EFFECT OF LAND USE ACTIVITIES ON WATER QUALITY, SOIL AND VEGETATION COVER FOR THE CONSERVATION OF NSOOBA LUBIGI DRAINAGE SYSTEM, KAMPALA CITY

BY

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DECLARATION

This dissertation is my original work and has not been presented for a degree in any other University.

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APPROVAL

This dissertation has been submitted to Kyambogo University Directorate Of Research And GraduateTraining with our approval as university supervisors.

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LIST OF ACRONYMS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
NEMA	National Environment Management Authority
MWE	Ministry of Water and Environment
LULC	Land Use Land Cover
TOC	Total Organic Carbon
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
KCCA	Kampala Capital City Authority
TDS	Total Dissolved Solids
APHA	American Public Health Association
As	Arsenic
Cd	Cadmium
Pd	Lead
Hg	Mercury
CFU	Colony Forming Units
ISC	Interactive Supervised Classification
GIS	Geographic Information System
MLSB	Membrane Lauryl Sulphate Broth

ABSTRACT

Human activities such as agriculture, rural-urban development, industrialization as well as excessive deforestation cause land-use changes associated with water pollution and consequently degradation of the natural vegetation and soil resource. This study, thus, sought to assess the impact of such land use activities on water quality, soil and vegetation cover on Nsooba Lubigi drainage system. The study used quantitative research design where the physical-chemical characteristics of soil and water samples along the catchment area were determined by American Public Health Association standard analytical methods. The actual effect of human activities on land use and vegetation coverage was assessed using image acquisition and processing using GIS. A minimum of 48 water samples and 48 soil samples were collected from designated locations within Nsooba Lubigi drainage system and stored in Duran bottles, ready for analysis. Kruskal-Wallis H-test, Fisher's exact test and ANOVA F-test were applied to analyze the obtained data. Results showed that the parameters differed significantly by stream ($p < 0.05$). The parameter concentrations of land-use types of wetland, built up areas and agriculture were EC (537.5 µs/cm, 472.5 µs/cm and 272.50 µs/cm), TDS(309.00 mg/l, 352.00 mg/l and 155.00 mg/l), TP (0.84mg/l, 0.82 mg/l and 0.53 mg/l), TN (8.05mg/l, 11.27 mg/l and5.96mg/l), BOD (5.75 mg/l, 14.00 mg/l and 8.75 mg/l), COD (41.00 mg/l, 49.50mg/l and 42.00 mg/l), TSS (25.00 mg/l, 42.00 mg/l and 10.00 mg/l) and TOC (16.70 mg/l, 20.50 mg/l and 5.65 mg/l). E coli and Total Coliforms concentrations for wetland, built up areas and agriculture were 317.50 CFU/ml, 384.00 CFU/ml and 586.50 CFU/ml; and 912.00 CFU/ml, 1481.00 CFU/ml and 1265.00 CFU/ml respectively. Lead and Cadmium values for wetland, built up areas and agriculture for were 0.614 mg/kg, 0.356 mg/kg and 0.495 mg/kg; and 0.002 mg/kg, 0.005 mg/kg and 0.003 mg/kg respectively. Wetland coverage declined by approximately 5 hectares (47.2% to 14.58%) whereas bare land declined from 14.5% in 1998 down to 7% by 2018. Land-use activity had a significant effect on land cover area with built-up area observed to be higher than area under agriculture and bare land. In conclusion, this study identified human activities as the main drivers for decline in water quality, soil quality and vegetation cover change within Nsooba Lubigi drainage system. This calls for urgent attention by responsible authorities such as NEMA, KCCA and sensitization of surrounding communities on the benefits of this catchment area.

CHAPTER ONE: INTRODUCTION

1.1 Background

Globally, water quality deprivation is one of the main persistent, and greatly observable signs of antropogenic impacts varying widely at local and regional scales on the natural environment with the major water pollutants resulting to chemical, physical and microbial factors originating from industrialized countries (Survey & Water, 2005). Surface water bodies such as reservoirs, river streams and lakes are enormously vulnerable to primary discharges of solid and liquid waste. Extremely dilute water bodies, specifically in headwater regions are vulnerable to impacts caused by atmospheric deposition (acid rain) (Sasakova *et al.*, 2018).

In developing countries, the changes in land use are directly and indirectly related to pollution challenges that include sewage, insecticides and pesticides, greatly contaminated water quality, principally near intensive agricultural areas and urban industrial centers (Wang *et al.*, 2015). This alters the ecological landscape, basic necessities in providing food, water, energy for heating and cooking (Norman *et al.*, 2005), severe strain from anthropogenic encroachment as well as consistent landfilling activities for reclamation, water drainage for agriculture and livestock farming, human settlements, clay and sand extraction, brickmaking, the harvesting of papyrus, municipal and industrial waste discharges, unsuitable and illegal solid waste disposal (Kayima *et al.*, 2018). In the natural ecosystem, heavy metal concentrations differ, human activities alter the distributions and natural cycles of metals creating an unbalanced ratio in the metal cycle resulting to accumulation (Wu *et al.*, 2016).

Proportionately, environmental problems have increased such that, poor management practices, principally the gross pollution of water quality with a connected increase in waterborne related diseases (Osibanjo & Adie, 2007). Edokpayi *et al.,* (2018) stated that cities in most developing countries produce on the average 30-70mm^3 of wastewater per person annually due to inappropriate wastewater treatment and management facilities, the effluents often are discharged directly into surface water bodies, which are receptacles for industrial and domestic wastes, acting as the major contributors to wastewater pollution. They further add that the discharge of raw and improperly treated wastewater into waterstreams severely impacts on the environment and human health, hence adequate treatment is required to avert adverse health risk of the user of surface water bodies and the aquatic ecosystem.

Water quality problems comprise of the biological and physical-chemical quality of a watershed, these reverberate from human-induced activities of organic pollution, eutrophication, acidification, toxic contamination, temperature changes due to indirect thermal discharges (Cloutier, Alm, & McLellan, 2015). Many studies of watershed microbiology focus largely on the detection of indicator microbes such as E. colienterococci, salmonella and coliform bacteria and how these might indicate potential risks to human health and environment (Lyons, *et al.,* 2021). Amenu, (2014) indicates that over 70% of the planet is covered by oceans, and therefore water bodies should be protected as dumping ground for waste discharge of raw sewage and garbage that completely contaminate rivers in major urban centers (Neboh *et al.,* 2013). The determination of dissolved oxygen levels is proportional to its saturation point and the oxygen utilization rate by micro-organisms measured as its BOD and it is a notable indication for ascertaining the contamination status of a water body (Tenebe *et al.,* 2018).

Hawumba (2017), indicated that; in Uganda, the leading causes of water quality impairment is highe nutrient (phosphorus and nitrogen) discharge to the ground and surface water bodies. He further added that, whereas nitrogen is of principal significance in affecting and preventing eutrophication in marine environments, phosphorous is the restraining nutrient in freshwater (or non-saline) ecosystems. According to Ding *et al.,* (2015), studying the correlation among water quality and land use supports to ascertain primary stresses to water quality, these are predetermined for efficient water resource and quality control since they can be used to target key land use regions and to incorporate pertinent methods to curtail contamination discharges.

Similar studies on land use have indicated its substantial impacts on water quality. Deforestation, urbanization and agriculture mostly alter land topography and characteristics, surface runoff volume, upsurge algal production, generate contamination and reduce concentrations of dissolved oxygen in water resources (Lyons, *et al.,* 2021). According to Wang *et al.,* (2015), vegetation cover is an indicator that assesses terrestrial environmental surroundings. Minor alterations of vegetation structures of the landscape inhibit ecological processes. The increasing rates of land-use change over natural habitats like wetlands, lakes, rives have resulted into the conversion of the natural environment for agriculture, sand mining, fishing and urbanization. Any deterioration of the natural vegetation raises the quantity levels of particulate matter in water, and consenquently can directly and indirectly affect water quality (Fierro *et al.*, 2017).

According to Sebhatleab (2014), land use change has triggered the decline in both soil physicochemical and biological properties depending on the classification levels across the landscape and soil profile. Constant exposure of top soil can attribute to longterm intensified vegetation deprivation and start a process of land pollution (Marinho *et al.,* 2016). The correlation between land use activities and its impact on soils involves studying the drivers of the variations in soil structure and help in illustrating good management processes to prevent desertification and attain conservation goals (Achparaki *et al.*, 2012).

Limited studies have been conducted to study the overall interactions between land use and water quality. The consequences of anthropogenic activities on water quality, soils, and vegetation cover are severe and call for sustainable management. In this study, the relationship between land use and water quality was assessed by determining the microbial and physical-chemical attributes of the water, soils intergrity, as well as examine the vegetation cover along Nsooba Lubigi drainage system. This study, therefore, seeks to evaluate the effect of land use on water quality, soil and vegetation cover on Nsooba Lubigi drainage system.

1.2 Problem Statement

In Uganda, land degradation is one of the environmental challenges highly impacted due to agricultural expansion, development of urban areas, industrialization as well as excessive deforestation causing water pollution and consequently degradation of the natural vegetation and the soil resource. Further, the unregulated discharge of both organic and inorganic solid and liquid polluntants from various source points and nonsource points into the natural ecosystem results into the deterioration of water quality, soil quality as well as deprivation of the vegetation cover.

The studies on human-induced activities on the environment, literature on water quality, soils and vegetation cover are limited in several developing countries, including Uganda. This study, therefore, explores the effect of land use activities on water quality, soil and vegetation cover on Nsooba Lubigi drainage system.

1.3 Objectives of the Study

1.3.1 General Objective

To evaluate the effect of land use activities on water quality, soil and vegetation cover for the conservation of Nsooba Lubigi drainage system.

1.3.2 Specific Objectives

1. To determine the effect of land use activities on physical-chemical composition of water within Nsooba Lubigi drainage system.
2. To determine the effect of land use activities on bacteriological composition of water within Nsooba Lubigi drainage system.
3. To assess the effect of land use activities on the quality of soil within Nsooba Lubigi drainage system.
4. To determine the effect of land use activities on the vegetation cover within Nsooba Lubigi drainage system.

1.4 Research questions

a. What are the effects of land-use activities on physical-chemical composition of the water within Nsooba Lubigi drainage system?

b. What are the effects of land-use activities on bacteriological composition of the water within Nsooba Lubigi drainage system?

c. What is the effect of the land use activities on the quality of soil within Nsooba Lubigi drainage system?

d. What is the effect of land-use activities on vegetation cover within Nsooba Lubigi drainage system?

1.5 Significance of the Study

This research aimed at analyzing the disparity in water quality, soil quality and vegetation cover resulting from land use activities along with Nsooba Lubigi drainage system with an overall objective of developing a methodological framework for the establishment of conservation and management policies at the local level. This information is conceived to help decision-makers, planners and other relevant stakeholders in the proper management of the Nsooba Lubigi drainage system that serves as a source for water resource utilization and habitat for various species. The study also provides information for the proper management of green spaces and a starting point for further studies by other researchers.

1.6 Scope of the Study

The present study was carried out in Nsooba Lubigi drainage system. It focused on the influence of heterogeneous induced activities on water quality, soil quality and the vegetation cover within Nsooba Lubigi drainage system.

