



**UGANDA CHRISTIAN
UNIVERSITY**

A Centre of Excellence in the Heart of Africa

**LAND USES IMPACTS ON SPATIAL AND TEMPORAL WATER QUALITY VARIATIONS
WITHIN KINAWATAKA WETLAND, UGANDA**

BY

SHARON MIRIEL OKONGA

B. A. ENVIRONMENT MANAGEMENT

(RM019M45/019)

**A DISSERTATION SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND
TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD
OF A DEGREE OF MASTER OF SCIENCE IN WATER AND SANITATION OF UGANDA**

CHRISTIAN UNIVERSITY

JUNE 2023

ABSTRACT

Uganda's urban wetlands like Kinawataka wetland are increasingly affected by effluent discharge from different industrial establishments which poses a great threat to their different components and surrounding dependant human communities. The wetland is a vital ecosystem that provides livelihood opportunities and acts as a watershed that removes nutrient loads from water. However, land use changes and wetland degradation have negatively impacted the quality of water flowing in and out of the wetland. This study summarizes the impacts of land use on spatial and temporal water quality variations within Kinawataka Wetland in Uganda. This study therefore assessed the impacts of pollution loading on water quality within Kinawataka wetland in Kampala district. The study primarily focused on mapping land use changes, geographical and temporal fluctuations in physico-chemical parameters, heavy metals, and nutrient concentrations in water along Kinawataka Wetland in order to provide baseline data for its future conservation and sustainable usage. This study undertook a quantitative research approach with data collected from four purposively selected sites within Kinawataka wetland. In addition to Land use mapping around purposively selected sites, some parameters were measured in-situ whereas others were analysed in the Laboratory. The study findings in Figure 3 illustrate land use changes in Kinawataka wetland (2010-2020): significant growth in built-up areas, a fluctuating pattern for agricultural land, and consistent declines in forested areas and papyrus coverage. Water quality analysis was performed according to Standard Methods for the Examination of Water and Wastewater. The study findings revealed that apart from pH, other physico-chemical parameters of water significantly differed

($P < 0.05$) at different sites within Kinawataka wetland and over study seasons. Heavy metal concentrations also varied among sites with sites closer to point source industrial effluent discharge such as site 2 having higher concentrations of heavy metals compared to sites distant from industrial establishments such as site 1, 6 and 3. Further, Nutrient concentrations in water varied differently among sites along Kinawataka wetland with each site irrespective of location having a particular nutrient in relatively higher concentration than that at other sites. Further research was recommended to ascertain the implications of the effluent discharge on the biological properties and diversity of Kinawataka wetland components in general.

DECLARATION

I, **Sharon Miriel Okonga**, do here by declare that this report is my original work except where otherwise acknowledged. To the best of my knowledge, this dissertation has never been submitted in any University for any award of a degree and in case any mistake is observable in the report I am entirely responsible.

Candidate

Signature.....

Date.....

Sharon Miriel Okonga (RM019M45/019)

APPROVAL

This dissertation was done under the guidance of my superior:

Supervisor

Signature.....

Date.....

Dr. Joel Kinobe (PhD)

DEDICATION

I dedicate this dissertation to my dearest mum (Mrs Okonga Betty) and Uncle (Amai Con) for their encouragement throughout this academic journey. In addition, I would like to further dedicate this piece of work to the fraternity of Uganda Christian University Mukono for the ambient environment and encouragement offered during my time of study.

ACKNOWLEDGEMENTS

This work would not have been possible without the Lord Almighty for the knowledge, Wisdom and good health. Thanks goes to my boss; Ms. Trinhah Kyomugisha who inspired me to take on the course to better my knowledge and who worked actively to provide me with the academic time to pursue those goals. Special thanks go to my supervisor Dr. Joel Kinobe who guided me throughout the journey of undertaking this research.

I am grateful to all of those with whom I have had the pleasure to work with during this and other related projects. They have provided me extensive personal and professional guidance and taught me a great deal about both scientific research and life in general.

