.C., Zhou,W.L., and Chen, X.C.(2016). Effects of HRT and water temperature on nitrogen removal in autotrophic gravel filter. Chemosphere, 147, 203–209.

Yadav, A., Gopesh, A., S. Pandey, R., Rai, D. K.,and Sharma, B. (2007). Fertilizer Industry Effluent Induced Biochemical Changes in Fresh water Teleost, Channa striatus (Bloch). *Bulletin of environmental contamination and toxicology*, Vol. 79, No. 6, pp 588- 595, ISSN 0007-4861

Yadav, S., Chandra, R. (2011). Heavy Metals Accumulation and Eco physiological Effect on *Typha angustifolia* L. And *Cyperus esculentus* L. Growing in Distillery and Tannery Effluent Polluted Natural Wetland Site, Unnao, India. Environ. Earth Sci., 62, 1235–1243.

Yilmaz, E and Koc,C.(2014).Physically and chemically evaluation for water quality criteria in a farm on Akay.J.water resour. Prot., 6:63-67.

Zhu, T. and Sikora, F.J., (1994). Ammonium and nitrate removal in vegetated and unvegetated gravel bed microcosm wetlands, in: *Proc. 4th Internat. Conf. Wetland Systems for Water Pollution Control*,ICWS'94 Secretariat, Guangzhou, P. R. China, pp. 355-366.

APPENDICES

Appendix I. Coordinates of sampling stations

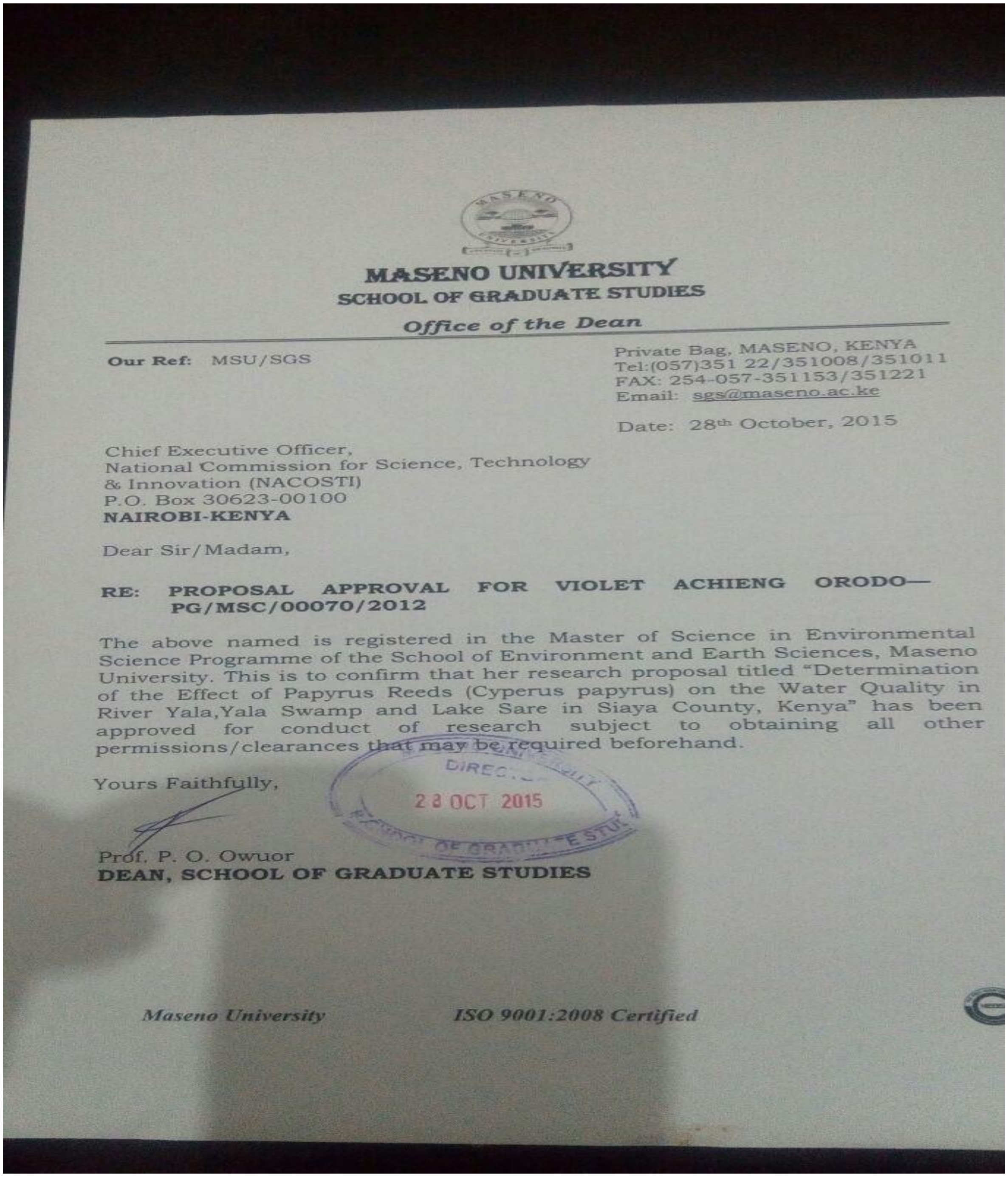
A	B	C	D	E	F
00.22864^{0}E 034.19646^{0}N	S 00.08686^{0}E 034.22622^{0}N	00.0385^{0}E 034.15344^{0}N	0.003043^{0}E 034.06506^{0}N	S00.06054^{0}E 034.04382^{0}N	S 00.05957^{0}E 034.05420^{0}N
00.01661^{0}E 034.11509^{0}N	S 00.08686^{0}E 034.33666^{0}N	N 00.6441^{0}E 034.14276^{0}N	0.003043^{0}E 034.07026^{0}N	S 00.06054^{0}E 034.04412^{0}N	S00.05957^{0}E 034.04292^{0}N
	N 00.03915^{0}E 034.15238^{0}N	N 00.05810^{0}E 034.14873^{0}N			S 00.08282^{0}E 034.02998N^0