1.7 Conceptual Framework

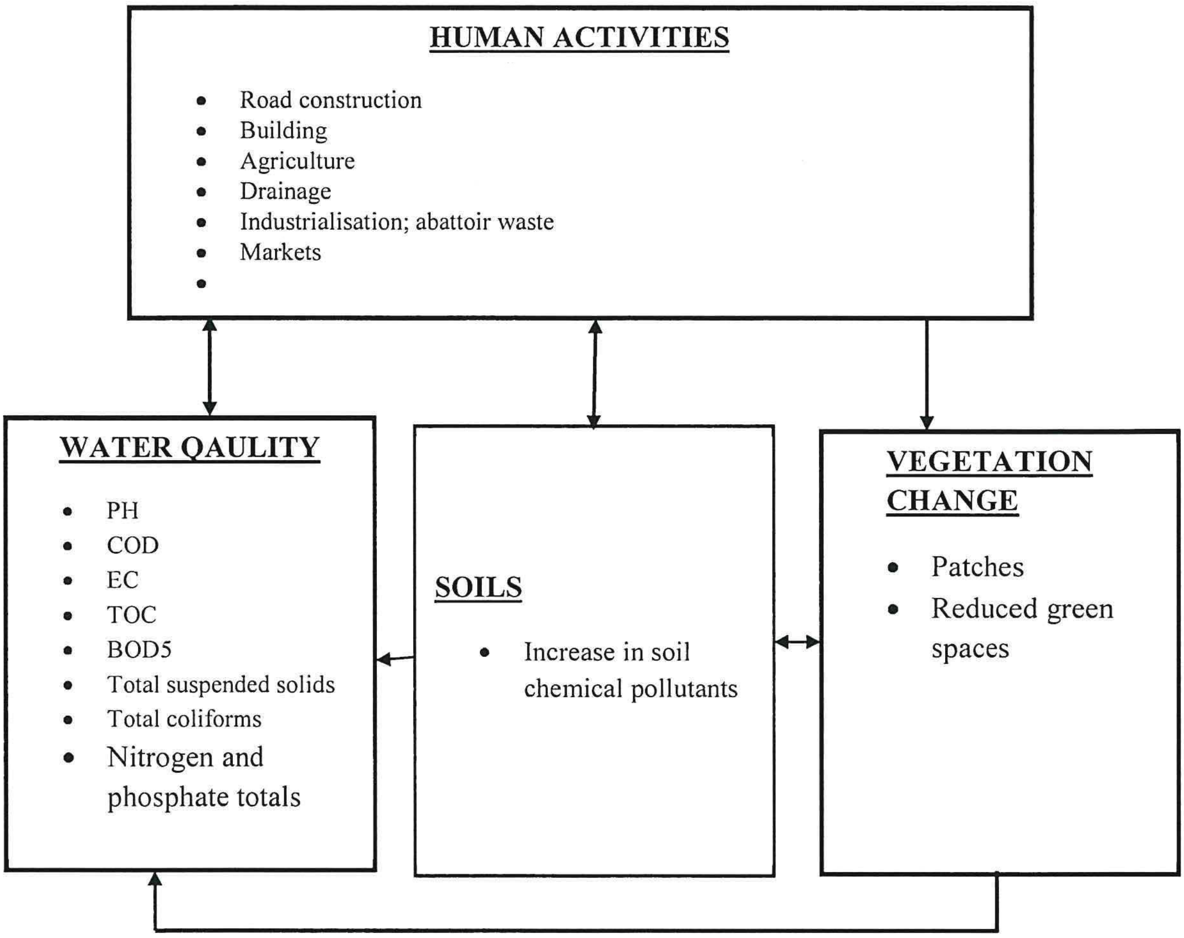


Figure 1-1: Conceptual Framework of the study; Source: Author's conceptualization.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter refers to the numerous literature linked to the human activity effect on water quality, soil and vegetation cover. It attempts to synthesize the different methods, procedures and arguments presented by the authors under question. The gaps in the literature are therein identified.

2.2 Overview of Land Use

Land use is a type of major use for land utilization, advances in urban land use as the activity system which indicates the expression of people to utilize the land for maximizing their benefits. Changes in the land brought about by human-induced activities have brought about soils modification (heavy metals concentration), changes in climate thus affecting the quality of many water resources globally (Boualla *et al.,* 2018).

Accoding to Shukla *et al.,* (2014), it is paramount to screen how land use change varies and impacts on the flora and fauna, ground water, river drainage patterns, stream flow, rainfall-runoff, water quality for sustainable planning and management of drainage systems. The correlation between numerous land-use activities and water quality indicators is dependent on the site features whereby the drainage systems and water quality are vulnerable to the variations in the landscape configuration and their spatial degree (Deb, 2019).

Ding *et al.,* (2015), emphasized a methodology that uses analysis of the degree of spread in a data set to evaluate the Euclidean distances as a standard measure of comparison between groups in an effort to curtail the summation of squares of any 2 likely groups to ascertain the spatial distribution of the sampling points, classified group examination was conducted on catchment-wide land use based on Ward's IDW interpolation method. The validated results were overlaid with the definite data generated from the physical field survey and outcomes of laboratory examination of the water and soil samples, the results interpolated using a map well correlated with validated field data. (Serre and Karuppannan, 2018).

The natural conditions of rivers and streams may degrade due to the variations in the land use patterns, land management processes have been observed as the main manipulating features for dissimilarity of water systems leading to variations in runoff and water quality (Huang *et al.*, 2013). Generally, its difficult to comprehend the precise effect of different contamination causes and the major trails for water quality management intercessions on big and lesser scales where desirable, taking the prevailing pathways into account (Vrebos *et al.*, 2017). The continuous change in water quality calls for the creation of environmental management plans (Jiang *et al.*, 2017).

2.2.1 Land use activities in Nsooba-Lubigi drainage system

There is significant evidence showing that land-use activities have continuously lead to serious impacts, both directly and indirectly, on ecosystem processes exposing the vulnerability of surface water to anthropogenic variations in a watershed. The human significance can be witnessed around Nsooba-Lubigi drainage system with the many settlements and structures. This has not only left its natural vegetation for the development of commercial and residential apartments but also houses one of the three main abattoirs in Kampala city (Abdullahi *et al.*, 2017). This has necessitated studying the correlations these interrelated domains and related transformations in biogeochemical and microbial processes in rivers is an essential scientific encounter (Yadav and Pandey, 2017).

Abdullahi *et al.,* (2017) conducted study examining the effect of Kalerwe abattoir wastewater on water quality of Nsooba-Lubigi, concluding that the discharge of waste effluents greatly impacts the water quality. Although the study fell short of documenting other land use activities contributing to the degraded quality and did not also investigate the effect of the abattoir effluent on soil chemistry of Nsooba drainage system. This presents a plausible gap in the literature to examine the effect of human activities contributing to soil pollution, vegetation change and water quality, thus essential for appropriate water resource management and for categorizing primary challenges to water quality, coupled with interactions that are expressive for appropriate water quality management (Brazil *et al.,* 2017). Ding *et al.,* (2015) estimated the effects of land use activities on the water quality in both rainy and dry seasons in the Dongjiang River catchment and found that water quality characterizations showed considerable disparities between the forest -and urban -dominated areas with a consistently positive correlation of forested land with DO levels.

The increased uptake of water from springs that drains into water streams partially accounts for the characteristic low depths of certain river streams in the dry seasons, resulting in reduced river stream discharge has considerably reduced the capacity of Nsooba-Lubigi drainage system to transfer waste/ slowed rate of solid waste removal hence leading to waste buildup on Lubigi beds leading to flooding by blocking Lubigi wetland hence impeded flows and poor drainage (Mubiru, 2011).

2.3 Water quality

Water quality includes the characterization of physico-chemical and microbail characteristics of a water body (Norman *et al.,* 2006). The water resource attains these qualities from a set of multifaceted interfaces between the soils, water, atmosphere and lithology. Land use events impact both water quality and quantity. Athropogenic activities alter land use topography which modifies the water hydrology and affetcs the comparative prominence of ecosystems governing the quality water. Moreover, land-use activities produce radioactive solid, gaseous and liquid waste. Serre and Karuppannan, (2018) assessed groundwater quality in the Modjo River basin whereby 31 groundwater samples analysed for pH and EC using portable pH and EC meters. They further analyzed EC of groundwater samples to calculate TDS, cations and anions such as Na^+, Ca^{2+}, K^+, Mg^{2+}, F^-, Cl^-, NO_3^-, HCO_3^-, PO_4^{3-} and SO_4^{2-} according to the standard methods by American Public Health Association APHA (2005). Along with the frequent concerns, each lan-use activity has a likelihood of recurring impact on water quality and quantity along the hydrologic cycles (Peters *et al.,* 2005). Water quality monitoring is often meagre in most developing countries especially Uganda whereby few parameters such as pH, alkalinity and turbidity are examined, the consequence of organic pollutants in drinking water is determined. In Nsooba, although the management agencies are aware of the illegal discharge especially from human-induced activities, wastewater management becomes challenging (Hongtao .. *et al.,* 2014).

Waterbodies are susceptible to anthropogenic variations arising in watersheds. Rivers and other watersheds are contaminated through stream erosion and transport, and studying the varying correlation and related transformations in microbial and biological, geological and chemical processes in rivers is n significant scientific conodrum, therefore the study could be a high-quality criterion to evaluate river health (Yadav and Pandey, 2017).

2.3.1 Implications of human activities on water quality

Antropogenic activities modify the natural qualities of the land, air and water that consequently impact water quality (Norman, 2006). Water quality deprivation to a very big degree is an obvious sign of anthropogenic impacts on the natural ecosystem either directly and/ or indirectly. Water quality encompasses the physico- chemical and microbial characteristics of water resources. Direct impacts alter the quality of water from several sources including chemical, physical or biological component (Norman, 2006). Effluent discharge into the streams, and the application and leaching of fertilizers directly impact the chemistry of the stream, affecting both surface and groundwater discharge (Norman, 2006). Indirect landuse impacts include changes to the landscape, which affects hydrological cycles that alter the degree at which water interrelates with ecosystems.

Notable human activities such as agriculture and industrialization have also had an effect on water quality in and around Kampala, especially the non-organized small-scale industries in Kalerwe, Katwe, Nakivubo, Bwaise, Wandegeya, Nakawa and Port Bell. Industries contribute to water pollution by wastewater discharge (Matagi, 2001). Solid and liquid waste from these industries is discharged directly into public sewers which finally enter and alter surface water quality. Consequently, the future security and quality of the city's water supply source is uncertain, if industrial effluent treatment is not properly implemented (Matagi, 2001).

Annapoorna and Janardhana, (2015) stated that anthropogenic activities are a result of land use characteristics which is useful in detecting major threats to water quality for effective water quality management so as to institute relevant measures to curtail pollutant loading.

With the current high population growth rate and development in Uganda, this is proving to be a threat to the sustainable management of water quality. Calling for awareness on better agricultural techniques that have less or no impacts on the water sources. Relaxing measures that control contamination from landuse-based pollutant points would result into water sources deterioration in the long-term given inadequate technical and financial aspects to address them (Bay, 2009). Additionally, urban agriculture is having a stump on water quality in Uganda. Agriculture is done on peripheral zones like slopes and swamps that are also flimsy ecosystems prone to degradation. Today, several streams dry up during the dry seasons and this impacts suburb population whose only source of water is from wells and springs. Further, the dependence of surburbs populationon swamps has drained them leading to losing their function as wastewater purification schemes.

2.3.2 Surface water quality and conservation

Surface water includes springs, rivers, lakes and oceans. The status of water bodies is one of the key important matters exposing most sources of water to pollution principally the rivers because they transmit solid and soluble waste through soil erosion. Anthropogenic activities and natural processes like weathering processes and soil erosion play a key part in influencing the surface water quality of a region (Khan *et al.,* 2016). Nevertheless, several undertakings have been made to comprehend the effects and correlations between land-use and water quality and also to understand the functional aspects of the Nsooba-Lubigi drainage system and propose methods for its conservation (Garg *et al.,* 2009). The water conservation approaches against wastewater may be identical and entail placing the country's water resources to better utilization (Kumari and Singh, 2017).