In addition, would like to thank my family members who have been very instrumental and provided me with unending inspiration in pursuit of this project and especially my loving Mother (Mrs Okonga Betty) and Uncle (Amai Con), whose love and guidance are with me in whatever I pursue. They are the ultimate role models.

TABLE OF CONTENTS

ABSTRACT	i
DECLARATION.....	iii
APPROVAL	iv
DEDICATION	v
ACKNOWLEDGEMENTS.....	vi
TABLE OF CONTENTS.....	vii
LIST OF TABLES.....	x
LIST OF FIGURES	xi
LIST OF ACRONYMS AND ABBREVIATIONS.....	xiii
CHAPTER ONE: INTRODUCTION.....	1
1.1 Background	1
1.2 Statement of the research problem.....	5
1.3 Objectives.....	7
1.3.1 Main objective	7
1.3.2 Specific objectives	7
1.4 Research questions	7
1.5 Significance of the Study	8
1.6 Conceptual Framework	8
CHAPTER TWO: LITERATURE REVIEW	11
2.0 Introduction.....	11
2.1 Kinawataka Wetland and its Ecological Significance	11
Impacts of land use on wetland ecosystem.....	13

2.2.1 The Impact of Land Use Change on Water Quality: A Spatial and Temporal Perspective	15
2.2.2 Remote Sensing and GIS Techniques for Land Use Mapping:	19
2.3 Physico-Chemical Water Parameters.....	22
2.3.2 Spatial Variations in Water Quality Parameters.....	23
2.3.3 Temporal Variations in Water Quality Parameters	26
2.4 Conclusion	28
CHAPTER THREE: METHODOLOGY	30
3.0 Introduction.....	30
3.1 Area of study	30
3.2 Study design	32
3.3 Sampling techniques.....	32
3.4 Data collection	34
3.4.1 Objective One: Land Use Changes	34
3.4.2 Objective Two	39
3.4.3 Objective Three.....	41
3.5 Quality control	42
3.6 Data analysis.....	43
3.7 Methodological constraints	43
3.8 Ethical considerations.....	44
CHAPTER FOUR: RESULTS AND DISCUSSION.....	45
4.0 Introduction.....	45

4.1 Spatial and temporal variation in Land uses within Kinawataka wetland from 2010 to 2020.....	45
4.2 Spatial variations in the physico-chemical water parameters	49
4.2.2 Spatial variations in nutrient concentrations in water along Kinawataka wetland	56
4.3 Temporal variations in the physico-chemical water parameters	67
4.3.1 Temporal variations in nutrient concentrations in water along Kinawataka wetland	77
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS	92
5.1 Conclusions	92
5.2 Recommendations	93
REFERENCES	95
APPENDICES	120

LIST OF TABLES

Table 1: Characteristics of studied sites along Kinawataka wetland	33
Table 2: Summary of the spatial datasets	34
Table 3: Showing the Landsat imagery that were selected and corresponding sensors used.....	35
Table 4: The observed land use and cover activities and their assigned LULC classes.	38
Table 5: Data collection methods and equipment for the different tested parameters	40
Table 6: Status physico-chemical water quality parameter along Kinawataka wetland	50

LIST OF FIGURES

Figure 1: Conceptual framework for the research project	10
Figure 2: Map of Kinawataka wetland showing the effluent water sample collection sites.....	31
Figure 4: Chloride concentration in water along Kinawataka wetland	56
Figure 5: Sulphate concentration in water along Kinawataka wetland	57
Figure 6: Nitrite concentration in water along Kinawataka wetland.....	60
Figure 7: Ammonium concentration in water along Kinawataka wetland	62
Figure 8: Phosphate concentration in water along Kinawataka wetland	63
Figure 9: Nitrate concentration in water along Kinawataka wetland	65
Figure 10 : Temporal variations in water pH along Kinawataka stream	68
Figure 11: Temporal variation in electrical conductivity along Kinawataka wetland .	69
Figure 12: Temporal variation in alkalinity of water along Kinawataka wetland	71
Figure 13: Temporal variation in water hardness along Kinawataka wetland	73
Figure 14: Temporal variation in BOD along Kinawataka wetland.....	74
Figure 15: Temporal variation in water COD along Kinawataka wetland.....	76