Appendix II. Correlation coefficient values (r) of AAS calibration curves.

Element	Correlation values (r)
Pb	0.99900
Zn	0.99900
Cu	0.99900
Fe	0.99490
Cd	0.99300

The linear ranges of the obtained calibration curves were determined by considering concentration ranges of the standards. This is the range of the concentration of standards (Mg/l) along the linear portions of calibration curves for the selected heavy metals from AAS. Based on the above results, it can be concluded that the established calibration curves were good and that the results were accurate.

Appendix III. Letter of approval to carry out research



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Date: 28th October, 2015

Chief Executive Officer,
National Commission for Science, Technology
& Innovation (NACOSTI)
P.O. Box 30623-00100
NAIROBI-KENYA

Dear Sir/Madam,

RE: PROPOSAL APPROVAL FOR VIOLET ACHIENG ORODO— PG/MSC/00070/2012

The above named is registered in the Master of Science in Environmental Science Programme of the School of Environment and Earth Sciences, Maseno University. This is to confirm that her research proposal titled "Determination of the Effect of Papyrus Reeds (Cyperus papyrus) on the Water Quality in River Yala,Yala Swamp and Lake Sare in Siaya County, Kenya" has been approved for conduct of research subject to obtaining all other permissions/clearances that may be required beforehand.

Yours Faithfully,

28 OCT 2015

Prof. P. O. Owuor
DEAN, SCHOOL OF GRADUATE STUDIES

Maseno University *ISO 9001:2008 Certified*

Appendix IV: Existing NEMA and USEPA Standards for Discharge of Effluents into Aquatic Environment

Parameter	Limits	Remarks
PH	6.0 – 9.0	
BOD (5 Days at 20^0C	20 mgO_2/l	
COD	50 mgO_2/l	
Suspended solids	30 mg/l	
Total phenols	0.001 mg/l	2.0 mg/l in some cases
Copper	3 mg/l	0.05 mg/l in some cases
Zinc	0.5 mg/l	
Sulphates	250 mg/l	500 mg/l in some cases
Dissolved iron	10 mg/l	
Dissolved manganese	10 mg/l	0.1 mg/l in some cases
Chromium (Total)	2 mg/l	
Chromium (Hexavalent)	0.5 mg/l	
Chloride	200 mg/l	1000 mg/l in some cases
Fluoride	2.0 mg/l	
Free ammonia	0.2 mg/l	
Coliform Bacteria	300 mg/l /100 ml	1000/100 ml in some cases
Colour (Hazen units)	5	Not objectionable to the eye
Dyes	Nil	
Sulphide	0.1 mg/l	
Cadmium	0.1 mg/l	0.05 mg/l in some cases
Cyanide	0.1 mg/l	
Organic phosphorus	1.0 mg/l	
Nickel	1.0 mg/l	
Selenium	0.05 mg/l	
Barium	2.0 mg/l	
Lead	1.0 mg/l	
Arsenic	0.02 mg/l	
Total mercury	0.005 mg/l	
Alkyl mercury	Not detectable	0.001 mg/l in some cases
Polychlorinated biphenyls	0.03 mg/l	
Smell	Not objectionable to the nose	
Toxic substances	Nil	
Pesticides	Nil	0.05 mg/l in some cases
Oils and grease	Nil	
Degreasing solvents	Nil	
Calcium carbide	Nil	
Chloroform	Nil	
Condensing water	Nil	
Inflammable solvents	Nil	
Temperature	30^0C	
Dissolved solids (total)	1200 mg/l	