In a recent investigation of global water shortage, the UNS (1997) recognized water quality as a principle issue based on the fact that the severity of water quality deprivation in many countries has designated noticeable indication of severe human health risks related with the eutrophication of rivers and lakes, and release of pathogens into water bodies resulting point and non-point source discharge of nutrients (FAO, 2000).

The water storage by the construction of numerous water reservoirs has been one of the oldest methods of water conservation. The scope of wastewater storage differs from place to place basing on water accessibility and topographic environments. The environmental impact of such storage also necessities to be scrutinized for developing conservative environmentally friendly strategies (At and Levels, 2014).

2.4 Soil Pollutants

Generally, priority soil pollutants such as Zinc (Zn), Cadium (Cd), mercury (Hg), arsenic (As), Nikkle (Ni), lead (Pb), Copper (Cu), chromium Cr (as Cr(VI)) and platinum (Pt) perform contrarily under the similar set of environmental circumstances, and consequently their abilities to be isolated by the numerous approaches also differ owing to several combinations of binding mechanisms and related sediment sections. This process only transpires under anaerobic conditions. All of the metals recorded are described in the previous studies to be bio accumulated by plants (Lesniewska *et al.,* (2004). Soils and sediment generally tend to be harbor heavy metals or they act as storage zones due to their extensive binding abilities. Non of the metals removed can completely be extracted from the water column via processes of volatilization or photolysis. Anaerobic condictions can be applied to produce volatile organo-metal compounds within sediments.

a. Heavy metals

These a density (specific gravity) of more than 5 times that of water (1 at 4°C). Specific gravity is defined as a measure of density of a particular quantity of a solid material when compared with equivalent volume of water in the soil. Heavy metals once discharged into the ecosystem can persist in water systems for many years, in high levels that are sufficient to cause a health risk. Numerous approaches are applied to neutralize the environment from these types of pollutants, but most of them are costly and challenging to get optimum results (Bieby *et al.,* 2011; Maxwell *et al.,* 2020).

b. Arsenic, As

As is an element with atomic number 33 and relative atomic mass 74.92, a melting point of 817°C (at 28 atmospheres), specific gravity of 5.73, boils at 613°C and vapor pressure of 1 mmHg at 372°C. it is also odorless and tasteless (Mohan *et al.,* 2007).

c. Lead

Lead (Pb) is bluish or silvery-grey metal having an atomic number of 82, an atomic weight 207.19 and a specific gravity of 11.34, with a melting point of 327.5°C, having four naturally occurring isotopes with atomic weights 208, 206, 207 and 204. Lead exists in many forms and from many sources, is also amongst the most poisonous and carcinogenic heavy metals, and equally spread trace metals in the soils (Jackson *et al.,* 2005).

d. Mercury

Mercury is a shiny and naturally occurring metal that is exists in numerous forms. It has of the lowest melting point (−39°C) of all the pure metals and is the only pure metal that is liquid at room temperature. Nonetheless, due to its numerous physical and chemical benefits it is still a vital material in many industrial products (Chang *et al.*, 2009). In the soils, it exists in numerous forms: metallic mercury, inorganic and organic mercury compounds. Hg^+ is unstable under normal atmospheric conditions since it disintegrates into H_gO and Hg^{2+}.

2.5 Effects of Human Activities on Vegetation Cover

Vegetation, which is the link between atmosphere, water and soil, is a most sensitive factor that reflects the change of ecological environment directly. A dynamic and long-term monitoring of vegetation growth is helpful to better simulate the trend of ecological environment change and better evaluate the functionality and serviceability of ecosystem (Wu, Zhu, & Zhao, 2023).

According to Wang *et al.* (2015), human activities have a significant impact on changes in vegetation. Changes in land use resulting from human activities such as urbanization and agriculture are important factors influencing the spatial pattern of vegetation. Lin, *et al.* (2022) stated that human activities not only reduce the vegetation coverage through grassland reclamation, deforestation and urban expansion, but also improve the vegetation coverage through afforestation and returning farmland to forest. Investigating the impacts of land-use changes on vegetation is of great significance when placing limits or standards on human activities and protecting ecosystems.

Humans have changed the landscape to satisfy their basic needs in providing food, water, shelter, energy for heating and cooking (Norman *et al.*, 2005). Due to population pressure, this has also led to an increased uptake on resources and so does production to match the growing demand.

Human activities such as grazing, farming, and mining, as well as industrialization, construction of roads, building and deforestation among others have altered the vegetation cover. Deforestation does not only affect the landscape but also increases erosion that affects the water quality in streams. The changes in land use activities such as rapid urbanization and agriculture as a cause for vegetation change (Wang *et al.,* 2015), alter the structure and the functioning of ecological processes. Agriculture has also caused fast rate of deforestation and devastation green belts as trees are cut-down to make land ready for agricultural activities. This has led to CO_2 sink loss, increased dryness/ heat in the city, accelerated soil erosion and reduced soil water retention capacity.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

This chapter explicitly spells out the materials and methods that the study adopted in assessing the impact of anthropogenic activities on quality of surface water, soil and vegetation cover. It comprises the study area, the sampling procedures, materials and methods.

3.2 Study Area

The study area lies within Nsooba-Lubigi drainage system, stretching from Bukoto hills the origin of Nsooba-Lubigi to Lubigi wetland in Namungona. It is located between 0° 21'N latitude and 32° 35'E longitude, in Kawempe Division, Kampala City.

The discharge closely emanating from the surrounding environment to Nsooba-Lubigi drainage system with capacity of about 220,000 m^3/day, ranging from the daily human activities, industrial and municipal effluent, automotive and mechanical discharge, rainwater run-off, surface and sub-surface water flow from the upstream, as well as the populous rejuvenating slums of Kawaala, Kyebando, Kalerwe, Bwaise, Kanyanya, Nansana and Namungoona.

Due to insufficient environmental policies like development of the buffer zone to protect drainage system, Nsooba-Lubigi drainage system has and will continuously receive the initial and direct trickle-down effect of the visually and severely contaminated wastewater from the up-stream storm water drainaging to the channel as well as the Lubigi Sewage Treatment Plant.

Additionally, Nsooba-Lubigi drainage system has continuously been under serious pressure emanating from human actions and encroachment including unplanned landfilling for reclamation, water drainage for agriculture, human settlements and livestock farming, use of agricultural pesticides in management of crops, sand and clay mining, brickmaking, the harvesting of papyrus for handcrafts, inappropriate solid waste disposal, municipal and industrial effluent disposal and other forms of discharges have led to pollution and contamination of the drainage system thus being a haphazard to the environment and surrounding community.

The area was selected as an ideal site because of the urbanization levels (construction of northern by-road), crowded settlements and the apparent poor sanitation and management of waste water. Further, Nsooba slaughter house also discharges solid and waste water into Lubigi wetland, creating severely contaminated wastewater from the upstream Nsooba-Lubigi water drainage stream and the Lubigi Sewage Treatment Plant.

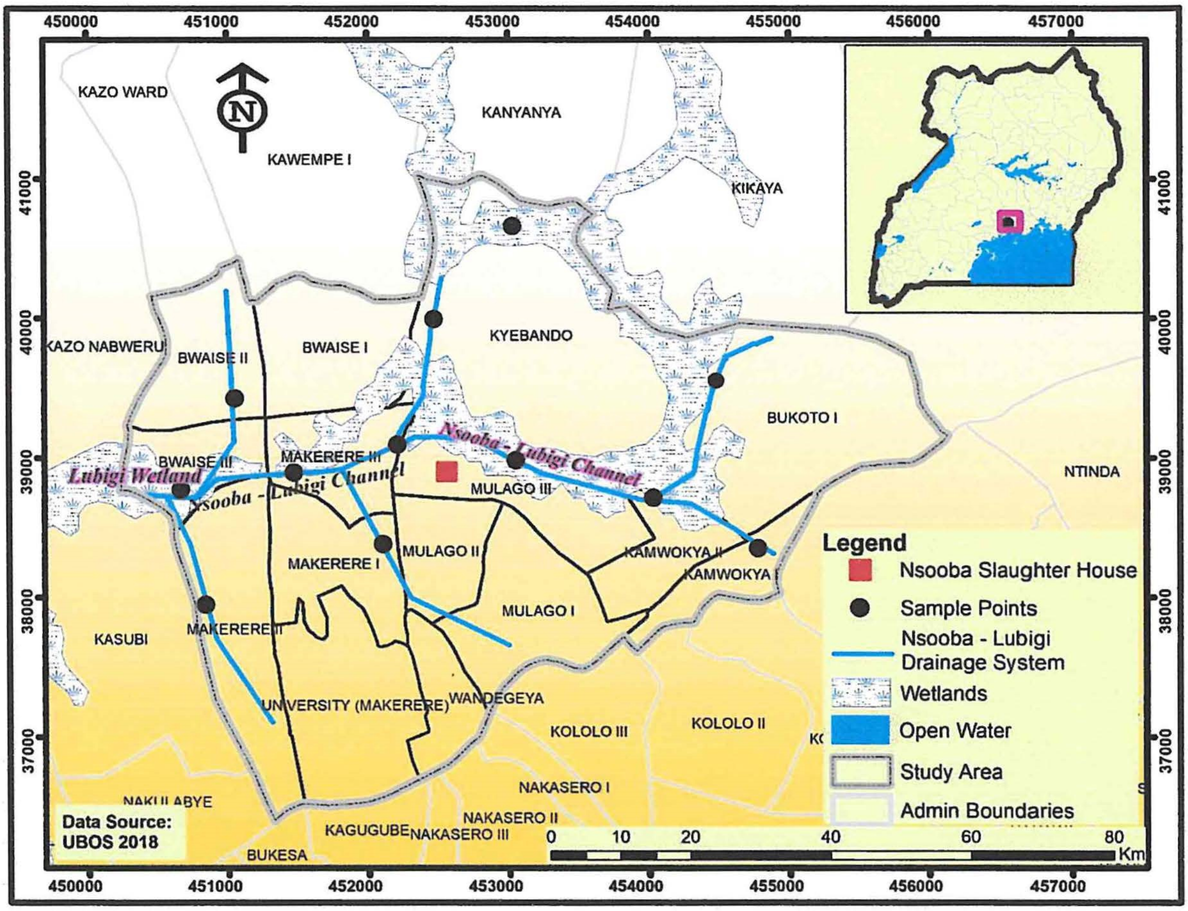


Figure 3-1: *A topographic map showing the location of the study sites in the Nsooba-Lubigi drainage system.*

3.3 Research Design

The research used only quantitative investigative techinique. The study was conducted through an empirical research design because it involved the manipulation and control of variables. It was therefore executed under the quantitative research approach.

3.4 Data Collection Tools and Methods

3.4.1 Land Use Land Cover Change Activities

Landsat-5 TM, Landsat-8, and Sentinel 2 images with a spatial resolution of 30m and 10m for 3 years (2018, 2008, and 1998) were downloaded from an open-source at no cost. These were used for the spatial analysis of land use activities and vegetation cover change in Nsooba-Lubigi.

3.4.2 Sampling Strategy

Field sampling of water and soil samples for analysis was conducted. A minimum of 48 water samples and 36 soil samples were gathered from 12 sites along Nsooba-Lubigi drainage system. The sites were selected due to the high athropogenic activities (urbanization, slaughterhouse, industries and road construction) carried out within the wetland area. A minimum 4 sampling at each sampling site were collected in Duran. Parameters for analsysis included pH, EC, TSS, TN, TP, total coliform and *E. coli*, BOD and COD. These constitute the major parameters in measuring the degree of contamination of a water body (Chapman, 1992; Longe and Omole 2008). All the samples were preserved at 4°C using a sampling cooler box and transported to the laboratory for analysis. Sampling was done between 08.00 am and 05.00 pm, the time of peak activities at the Nsooba-Lubigi drainage system in July 2020 and October 2020. During sample collection, sampling containers were rinsed twice with sampled water and, labeled and then taken to the Ministry of Water and Environment laboratory in Entebbe, stored in the cool-box while maintaining a temperature of 4°C prior to analysis.