Figure 16: Temporal variation in chloride along Kinawataka wetland	78
Figure 17: Temporal variation of sulphates along Kinawataka wetland	80
Figure 18: Temporal variation in nitrites concentration along Kinawataka wetland ..	82
Figure 19: Temporal variation of nitrates along Kinawataka wetland	84
Figure 20: Temporal variation of ammonium along Kinawataka wetland	86
Figure 21: Temporal variation in phosphate along Kinawataka wetlands	87
Figure 22: Temporal variation in manganese along Kinawataka wetland	90

LIST OF ACRONYMS AND ABBREVIATIONS

°C	Celsius
ANOVA	Analysis of Variance
APHA	American Public Health Association
BOD	Biological Oxygen Demand
DNA	Deoxyribonucleic Acid
EC	Electrical Conductivity
COD	Chemical Oxygen Demand
pH	Potential of Hydrogen
CL	Chloride
NDP	National Development Plan
NEMA	National Environmental Management Authority
UN WWAP	United Nations World Water Assessment Programme
UBOS	Uganda Bureau of Statistics
GIS	Geographical Information System
GPS	Geographic Positioning System

LULC Land Use Land Cover

RS Remote Sensing

CHAPTER ONE: INTRODUCTION

1.1 Background

Wetlands account for 47% of the ecosystem and play a vital role in regulating climate change, protecting the ecosystem and providing economic value to human beings (Hu S.J., 2017). The role of wetlands within the world is rather evident, mainly to the people that live within its neighborhood and in the improvement of water quality from one point to another, not to mention the preservation of biodiversity. Wetland areas inherently provide beneficial functions such as flood control, water storage, purification of pollutants and maintenance of biodiversity. Globally, many wetlands have been exploited or used unsustainably which has resulted in a 35% loss in the global wetland extent since 1970 despite 169 countries having ratified the Ramsar Convention, wetland losses and degradation (Gardner, 2018). Due to social economic development and land use changes in wetland areas, the total wetland area in the world is reducing gradually as a result of agricultural intensification , expansion of farmlands and construction activities. Where wetlands are not directly destroyed by land use changes, pollution of the wetlands has significantly reduced water quality of the wetlands which inturn impairs ecosystems (Zeng et al., 2015).

In Uganda, wetlands occur all over and cover an area of 11% of the land area. A simple classification by AFRICOVER denotes the area covered by wetlands as follows: seasonal wetlands (7.7%), permanent (3.4%) and swamp forests (<0.1%) (MWE, 2013).

Uganda has multiple legislation and framework designed to ensure protection of wetlands which includes The National Policy for the Conservation and Management of Wetlands, Environment Act of 1995, Land Act 1997, Local Government Act 1997,

Environment Impact Assessment Regulations 1998, the Wetland Regulations 2000 and the Constitution 2010. Despite all these legislations and policies, wetlands have continually been degraded across the country in Urban areas due to encroachment for settlement and in the rural areas for agriculture (MWE, 2014). Additionally, the wetlands in different river basins have experienced a decline of over 53.8% in Lake Victoria basin and 14.7% in Lake Albert drainage basin due to weak enforcement of existing laws, continued disregard for the existing laws and policy with impunity making enforcement difficult, and lack of coordination amongst key government institutions (UN, 2016). In 2015, the Ministry of Water and Environment estimated that Uganda was losing an average of 5,000 hectares of wetlands per year. In 2023, it was noted that Uganda had a wetland coverage area of around 22,500km² which reduced from 30,000km² recorded in the year 2000 implying a 25% loss in the past two decades.