3.4.3 Soil Pollutants

Soil samples were collected from up-slope, mid-slope and lower slope of Nsooba-Lubigi drainage system. Soils were collected using an auger to get the soil samples at a depth of 0-15cm and 15-30cm. To avoid contamination of the soil samples, sterile (using sanitizer) hands were used to collect the soil samples and these were placed in clean disinfected plastic bottles, labeled and then kept in a cool-box and/ or in a refrigerator at 4°C awaiting analysis. Two sets of water and soil samples were collected between July 2020 and October 2020, collection of the first and second sets was to ensure that the results obtained are more representative. Each set consisted of 24 samples totaling to 48 samples.

3.5 Analytical Procedures and Measurement

In order to assess the effect of land use activities on water quality, soil, and vegetation cover quality of Nsooba-Lubigi drainage channel, physico-chemical properties, nutrients loads, microbial characteristics, upstream and downstream of the Kalerwe abattoir discharge area were evaluated. The physical-chemical characteristics were determined by APHA standard analytical methods of water analysis.

3.5.1 Determination of Nutrients (Total Nitrogen and Total Phosphorous)

HACH standard method was used to determine nutrients concentrations by using a DR 1900 spectrophotometer and a DRB 200 digester as defined in the HACH procedure manual for chemical and physical water quality.

3.5.2 Determination of Total Suspended Solids

Total suspended solids were analyzed using a gravimetric method. The Galen Kamp oven was used for drying at 105°c and a Mettlor Toledo weighing scale was used for weighing.

3.5.3 Determination of COD and BOD

Chemical Oxygen Demand was determined by a standard HACH procedure using a DR 6000 spectrophotometer and DRB 200 digester as described in the HACH procedure manual. A volume of 2mls of the sample were put in the COD vial and digested at 150 °c for 2hrs. The vials were allowed to cool and COD was read.

BOD was analyzed using a BOD_5 day test kit. This was used for digestion and monitoring oxygen changes.

3.5.4 Determination of pH and Electrical Conductivity

pH was photometrically analyzed using a thermo scientific Orion star 3 machine whereas Electrical conductivity was analyzed using an Orion star A 222 conductivity meter.

3.5.5 Determination Total Coliforms and *E. coli*

The membrane filtration technique was used to analyse water samples from different sources. Water samples were filtered from the Millipore membrane filters with pore size 0.45µm and 47mm diameter with a vacuum speed 5 to 15mmHg. The water sample were filtered and analysed in duplicate volumes to ensure accuracy of results. Other steps included:

1. Labeling the 2 sterile agar plates.
2. Filtering 100 mL of control and water samples through a filter.
3. Using sterile forceps, place the filter on the filter housing.
4. Clamping the top half of the assembly.
5. Pouring the water inside and open the vacuum.
6. Once all the water is passed through close the vacuum, removed the top half of the filter.
7. With sterile forceps, removed the filter and place it in the middle of the plate.

The membrane filters were then placed on the Membrane Lauryl Sulphate Broth (MLSB) agar surface and incubated at 35°C for 24hours using an incubator. Organisms were observed to concentrate on the surface of the membranes. The colonies formed on the surface of MLSB agar were counted using a colony counter and a bacterial density calculated. Total coliforms were confirmed by colour change to pink at incubation temperature of 37°C for 24 hours, while E.coli is determined by colour change to purple at incubation temperature of 37°C for 24 hours. They were represented in form of colony Forming Units per 100ml.

3.6 Determination of Heavy Metals Concentration in Soil

Flame Atomic Absorption Spectrophotometer (FAAS) was used to determine the concentration of heavy metals in the soil samples. From each of the locations, 1 litre of water samples was vaporized to dryness, to which digestion of the soil samples was carried out by adding 10ml conc nitric acid, 2ml perchloric acid and 4ml hydrofluoric acid. Then this was reheated to dryness. The final residue was reconstituted in 2 ml of hydrochloric acid (2M), transferred to a 25 ml volumetric flask and made up to the mark with distilled, deionized water. At least 2 calibrations of the FAAS was done of the relevant blank standard solutions. The resultant aqueous solutions were analyzed for each of the heavy metals Hg, As, Cd and Pb using a FAAS (Perkin-Elmer GmbH, 2014). The heavy metals were selected in this study because they are the primary elements from the human-related sources including industrial and municipal effluent, automotive and mechanical discharge. A lamp emitting light at a wavelength specific to the metal atoms were passed yhrough the flame, to determine the relationship between the light absorption and concentration of the element in accordance to the Beer-Lambert law, below.

$A = \varepsilon * c * L$

A is the absorbance measured by the AAS

ε is the molar absorption coefficient

c is the determined coefficient of the element

L is the path length

3.7 Determination of Vegetation Cover Change

This was determined using Landsat8 and sentinel 2. Landsat enabled the acquisition of old satellite images of 2008 and 1998, whereas sentinel facilitated the acquisition of satellite image of 2018.

3.8 Data Analysis

This sub-section describes the methods/ techniques of data analysis that were used per objective

Physical-chemical and bacteriological composition of water within Nsooba-Lubigi drainage system.

SPSS version 20 was used to calculate the water quality and soil parameter values. Descriptive statistics such as, median was obtained for the physical-chemical and bacteriological parameters of the water samples. To compare the parameters across land use types, the data were subjected to a non-parametric test known as Kruskal-Wallis *H*-test, because it is more robust and requires smaller samples sizes. The test compares medians among k independent groups ($k > 2$) and is formulated based on ranks rather than actual observations (Daniel, 1990). The test is generally robust to departure from normality and homoscedasticity and is less sensitive to outliers.

Kruskal-Wallis *H*-test only indicates that more than two groups are significantly different. It cannot show which specific groups of the independent parameters are statistically different from each other. So following the rejection of the null hypothesis of equal medians, a post-hoc test was carried out using the Dunn test to determine which land use types were statistically significantly different from each other. Dunn test investigates the hypothesis that samples from any two groups have the same distribution. Fisher's exact test was used were the data was categorical in nature and therefore difficult to compute the median.

3.9 Effect of Land Use Activities on the Quality of Soil within Nsooba-Lubigi Drainage System

In addition to the Kruskal-Wallis *H*-test described above, the study employed Fisher's exact test of independence to assess the association between land use activities and levels of metals in soil. The associations were presented in form of contingency tables (cross-tabulations). Fisher's exact test of independence is a technique used to check the significance of association between two categorical variables in an r x c contingency table. Fisher's exact test is employed when sample sizes are small resulting in low expected cell counts (< 5). In such a scenario, Fisher's test is considered more accurate than the Chi-square test (Upton, 1992). Unlike other statistical tests, the significance (*p*-value) for the Fisher's test can be calculated exactly, rather than relying on an approximation. The test was used to investigate the null hypothesis that there is no association between levels of metals in soil and land use activities.

3.10 Effect of Land Use Activities on the Vegetation Cover within Nsooba-Lubigi Drainage System.

3.10.1 Image Acquisition

Re-classification process and change detection analysis of various land-use land-cover classes were performed by three Landsat satellite images of 5 TM, Landsat 7 ETM+ and Landsat 8 OLI/TIR all acquired from path 172 and row 059 as indicated in Table 3.1. The satellite imagery data was downloaded from the United States Geological Survey website (USGS) (ftp://ftp.glcf.umd.edu/glcf/Landsat/WRS2 and https://earthexplorer.usgs.gov/). After downloading, the images were all geo-referenced to the WGS 84 datum with the UTM Zone 36N of the coordinate system. All satellite data were analyzed by assigning per-pixel signatures and segregating the land uses to 5 classes based on different landscape elements. The delineated classes were; forestry, grassland, wetland, settlement, and small scale farming (Table 3.2). For each of these, predetermined landuse/ cover category was assigned training samples by defining polygons within each sites, and signatures files created for the particular landuse/ cover categories downloaded from the satellite imagery recorded by using pixels enclosed by polygons. The unsupervised classification was performed using the ISO Clustering Classification method which was followed by ground-trothing to guide in the performance of the Maximum Supervised Classification for accuracy assessment. A satisfactory spectral signature ensures 'minimal confusion' among the landuse/ covers to be mapped (Gao and Liu, 2010). All classification processes were executed using ArcGIS 10.2 as explained in the subsequent paragraphs.

3.10.2 Supervised classification

As a method of classification, it involved classification according to spectral signatures called categories (land use classes) such as forests, wetlands, settlement, small scale farming, and grassland, in the due process, the software attaches each pixel in the image to the cover types which its signature correlates. Controlled classification helped in processing and quantitative analysis of remotely sensed imagery data applied after describing the particular zones of concern called training sample classes.

Obtaining sample training sites. This involved finding areas used as training locations for each land use land cover classes and was performed by an on-screen feature called Specific Area of Interest (SAOI) and involved identification of too many SAOI.

Creation of signatures files. After digitization of the sample training sites (SAOI), statistical characterization of each land-use class aimed at creating signature files for each land-use class using ArcGIS 10.2 was performed.

Classification using Maximum Likelihood Classification (Supervised classification): This was applied after the creation of the signature files with one or more training sample classes to represent specific classes which were made of five categories such as forestry, wetlands, small scale farming, settlement and grassland. In the supervised classification process, a signature file was created from the training sample manager and the image was classified into five classes (Table 3.2)

3.10.3 Land use/cover detection and analysis

For better classification of results, Landsat TM and ETM images (path 172, row 059) at a resolution of 30 m with a ten-year interval period from 1998 – 2018 were all sourced from USGS.

Table 3-1: Data specifications

Satellite Data	**MM/DD/YY**	**PATH and Row**	**Band**	**Resolution**	**Source**
Landsat 5 (TM)	08/07th/1998	172,059	3,4,5	30m x 30m	USGS
Landsat 7 (ETM+)	09/14th/2008	172,059	3,4,5	30m x 30m	USGS
Landsat 8 (OLI/TIR)	10/07th/2018	172,059	3,4,5	30m x 30m	USGS

A hand held GPS receiver was used for ground verification in evaluating the five land use/ cover classes as indicated in Table 3.2.

Table 3-2: Land Use Land Cover (LULC) classification

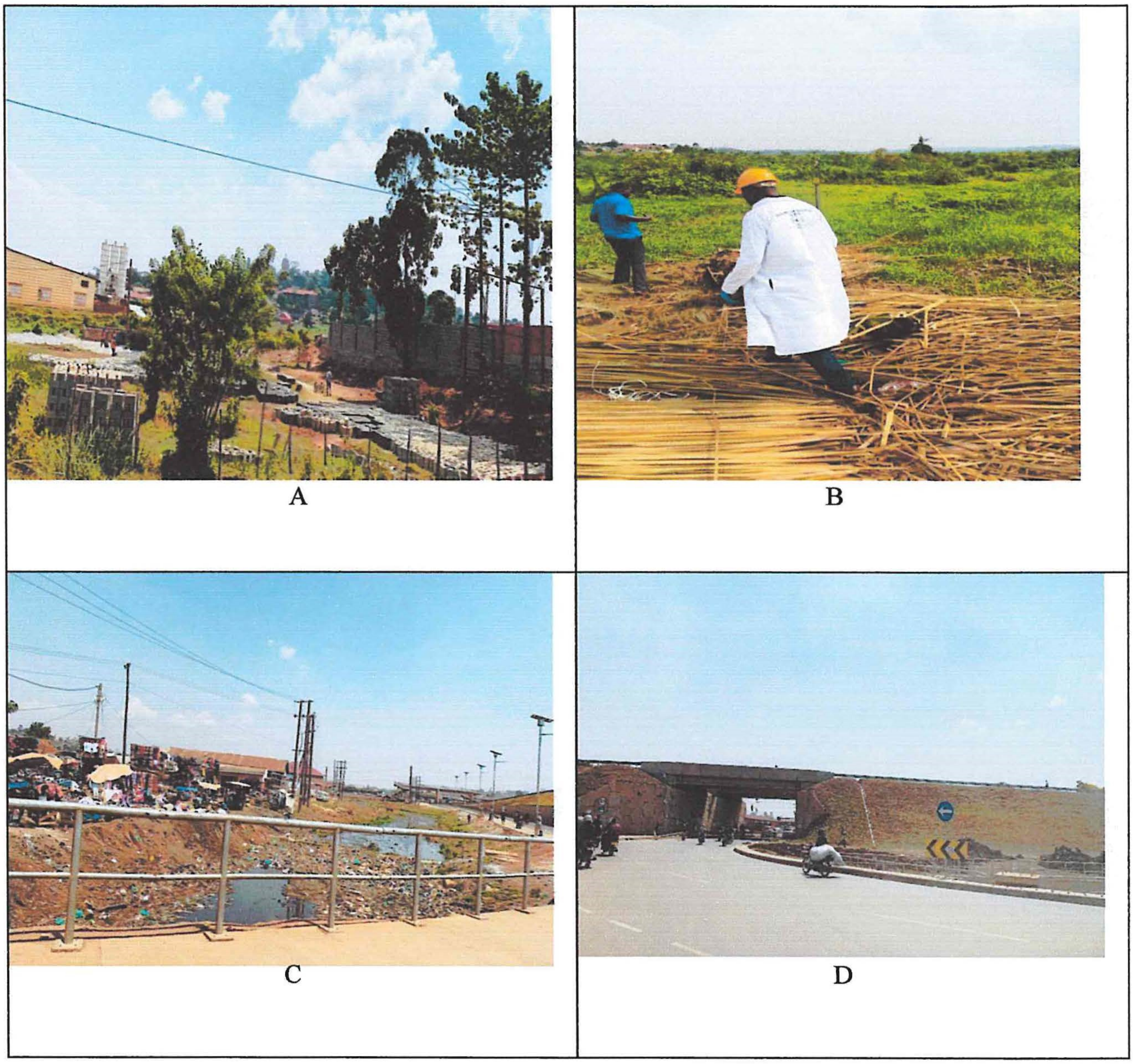
Land use/cover classes	**Description**
Agriculture	Subsistence Farming: Mixed farming characterized by crops grown for survival
	Small Scale Farming: Mixed farming, single and multi farming, dry and irrigated farming
Bare Land	Land that is productive and unproductive with no developments activities going on
Wetlands	seasonal and permanent wetlands, swamps, bog
Built-up Areas	Settlements like residentials, commercials, non-residentials, roads

As supervised classification was performed at the study area, each class was calculated while considering the pixel counts and total site. Thus, categorizations were made based on area coverage and presented in both hectares and percentage. The five classes included Forestry, Grassland, Wetlands, Settlement, and Small scale farming. Percentages of classes based on these results portrayed land use/land cover events seen in the study area during 1998, 2008, and 2018 respectively.

CHAPTER FOUR: RESULTS

4.1 Introduction

This chapter presents a detailed report of results generated from the study. It is structured based on the objectives of the study. Some of the land use activities that were observed within Nsooba-Lubigi wetland include but not limited to; papyrus harvesting, mechanized brick making, kalerwe abattoir, markets and shops, settlements, communication networks, road construction, sewage treatment plant at Lubigi, gas stations, small scale agriculture as shown in Figure 4.1.



A

B

C

D

Figure 4-1: Selected photos showing: A-Mechanized brick-making, B-papyrus harvesting, C-Kalerwe market, D-road construction..

4.2 The effect of land use activities on physical-chemical composition of water quality within Nsooba-Lubigi drainage system

The results for the effect of land use activities on physical-chemical composition of water quality are presented in Table 4.1, and presents a significant correlation between land use activities and physical-chemical composition of water for parameters EC, TDS, pH, TP, TN, BOD, COD, TSS & TOC. According to Table 4.1, the Kruskal-Wallis test showed p values of less than 0.05 for EC (0.007), TDS (0.022), pH (0.022), TN (0.007), BOD (0.000), TSS (0.003) and TOC (0.010), indicating that they are significantly affected by LUAs. On the contrary, no significant correlation was found between land use activities and TP and COD. The p value was greater than 0.05 with TP recording a p value of 0.317 and COD with 0.203.

The results from descriptive statistics indicate that the data from eight out of the nine physicochemical parameters were positively skewed (skewness > 2.0) signifying the presence of large outliers. These values for the parameters EC, TDS, TP, TN, BOD, COD, TSS and TOC are 2.563, 2.700, 2.731, 2.996, 4.400, 6.808, 2.412 and 2.867 respectively. This implied that the median was preferred to the mean as the measure of central tendency of the data and for comparison to the National Standards. The pH value of 0.966 was negatively skewed, signifying accurate correlation.

According to Table 4.1, the EC values for wetland (537.5 µs/cm), built-up areas (472.5 µs/cm) and agriculture (272.50 µs/cm) remained below the recommended threshold of 1000 µs/cm. The average values for TDS across all the land-use types of wetland, built up areas and agriculture (309.00 mg/l, 352.00 mg/l and 155.00 mg/l respectively) were lower than the National Standard (750 mg/l). A similar pattern of land-use types of wetland, built up areas and agriculture was observed for the parameters TP (0.84mg/l, 0.82 mg/l and 0.53 mg/l respectively), BOD (5.75

mg/l, 14.00 mg/l and 8.75 mg/l respectively), COD (41.00 mg/l, 49.50mg/l and 42.00 mg/l respectively), TSS (25.00 mg/l, 42.00 mg/l and 10.00 mg/l respectively) and TOC (16.70 mg/l, 20.50 mg/l and 5.65 mg/l respectively), where the observed average values were all below the National Standards of 10mg/l, 50mg/l, 70mg/l, 50mg/l and 50mg/l respectively. For TN, the average value for built-up areas (11.27 mg/l) was higher than the national standard of 10 mg/l while the remaining land use types of wetland (8.05mg/l) and agriculture (5.96mg/l) were below that of the recommended standard.

Table 4.1: Descriptive summary statistics and test for equality of medians for physical chemical parameters of water quality by land use

Parameter	**Land use Land cover**	**No. of obs. (*n*)**	**Median (homogenous groups**)**	**Kruskal-Wallis test***	**Overall skewness**	**National standard for waste water discharge, NEMA**
Electrical conductivity (µs/cm)	Wetland	8	537.50^{a}	$H = 9.838$ $p = 0.007$	2.563	1000 (µs/cm)
	Built Up Areas	36	472.50^{a}			
	Agriculture	4	272.50^{b}			
Total dissolved solids (mg/l)	Wetland	8	309.00^{a}	$H = 7.612$ $p = 0.022$	2.700	750 (mg/l)
	Built Up Areas	36	352.00^{a}			
	Agriculture	4	155.00^{b}			
pH	Wetland	8	7.30^{a}	$H = 7.245$ $p = 0.027$	0.966	5.0-8.5
	Built Up Areas	36	7.20^{b}			
	Agriculture	4	7.45^{a}			
Total Phosphorus (mg/l)	Wetland	8	0.84^{a}	$H = 2.298$ $p = 0.317$	2.731	5 (mg/l)
	Built Up Areas	36	0.82^{a}			
	Agriculture	4	0.53^{a}			
Total Nitrogen (mg/l)	Wetland	8	8.05^{b}	$H = 9.895$ $p = 0.007$	2.996	10(mg/l)
	Built Up Areas	36	11.27^{a}			
	Agriculture	4	5.96^{b}			
BOD (mg/l)	Wetland	8	5.75^{b}	$H = 16.666$ $p = 0.000$	4.400	50 (mg/l)
	Built Up Areas	36	14.00^{a}			
	Agriculture	4	8.75^{b}			
COD (mg/l)	Wetland	8	41.00^{a}	$H = 3.185$ $p = 0.203$	6.808	70 (mg/l)
	Built Up Areas	36	49.50^{a}			
	Agriculture	4	42.00^{a}			
TSS (mg/l)	Wetland	8	25.00^{a}	$H = 11.896$ $p = 0.003$	2.412	50 (mg/l)
	Built Up Areas	36	42.00^{a}			
	Agriculture	4	10.00^{b}			
TOC (mg/l)	Wetland	8	16.70^{a}	$H = 9.126$ $p = 0.010$	2.867	50 (mg/l)
	Built Up Areas	36	20.50^{a}			
	Agriculture	4	5.65^{b}			

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* National Environment (Standards for Discharge of Effluent into Water or Land) Regulations, 2020

4.2 The effect of land use activities on bacteriological composition of water quality within Nsooba-Lubigi drainage system

The results for the effect of land use activities on bacteriological composition of water quality are presented in Table 4.2. Results from Kruskal-Wallis test revealed that the average p values for E. coli (0.538) and Total Coliforms (0.235) were not significant across the land-use types ($p > 0.05$). This finding further implied that land-use had no significant impact on bacteriological composition of water quality. Further, the results from descriptive statistics showed that the data for the two bacteriological parameters, E. coli (3.006) and Total Coliforms (5.123) were highly skewed to the right (skewness > 2.0) signifying the presence of extreme values. This implied that the median was preferred to the mean as the measure of central tendency of the data and for comparison to the National Standards.

The average bacteriological parameter values of the three land-use types including wetland, built up areas and agriculture for E. coli (317.50 CFU/ 100ml, 384.00 CFU/ 100ml and 586.50 CFU/ 100ml) and Total Coliforms (912.00 CFU/ 100ml, 1481.00 CFU/ 100ml and 1265.00 CFU/ 100ml) respectively. Wetlands and built-up areas presented lower E. coli concentrations compared to the National Standard, while E. coli concentrations in agriculture significantly exceeded the National Standard requirements (400 CFU/ 100ml). On the contrary, Total Coliforms concentrations in all the land use activities exceeded the recommended National Standards (400 CFU/ 100ml).

Table 4.2: Descriptive summary statistics and test for equality of medians for bacteriological composition of water quality by land use

Parameter	**Land use**	**No. of obs. (n)**	**Median (homogenous groups**)**	**Kruskal-Wallis test***	**Overall skewness**	**National standard for wastewater discharge, NEMA (CFU/ 100ml)**
E. coli (CFU/ 100ml)	Wetland	8	317.50^a	H = 1.242 $p = 0.538$	3.006	400
	Built Up Areas	36	384.00^a			
	Agriculture	4	586.50^a			
Total Coliforms (CFU/ 100ml)	Wetland	8	912.00^a	H = 2.898 $p = 0.235$	5.123	400
	Built Up Areas	36	1481.00a			
	Agriculture	4	1265.00^a			

* National Environment (Standards for Discharge of Effluent into Water or Land) Regulations, 2020

4.3 The effect of land use activities on the quality of soil within Nsooba-Lubigi drainage system

The results for the effect of land use activities on the quality of soil are shown in Table 4.3. Results from the Kruskal-Wallis test revealed there is a significant correlation ($p < 0.05$) between LUA and soil parameters lead and cadmium with p value of lead (0.029) and cadmium (0.042). This implies that lead and cadmium were significantly affected by LUAs. The quantity of Lead recorded in agriculture areas was on average significantly higher than that of wetland areas ($p < 0.05$). A reverse pattern was observed for Cadmium where agriculture areas recorded a significantly lower quantity on average as compared to wetland areas ($p < 0.05$).