Kinawataka wetland falls along a line and string of wetlands that are crucial to the water system of the country along the River Nile. The Kinawataka wetland is an important habitat in the Lake Victoria watershed that helps to reduce pollution and floods while also sustaining groundwater supplies and quality (Amos, 2021). Wetland management, in its most basic form, entails planning for the long-term use of this ecosystem, implementing measures, and monitoring them to ensure that adequate livelihood possibilities are realized (Kakuba & Kanyamurwa, 2021). However, due to intensive cultivation, climatic change, industrial pollution, and other anthropogenic activity, this wetland has suffered serious ecological deterioration. Wetland's capacity to give supportive opportunities, on the other hand, can only be sustained if

its exploitation is accompanied by efficient wetland management methods. From 1992 to the present, the Kinawataka wetland, the research's focal point, has dropped by 46% and its deterioration has increased from 49% to 95% (Kakuba & Kanyamurwa, 2021). This condition of affairs serves as the foundation for assessing the impacts of urbanization around the wetland within the recent years.

Evidence from other wetlands; in Nigeria, Kenya and UN documents indicate the deterioration levels of wetland integrity based on population growth, industrialization and other developments which is also a trend being identified in Kinawataka (Maximus, 2008, UN, 2019). Also, more recent studies indicate that the wetland's efficiency to filter water has deteriorated; Total nitrogen, total dissolved solids, and total phosphorus concentrations in the stream flowing out of the upper Kinawataka wetland were all above NEMA's maximum permitted threshold, wetland retention of most toxins was far lower and the worsening of the quality of water moving into and out of the Upper Kinawataka wetland has been linked to the shrinkage of the wetland over the previous 20 years, mostly due to industrialization, agriculture, and settlement (urbanization) (Amos, 2021). SDG 15 enjoins UN member states to "protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, reverse land degradation, and halt biodiversity loss" (Kumar *et al.*, 2016, Kakuba & Kanyamurwa, 2021). Despite Uganda having the Uganda Wetlands policy in action as compared within the legal framework which directs that all wetlands should not be; drained for use, their roles maintained and environmental impact assessments always done to ensure sustainability (Government of Uganda, 1995), the Kinawataka wetland still faces

trouble with increasing changes that result from urbanization. It is in this light that the study aims to show the impacts of urbanization practices such as population growth, industrialization and infrastructure development on the filtration ability and community in the wetland.

In addition, changes in the concentration of nutrients in water from aquatic sources such as Kinawataka wetland may lead to harmful effects on humans and aquatic life. Many heavy metals in watercourses are often associated with industrial emissions (Mdamo, 2001) and probably heavy metals that are common in industrial effluents are toxic to aquatic life. The chemical composition of the aquatic organism reflects not only the type and diversity of aquatic biota but also the level of water and water pollution (Birley and Lock, 1999). For example, Cadmium is believed to inhibit the absorption and retention of Calcium in the bones, while excess lead in humans severely impairs the function of the central nervous system. Second, depending on its availability for biota, Cadmium may accumulate a number of aquatic organisms, including fish. Also, studies have shown that fish can be as badly affected as 0.03 mg / l of lead in water. In addition, copper is essential for the normal growth of many aquatic organisms but is toxic to concentrations as low as 10 g / l (Birley and Lock, 1999). All of this points to the health risks of exposure to areas contaminated with heavy metals. Many heavy metals in flowing water are often associated with industrial extraction and almost all common heavy metals in industrial wastewater are accumulating toxins from the water (Kansiime., *et al*, 1994)

Biodiversity collection may also increase their focus on toxic levels and endanger endangered species, which in turn need to be conserved for tourism activities and future research. Oils and oils are naturally toxic and may contain heavy metals such as Lead and Cadmium. Oil and grease are not certain chemical substances but can include thousands of natural chemicals with different physical, chemical and toxic properties (Alsbou, *et al*, 2018) Oil and grease give off odors, disrupt the natural balance of flow components and are harmful to human health and the functioning of other organisms that use running water as a habitat and other activities. Phosphates are generally not considered to be harmful to human consumption but show a complex effect on the natural environment especially the eutrophication of open water systems. For example, the phosphate found in purifiers may lead to eutrophication of surface water (Ramachandra, 2017). Nitrites (NO_2) and Nitrates (NO_3) are nutrients that when released from open water can cause eutrophication. Excessive concentration of nitrate promotes the growth of marine organisms such as algae (Zhang *.et al*,2017)