The soil parameter values of the three land-use types including wetland, built up areas and agriculture for Lead (0.614 mg/kg, 0.356 mg/kg and 0.495 mg/kg) respectively, were observed to be significantly high compared to the National Standard requirement (0.1 mg/kg); and for Cadmium (0.002 mg/kg, 0.005 mg/kg and 0.003 mg/kg) respectively, were observed to be lower than the recommended National Standard (0.01 mg/kg).

Table 4.3: Descriptive summary statistics and test for equality of medians for soil parameters (Pb and Cd) by land use

Parameter	**Land use activity**	**No. of obs. (*n*)**	**Median (homogeneous groups[**])**	**Kruskal-Wallis test[*]**	**National standard, NEMA (mg/kg)**
Lead (mg/kg)	Wetland	9	0.614^a	$H = 7.093$ $p = 0.029$	0.1
	Agriculture	9	0.356^b		
	Built-up area	27	0.495^a		
Cadmium (mg/kg)	Wetland	9	0.002^b	$H = 6.317$ $p = 0.042$	0.01
	Agriculture	9	0.005^a		
	Built-up area	27	0.003^b		

[*] National Environment (Standards for Discharge of Effluent into Water or Land) Regulations, 2020

Results from Fisher's exact test (Table 4.4) suggest that the level of mercury in the soil was significantly associated with land-use activity ($p < 0.05$). Whereas the highest proportion of all three land-use activities (≥ 66.7%) had mercury levels of below 0.001 mg/l, about one-third of built-up areas (33.3%) had mercury levels above 0.001 mg/kg. On the other hand, there was no evidence of a relationship between land-use activity and arsenic levels ($p > 0.05$). Fisher's exact test on Arsenic and mercury was used because the data pertaining to these metals was categorical in nature and therefore difficult to compute the median where as for lead and cadmium, the data was continuous in nature and median could easily be calculated.

Table 4.4: Test for the association between levels of mercury/arsenic and land-use activity

Parameter-Metal	**Level**	**LAND-USE ACTIVITY Count (Percent)**							**National Standard, NEMA (mg/kg)**
		Wetland		Agriculture		Built-up area		Fisher's exact test	
		<0.001	>0.001	<0.001	>0.001	<0.001	>0.001		
Mercury[1] (mg/kg)		9 (100.0)	0 (0.0)	9 (100.0)	0 (0.0)	18 (66.7)	9 (33.3)	0.032	0.01
	Total	9 (100.0)		9 (100.0)		27 (100.0)			
Arsenic[2] (mg/kg)		8 (88.9)	1 (11.1)	6 (66.7)	3 (33.3)	21 (77.8)	6 (22.2)	0.546	0.1
	Total	9 (100.0)		9 (100.0)		27 (100.0)			

[1] *Test for association*: Fisher's exact test statistic = 6.59 Significance (*p*) = 0.032;

[2] *Test for association*: Fisher's exact test statistic = 1.27 Significance (*p*) = 0.546

National Environment (Standards for Discharge of Effluent into Water or Land) Regulations, 2020

4.4 The effect of land use activities on the vegetation cover in Nsooba-Lubigi drainage system

The results for the effect of land use activities on the vegetation cover for the years 1998, 2008 and 2018 are shown in Table 4.4.

Table 4.5: LULC classes showing the study area from 1998 to 2018

Year	**1998**		**2008**		**2018**		**Percentage Change (%)**
Land Use Land Cover	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	
Wetlands	6.93	47.21	4.05	27.59	2.14	14.58	-32.63
Agriculture	2.06	14.03	4.55	31	4.47	30.45	16.42
Bare land	2.13	14.51	1.05	7.15	1.04	7.08	-7.43
Built Up Areas	3.56	24.25	5.03	34.26	7.03	47.89	23.64
Total	14.68	100	14.68	100	14.68	100	0

The vegetation cover change from 1998 to 2018 was investigated for the four land use classes namely; wetlands, agricultural activities, bare land and built-up areas. According to results from table 4.3.1, the wetlands gradually declined from 47.21% in 1998 to 27.59% in 2008 and 14.58% in 2018. Similarly, results for bare land showed 24.5% in 1998, and drastically dropped to 7.15% in 2008 and with no significant change (7.08) in 2018. Seemingly, there was gradual increase in agriculture and built-up areas by 14.03% in 1998 to 31% in 2018 and slowed growth of 30.45% in 2018; and 24.25% in 1998 to 34.26% in 2008 and 47.89% in 2018. The increase in built-up could have resulted into reduced agricultural activities. The Land use/land cover changes on soil, water quality and vegetation cover for the years 1998, 2008 and 2018 are shown in Figure 4.1. LULC types such as Agriculture and Built-up Areas have shown a notable increase for the last two decades (from 1998-2018).

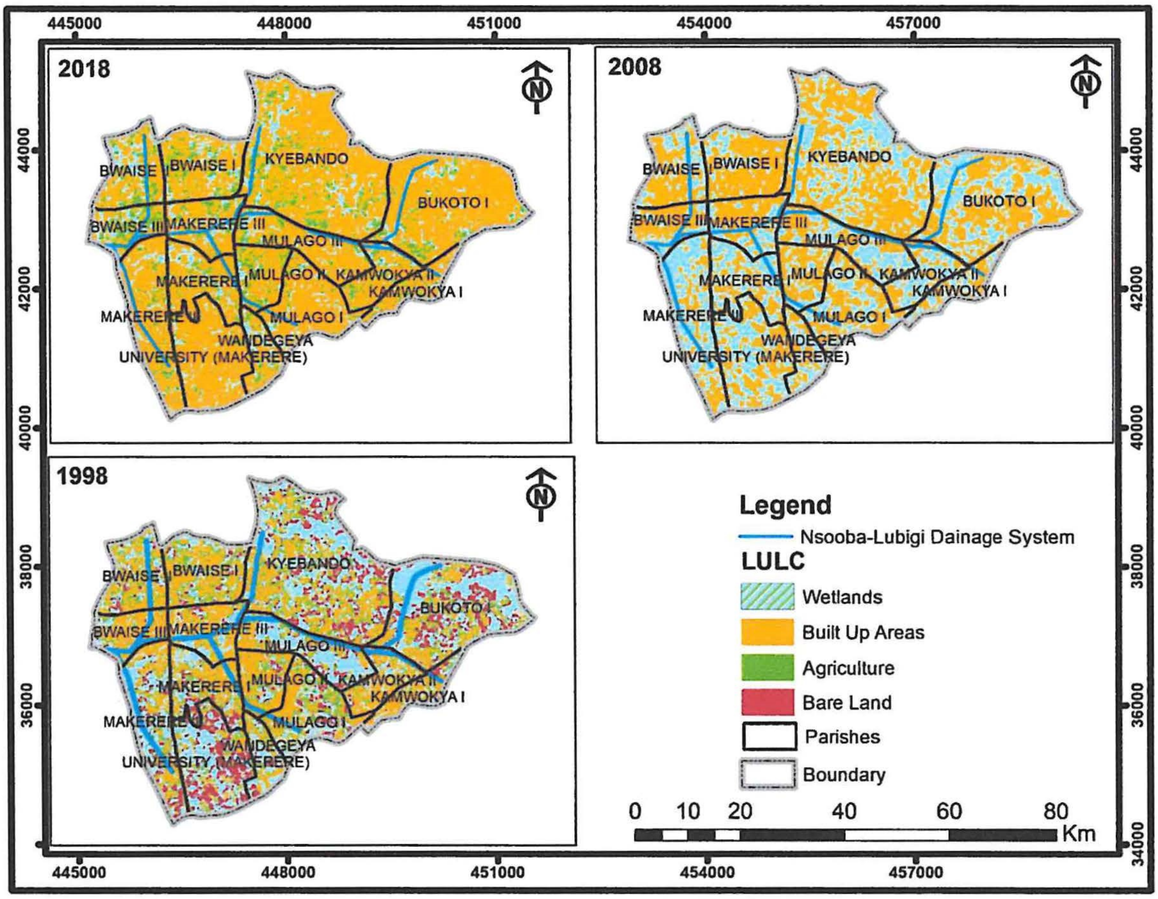

Figure 4.2: Land use/land cover changes on soil, water quality and vegetation cover within the Nsooba-Lubigi drainage system

a. Land use land cover, 1998

Results from table 4.3.1 show that, the total land area of the study area was 16.68ha with a variation in land use land cover change of the study area. The dominant land use type was wetlands with an area of 6.93ha (47.21%), followed by built up areas at 3.56ha (24.25%). Both agriculture and bare land showed minimal changes having 2.14ha (15.51%) 2,23ha (14.03%) of the land use land cover respectively.

b. Land use land cover, 2008

The analysis indicated that the surrounding environment within Nsooba-Lubigi drainage system shows an increase in built up areas 5.03ha (34.26%) and agriculture 4.55ha (31%), these are the major anthropogenic activities that result to contamination of water quality and degradation of the Nsooba-Lubigi wetland. There was a deliberately declined to 4.05ha (27.3%) as well as a significant decline in bareland to 1.05ha (7.15%) resulting from urbanization of the city centre.

c. Land use land cover, 2018

It was observed that built up areas consistently increased to 7.03ha (47.89%), followed by 4.5ha (30%) of the total land use and the natural vegetation cover especially wetlands to 2.14ha (14.6%) and bareland at 1.03ha (7.08%) respectively.

d. Percentage Change

The high levels of built up areas at 23.64% and agriculture to 16.43% of the total percentage land use change between 2018 and 1998 meant intensive pressure is on the natural resources especially the wetlands thereby altering the water quality levels to -32.63% between 2018 and 1998, leading to expansion of urban agriculture along and on marginal lands as well as encroachment into protected Nsooba-Lubigi wetland.

CHAPTER FIVE: DISCUSSIONS

5.2 Introduction

This chapter presents a summary of the research results in the study area. To determine the effect of land use activities on water quality, soil and vegetation cover along the Nsooba Lubigi drainage system concurrent field visits were conducted within the study area as data and observations were documented for various land use activities. It was noticed that there are various activities and variations in past land use as compared to the current land uses and activities. The previous style of land use prevailed on both sides of the Nsooba-Lubigi drainage system in the form of road structures, communication networks, settlements (planned and unplanned), and farmlands. Evidence shows that the land and vagegtation cover has deliberately changed compered to the past years. The Nsooba-Lubigi drainage systeme has been seriously affaected by mainly human activities, this is evidenced by the on-going developments of the multi-trillion road construction of the Kampala-Entebbe express way for eassy accessibility to the Entebbe international airport, this has greatly affected the natural vegetation cover thereby endangering the species diversity within the study area.

The physical-chemical and bacteriological Parameters that were analyzed in water include, Electrical conductivity, Total dissolved solids, pH, total nitrogen, total phosphorous, BOD, COD Total suspended solids and total organic carbon, *E. coli* and Total coliforms. The heavy metals included Lead, Cadmium, arsenic and mercury. These were selected because they bring about severe pollution and eutrophication if not controlled or regulated which subsequently impacts on the receiving ecosystem. Electrical conductivity and Total dissolved solids contribute to an ion influx which consequently increase the saltiness of the water. This makes it hard for the water born species to survive. Ph, on the other hand increases the alkalinity or acidity of the water hence affecting the aquatic life since they have specific pH in which they survive. Total nitrogen and total phosphorous are nutrients that bring about excessive growth of the algae and the other green plants in the water. This overtime triggers inhibits direct light penetration into the water, also inhibits atmospheric reoxygenation of the water which consequently leads to suffocation of the fish and other water borne species.

Bacteriological parameters included E.coli and total coliforms and other physical-chemical parameters such as COD, BOD and TOC deplete the oxygen levels in the water due to increased oxygen uptake by the microorganisms that break down oxidizable organic matter into its simple molecules. This may lead to suffocation of the other water borne species like fish. E.coli and total coliforms are an indicator of fecal matter in water. The water within Nsooba –Lubigi drainage system ends up into Lake Victoria where people draw water for domestic use. If not controlled it may lead to water born diseases like typhoid, cholera, bilharzia among others.

Heavy metals in soil end up into the food chain after being taken up by plants, human beings and fauna. Most heavy metals are known for being carcinogenic. In general, the presence of the above-mentioned parameters in water in high concentrations increase the cost of water treatment thus making access to clean water very expensive.

Further, land use activities in the study area range from agriculture which includes animal husbandry, horticulture, floriculture in the Lubigi wetland, road construction, settlement both planned and unplanned. Construction of northern bypass has attracted more development and population increase, this later led to creation of slums in the wetlands for example Bwaise and Kalerwe. National water and sewerage cooperation has also constructed a sewage treatment plant which encroached on the vegetation cover of Lubigi wetland, construction of churches and hotels like La Grande hotel, markets like Kalerwe market and Nsooba abattoir, gas stations along the northern bypass. All these land use activities have led to degradation of the wetland and loss of vegetation cover.

5.2 The effect of land use activities on the physical-chemical and bacteriological composition of water within Nsooba-Lubigi drainage system.

The results present that EC and TDS were significantly impacted by land use activities, and while COD, TTS and TOC were moderately impacted by land use activities. On the contrary, pH, TP, TN and BOD were minimally impacted by land use activities. Further, wetlands and built-up areas presented the highest significant impact on water quality, specifically EC and TDS, while agriculture presented the lowest impact on water quality and this could have been attributed to the low farming activities carried out in the sampling areas. Despite, the substantial (let's look up for a better word) effect of LUAs on the water quality, all the EC, TDS, pH, TP, TN, BOD, COD, TSS and TOC parameter values for wetland, built-up areas and agriculture activities were below the National Standard for wastewater discharge set by National Environmental Management Authority, 2020 as presented in Table 4.1. This indicates that the results from wetlands, built-up areas and agricultural areas have minimal impact on the water quality.

The agriculture activity recorded the lowest EC compared to built-up areas, which further increased significantly in the wetlands. Similar trends were obtained by Wachu, (2018) who presented that EC is highest in urban sites compared to cultivated areas and forested areas. The studies concluded that high EC concentrations in wetlands is due to the increased input of ions from industrial effluents including car garages in Masanafu and slaughterhouse in Kalerwe and domestic wastewater. This conquers with the findings attributed by Ochuka *et al.,* (2019); who stated that anthropogenic activities such as application of agro-chemicals and waste disposal are associated to higher EC in built-up areas.

In regard to TDS, the concentrations from wetlands, built-up areas and agriculture were attributed to different minerals dissolved in water which include potassium, sodium, magnesium, bicarbonates, these can be connected to numerous other compounds which can be water contaminants as well. However, the results of this study differs from recent studies conducted earlier within the drainage system by Hawumba, (2017) and Ochuka *et al.,* (2019) who stated that higher concentration of TDS yields noxiousness through heightened salinity and change in the ionic composition, affecting water taste, odour, colour and hardness. Palatability of water with TDS less than 600 mg/L is considered suitable (WHO, 2011.), though extreme low TDS reduces the taste of drinking water.

For pH, the average values obtained under the three land uses fell within the acceptable range of the national standard (5.0-8.5), signifying that land-use did not impact the water pH. TP had negligible impact on the water quality, since the activities indicated very low quality characteristics in comparison to the national standard. This could have been attributed to the low BOD levels that are recognized to favor phosphorus discharge to the freshwater ecosystem (Shafie, Wong, Harun, & Fikri, 2017). It was observed that TN is moderately higher in all the 3 activities (though below the national standard). Large increases in organic matter from wetland areas and built-up areas (domestic - household wastewater, sewage, detergent waste, etc.) areas might have led to an increase in the factors affecting moderate concentrations. This is also supported by moderate concentrations in TOC from both the wetland and built-up area activities.

This similar trend was also observed in the study conducted by Özdemir, Perktas, & Döndü, (2022) who indicated that wastes from agricultural and tourism activities in the field of study could affect nitrogen and its derivatives.

Built-up areas presented the highest TSS and this could be attributed attributed to poor waste management practices through littering and discharge of unhealthy effluent from both domestic and industrial activities. This in agreement with the studies conducted by Shafie *et al.* (2017); and Grimm, *et al.,* (2005) who highlighted that bare soil at building sites has frequently stemmed in large sediment inputs to the drainage streams through rainfall runoff events. The studies further indicated that the extent of fine particulate was generally higher in drainage streams around residential areas.

Other physical chemical parameters including BOD, COD TSS and TOC were moderately high though below the National Standard, as observed within the sampling areas. This clearly shows that the high values could be attributed to the undigested materials and animal solid waste released from the Nsooba slaughterhouse. It therefore implies that there is need for huge amount of oxygen to synthesize all of these organic materials into CO_2 and water, which in turn, cause high concentrations of COD and BOD within the study area which could clarify on the linear correlation between solids, COD and BOD. This is in line with Hawumba, (2017) who stated that, the subsequent highly concentrated discharge further adversely affects the water quality of Nsooba channel as detected by the increase in COD and microbial overload, revealing of significant nutrient quantities. The sedimentation of some suspended solids, and the mineralization of the organic loads as the water flows away from the discharge points, should partially describe the reduction in COD linked to what other researchers have studied.

5.3 The effect of land use activities on the bacteriological composition of water quality within Nsooba-Lubigi drainage system.

The results present that land use activities specifically built-up and agriculture areas presented higher relative abundances of Total Coliform concentrations in water bodies compared to E. coli concentrations. Further, wetlands presented minimal abundances of E. coli and Total Coliforms concentrations in the drainage system. However, according to Table 4.2, wetlands and built-up areas presented lower E. coli concentrations compared to the National Standard, while E. coli concentrations in agriculture significantly exceeded the National Standard requirements (400 CFU/ 100ml). On the contrary, Total Coliforms concentrations in all the land use activities exceeded the recommended National Standards (400 CFU/ 100ml). The results are in agreement with other investigations conducted by (Hawumba, 2017) who noted a high concentration of *E. coli* and total coliform for areas with intensive agricultural practices. The low concentration of ecoli and coliforms is attributed to the filtration ability of the wetland that traps both suspended particles in water flowing through them.

Further, the study has showed that bacteriological composition differed from the wetland, agriculture and the built up area. Wetland area recorded the lowest Total coliforms whereas *E.coli* in the built-up area was high as a result of discharge of untreated effluent from Nsooba slaughter house and fecal matter from the households. This implies that the level of pollution changes as the water flows from its source from upstream (Kisasi) to downstream (Lubigi). The high levels of *E.coli* and Total coliforms in the Nsooba slaughter house discharge is indicative of high pollution levels attributed to discharge of untreated effluent and improper waste management practices by occupants and residents of the densely populated market area (Kalerwe market). This is in agreement with Namugize *et al.*, (2018) who stated that, high levels of *E.coli* could be attributed to urban development and agricultural practices and in-channel process interactions, between the Nsooba channel and Lubigi wetlands. Results analysis using a one way ANOVA test revealed a significant difference in *E. coli* counts among the areas investigated within the study area ($F = 30.2$, $P = < 0.05$). *E. coli* counts in most areas investigated exceeded the maximum permissible limits set by NEMA for discharge of waste water into land and water.

The study has also shown that whereas the highest averages of physical-chemical parameters were recorded within the built up area (Nsooba slaughter house discharge/Bulaga), the lowest averages of these parameters were found either within the agriculture area (Kitala) or wetland area. This implies that the pollution levels are high in the built up areas which may be attributed to increased human activity that is usually associated with poor disposal of both solid and liquid waste.

5.4 The effect of land use activities on the quality of soil within Nsooba-Lubigi drainage system

The results have shown that land-use activities in Nsooba-Lubigi drainage system had a significant effect on quantities/levels of metals in the soil. High quantities of Lead and Cadmium were eminent in the wetland and agriculture areas whereas built-up areas were predominated by high levels of Mercury. The land use activities in the study area that have potentially contributed to heavy metals in the soil include; agriculture, horticulture, floriculture within the Lubigi wetland, mechanical garages with poor management of waste including engine oils, used batteries among others that may find their way into the soil or water, poor methods of disposing plastic waste especially by burning, poor management of waste from medical facilities within the study area among other factors. Regarding the land cover, the Nsooba-Lubigi drainage system was found to be majorly composed of built-up areas and wetlands, holding the time factor constant.

A comparison of each of the classes from 1998 to 2018 shows a remarkable LULC. This increasing trend of LULC in the study area might be ascribed to livelihood and commercial forces. These are normally key inducement on anthropogenic change of land use resulting in contamination of water quality (Wang *et al.,* 2008; UNEP, n.d.). Aside, the LULC at the study area could be explained by the nature of the topography given its proximity to various hills such as Kololo hills, Mulago hill, Makerere hill, Kasubi hills. There is increasing urbanization in the area that could be accounting for the decline in some LULC classes (Wetlands and Bare Land) and the increase in others especially Built-Up Areas.

The land use changes have a substantial effect on worsening the physical, chemical properties and the biological characteristics of the soil (Bahrami et al. 2010; Kizilkaya & Dengiz 2010). All soils differ at all observations stages from the macro- to the micro-level, across the landscape and into the soil profile (Crepin & Johson 1993; Lemenih et al. 2005). The sources of discrepancies are not aspects of soil materialization only like climate, parent material nature, the action of living bacteria and landscape (Hillel 1998) but correspondingly land use change, agricultural work, the addition of soil nutrients and soil management practices (Lemenih *et al.* 2005). The main soil physical properties include bulk density, texture,colour, water holding potential and chemical properties forexample soil organic matter,soil organic carbon, pH, electrical conductivity among others (Sebhatleab, 2014).

The study has shown that areas made of urbanization, bare land, as well as agricultural activities are triggered by substantial increase in population, contributing to water quality and soil quality deterioration. This is line with Ding *et al.,* (2015) that, built-up land use was acknowledged as the solidest contributor of phosphorus and nitrogen in Dongjiang River basin and may have been extremely contaminated by point source as well as non-point source pollution, thus additionally supported by high concentrations of NH_3-N (6.31 mg·L−1). This coincides with findings by (Hossain, 2017), indicating that the impact of an individual land use significantly affects soil quality, indicating that as water in a shorter distance from the terrestrial reflects the land physical features much more compared to water at temperately longer distance. (Hossain, 2017) further adds that, as water flows over the land, continuous additional pollutants mix with water from different lands and water characteristics hence reflecting the whole catchment other than a specific portion of the catchment.

Heavy metal levels in surface deposits depend on solid mixtures not solitary associated with environmental features forexample pH, but similarly with particle structure. In order to lessen the mineralogical and grain-size influence on heavy metal concentration, standardization of one metal to a reference element which has slight relation with consequence of human activity, might be an active approach to assess the contaminated degree in residue (Wu *et al.,* 2016).

5.5 The effect of land use activities on the vegetation cover within Nsooba-Lubigi drainage system

From Table 4.1, it was observed that built-up areas and agriculture are the activities with the lowest stability as they are developing activities in the drainage system. This means that the transitions of wetlands and bare lands types are oriented towards urbanization and developing farming activities.

Further, it was observed that Nsooba-Lubigi drainage system has been subjected to a gradual process of reclamation and presently experiences some of the most dangerous threats and pressures, especially on the wetlands. The sites around the drainage system, including Nsooba channel and Lubigi wetland are observed as major sites for urbanization due to their proximity to the city center and industrial district. The LULC results showed that Nsooba-Lubigi drainage system was under several anthropogenic uses including industrialization, increased agriculture, road construction among others has increased the rate of loss of vegetation cover. This is agreement with Twesigye *et al.,* (2011) who stated that increased development such as urbanization and industrialization, and other anthropogenic practices have led to the decline in vegetation cover and its loss. Kayima *et al.,* (2018) also presented that rapid urbanization coupled with increasing population growth are one of the major driving factors of land use along Nsooba-Lubigi drainage system. This proportionately relates to Ding *et al.,* (2015) who elaborated that, in most urbanized areas, land use largely contributes to nitrogen and phosphorus emanating from point source and non-point source pollutants. Ribolzi and Mousque, (2011), in their study found that, most urban households are the common point source to pollution in waste water contamination, these contain pathogens which harbor low dissolved oxygen conditions in ground water supply leading to high metal concentration in the wetlands and other aquatic plant life.

Urbanization has additionally stretched to water-resistant areas larger volumes of runoff. Impervious rainfall runoff drains all types of pollutants including point and non-point source pollutants into rivers, which intensifies nutrients concentrations into surface waters. The strategic location of Nsooba-Lubigi drainage system means that it offers an exclusive and significant set of amenities to the residents within Bukoto, Kyebando, Bwaise and Kawempe among others. It serves as a buffer through which much of Kawempe division's and part of Kampala industrial and domestic effluents pass before being discharged into River Mayanja which eventually drains into River Kafu. Partially treated sewage from NWSC Lubigi treatment plant is mixed with the untreated wastewater present in the Nsooba Channel before entering the Lubigi wetland.

The current rise in settlements around Nsooba-Lubigi drainage system especially in the areas of Bwaise, Kalerwe, Kyebando and Makerere among others is largely due to the high demand for affordable accommodation by people who work in the motor vehicle garages, Kalerwe market and other markets around, petrol station fuel attendants and small companies located within Kawempe division. This is in line with Zhang *et al.,* (2011), who stated that macroeconomic activities such as industrialization and other businesses, contributing to the growth of GDP often require large areas also contribute to the transition of forest/shrub land/grassland into buildup areas.

A significant number of low income earners find affordable and cheap temporal housing along Nsooba-Lubigi drainage system and wetland. Some of the residents around Masanafu, Sentema, Namungoona and Bulaga settlements depend on harvesting of papyrus materials from Lubigi wetland as a way of making the ends meet. The degraded natural and cultural characteristics of the Nsooba channel and Lubigi wetland show lack of clear channel management policies. The location of Nsooba-Lubigi drainage system makes it suitable for providing exceptional and important ecological services to the residents of Kawempe division and KAMPALA CITY at large. Nsooba-Lubigi drainage system is consequently meant to play an important role in preserving the quality of both water supply and open waters. This signifies that areas made of urbanization, bare land, as well as farming activities are characterized by a significant population size that could be partly contributing to water quality and soil quality deterioration in the area.

5.6 Limitations

- Accessibility to sampling sites was difficult especially at the slaughterhouse during picking of samples, as some staff were hesitant to share critical information.
- Sampling Lubigi wetland was risky, especially when maneuvering through thick the papyrus and highly contaminated wastewater.
- Transportation means during data collection was difficult as this was done during COVID-19 lockdowns.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study assessed the effect of land use activities on water quality, soil and vegetation cover for the conservation of Nsooba Lubigi drainage system, Kampala City. Water quality assessment involved determining the physical-chemical and bacteriological characteristics in wetlands, built-up areas and agriculture, using laboratory analytical methods. Soil assessment involved determining the presence of heavy metals using Perkin-Elmer atomization method, while assessment of the vegetation cover was determined using ArcGIS for years 1998, 2008 and 2018.

1. The study results revealed interesting relationship between LU types and water quality parameters, soil and vegetation cover. The analytical concentrations of land-use types of wetland, built up areas and agriculture was observed for the parameters EC (537.5 µs/cm, 472.5 µs/cm and 272.50 µs/cm), TDS(309.00 mg/l, 352.00 mg/l and 155.00 mg/l respectively), TP (0.84mg/l, 0.82 mg/l and 0.53 mg/l respectively), BOD (5.75 mg/l, 14.00 mg/l and 8.75 mg/l respectively), COD (41.00 mg/l, 49.50mg/l and 42.00 mg/l respectively), TSS (25.00 mg/l, 42.00 mg/l and 10.00 mg/l respectively) and TOC (16.70 mg/l, 20.50 mg/l and 5.65 mg/l respectively), where the observed average values were all below the National Standards of 1000 µs/cm, 750 mg/l, 10mg/l, 50mg/l, 70mg/l, 50mg/l and 50mg/l respectively. For TN, the average value for built-up areas (11.27 mg/l) was higher than the national standard of 10 mg/l while the remaining land use types of wetland (8.05mg/l) and agriculture (5.96mg/l) were below that of the recommended standard.

2. Wetlands and built-up areas presented lower E. coli concentrations compared to the National Standard, while E. coli concentrations in agriculture significantly exceeded the National Standard requirements (400 CFU/ 100ml). On the contrary, Total Coliforms concentrations in all the land use activities exceeded the recommended National Standards (400 CFU/ 100ml).
3. The soil parameter values of the three land-use types including wetland, built up areas and agriculture for Lead (0.614 mg/kg, 0.356 mg/kg and 0.495 mg/kg) respectively, were observed to be significantly high compared to the National Standard requirement (0.1 mg/kg); and for Cadmium (0.002 mg/kg, 0.005 mg/kg and 0.003 mg/kg) respectively, were observed to be lower than the recommended National Standard (0.01 mg/kg).
4. There was a significant decline in land coverage for wetlands and bare land from 1998-2018 attributable to rapid urban development involving infrastructural development, farming activities and rapid population growth. Wetland coverage declined by approximately 5 hectares since 1998 which represents an average decline of 2 hectares per decade. Bare Land was also observed to have declined from 14.5% in 1998 down to 7% by 2018, signifying a rapid decline of about 50% from 1998 to 2008. The percentage changes for wetlands, agriculture, bare land and built-up areas between 1998 and 2018 were observed to be -32.63%, 16.42%, -7.43% and 23.64% respectively.

These results indicate that LU activities had significant effect on the soil characterization and microbial water quality in comparison with physical-chemical characteristics. Further, the topographic features of Nsooba-Lubigi drainage system has significant bearing on the ability of the wetland to support the physical chemical and bacteriological processes which are central to the transformation and removal of pollutants from the water. The Nsooba-Lubigi drainage system, with its natural status is potentially susceptible to land use changes attributed to anthropogenic pressures. This has brought about intensive pollution of the Nsooba channel and the wetland ecosystem thus exposing the wetland to increased surface pollution which is significant to wetland hydrogeology and water quality.

The physical and chemical examination of water quality revealed that built up area (Kalerwe) had the highest level of pollution attributed to rapid population growth and human activities including Nsooba slaughter house that discharges untreated effluents to Nsooba channel. This impacts negatively on the quality of the receiving waters. The findings of this research can offer scientific orientation for land use managment and water pollution regulator as well as guide in the creation of strategies for managing the water and other natural resource. However, other factors associated to water quality, such as the weather, precipitation, and density of population call for further research scientifically.

6.2 Recommendations

The study found a strong influence of human activities on bacterial and physical-chemical properties of Nsooba-Lubigi drainage system which have effected negatively on the quality of the catchment area and effected negatively on vegetation cover thus the following recommendations:

1. The government of Uganda through its lead agencies like NEMA, MWE, and KCCA should further sensitize the community within the Nsooba-Lubigi drainage system about the dangers of miss management of both liquid and solid waste. This will improve the water quality and intergrity of the soil within Nsooba Lubigi Drainage System.

2. The management of Nsooba slaughterhouse should ensure that an effluent treatment plant is constructed such that the wastewater from the abattoir is fully treated to meet the requirements of the wastewater discharge permit then can be discharged to the environment This will as well improve the water quality and intergrity of the soil within Nsooba Lubigi Drainage System.

3. The land body should incorporate LU management practices in planning and controlling the impacts of LU activities on the soil characterization and microbial water quality.

4. Similar studies should be conducted on other drainage systems within the city. For the current Nsooba-Lubigi drainage system, future research should be conducted to assess the perceptions of residents and market vendors on the likely challenges faced in the conservation of the drainage system and surrounding wetlands. This will enable a holistic understanding of potential remedies for the conservation of the wetland by the direct inclusion of the local people..
5. Use of advanced solid-waste handling machineries and purifying water set-ups along the urban, residential, and slum areas benefiting from Nsooba Lubigi Drainage System

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APPENDICES

APPENDIX A: Letter on Research Project Laboratory Analysis

THE REPUBLIC OF UGANDA
MINISTRY OF WATER AND ENVIRONMENT
NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

26.11.2020

To whom it may concern

RE: RESEARCH PROJECT LABORATORY WORK

This is to confirm that Kennedy Igunga (Mr) a student of Kyambogo University with Registration Number 18/U/GMSM/19515/PD pursuing a Master of Science in Conservation and Natural Resources Management did his Laboratory work with Ministry of water and Environment at the National Water Quality Reference Laboratory-Entebbe.

His research involved analysis of soil and water quality. During his time with us, he was supervised by my Self.

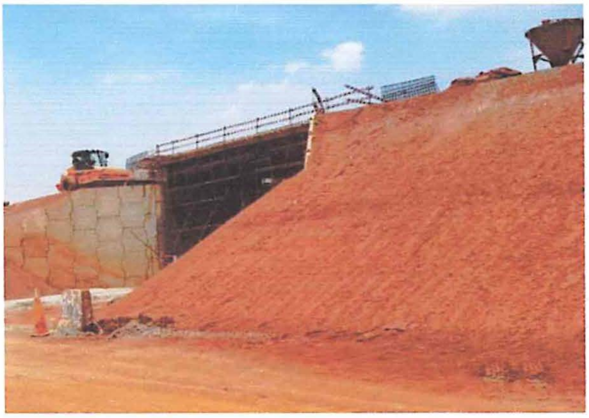
Should you have any request for clarification, please reach the Laboratory by any of the contacts below.

Yours sincerely

Katumba Godfrey
Principal Water Analyst.
Ministry of Water and Environment

APPENDIX B: Field photos

A: Human infrastructural activities on the Nsooba drainage system



Construction of roads and bridges

b) Encroachment of drainage reserves

B: Sampling of soil within Nsooba-Lubigi drainage system

a)Boring ground for soil

b) Obtaining 500g soil samples

C: Sampling for water from different drainage areas

Relatively stagnant water

b) Steadily flowing water

Appendix C: Operational definition of key terms:

Land use: This entails the management and change of natural environment into a built setting such as built-up structures and semi-natural habitats such as arable pasture fields, pastured, and managed woods.

Physical-chemical properties: These relate to chemistry that deals with properties of soil and water such as pH, Total Organic Carbon (TOC), Chemical Oxygen Demand (COD), Total Nitrogen (TN), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), Electrical Conductivity (EC), Total Phosphorous (TP) and heavy metals among others.

Bacteriological properties: This represents an estimate of the numbers of bacteria present and where possible an understanding of what sort of bacteria are present. The Properties are used to represent aspects of water quality.

Vegetation Cover: This is the percentage of soil that is covered by green vegetation. A vegetation cover of 45-50% is considered a key value beacuse beyond this limit soils are sufficiently safeguarded from soil erosion and raindrop impact is considerably reduced. Vegetation cover can be measured in the field by evaluating the percentage of the ground that is covered by the current annual or perennial vegetation.

Dainage System: is a pattern formed by rivers, wetlands, streams, and lakes in a paticular drainage pattern controlled by land topography dominated by hard rock or soft rock and the gradient of the land. A Drainage system can be described as accordant if its patterns correlate to the relief stuctue of the landscape over which it flow. While a discordant drainage system is one that does not correlate to the topogaph and geology of the area.