1.2 Statement of the research problem

Biodiversity use in a sustainable manner within Uganda is a struggling case and as such, wetlands have also been degraded and changed from their natural function based on anthropogenic activity. The Kinawataka wetland, has in fact, continuously shown deterioration in its functionality with evidence of consistent cases of flooding and delivery of unsafe water which indicates that the wetland is being destroyed. Considering the activities around the wetland, the filtration capacity of the wetland has become a problem, which, if not solved, has possibility to elevate flood

occurrence and spread of infectious diseases in the neighborhood. Increased Activities (car washing in the swamp, industrialization) in the wetland are destroying its capacity to fully filter water. Flooding is at an increased level due to swamp reclamation and Reduction in Animal and plant species in the wetland is becoming a biodiversity issue.

Wetlands such as Kinawataka wetland are known to act as natural filters for nutrients and contaminants that originate from the catchment area, thereby protecting the water quality (Kansiime and Nalubega, 2000). However, Kinawataka Wetland is overwhelmed with partially treated effluent that do not meet the minimum effluent standards. Effluent from industries is discharged into Nakawa-Ntinda streams without adequate treatment or no treatment at all resulting in nutrient enrichment, the accumulation of toxic compounds in biomass and sediments (Dunbabin, 1992), loss of dissolved oxygen in water and other nuisances. The presence of such pollutants not only degrade the quality of water, but are also a potential health risk to the aquatic and associated biota. Several studies have been done in Uganda on the effects of industrial effluents on the quality of water in receiving streams (Angiro *et al*, 2020; Wanasolo *et al*, 2018; Walakira & Okot-okumu, 2011). Specific to Kinawataka wetland, there is gap in literature on the relationship between the quality of water up-stream and that quality of water where the stream drains in relation to the subsequent industries that discharge at Nakawa-Ntinda stream. This study will therefore fill that gap.

1.3 Objectives

1.3.1 Main objective

The study assessed the impacts of land uses on the spatial and temporal water quality variations within Kinawataka wetland in Kampala district.

1.3.2 Specific objectives

The specific objectives of the study were;

- i. To determine and map out the different land uses within Kinawataka wetland over the past 10 years
- ii. To assess the spatial variations in the physico-chemical water parameters and nutrient concentrations within Kinawataka wetland.
- iii. To assess the temporal variations in the physico-chemical water parameters and nutrient concentrations within Kinawataka wetland.

1.4 Research questions

The following research questions guided the study;

- i. How has land-use evolved within Kinawataka wetland and its overall impact on water quality within the different areas?
- ii. What is the level of physico-chemical parameters and nutrients in water at different locations within Kinawataka wetland?
- iii. What is the state and concentration of physico-chemical parameters, and nutrients in water over the different seasons within Kinawataka wetland?

1.5 Significance of the Study

Wetland management is critical in promotion of conservation and smart use of all wetlands through a variety of local techniques and international cooperation in order to achieve global sustainable development (Rojas-Uredo, 2017). The analysis of the deterioration functionality of the Kinawataka wetland does not only benefit the wetland community therein, but also the people around. The study will assist the relevant industries and authorities in designing appropriate preventive measures to ensure that the water quality in the streams is improved. It will also act as an enforcement tool for compliance monitoring. The information generated by this study can support Kampala Capital City Authority and Wakiso District Local Government in strengthening capacity for wetland management and water quality assessment. Kinawataka water quality data generated by this research can be used at national level in pollution monitoring of various water sources like wetlands by various government authorities such as Ministry of Water & Environment, National Environment Management Authority, Directorate of water Development and other authorities.

1.6 Conceptual Framework

The conceptual framework shows the cause-effect relationship between land uses and anthropogenic activities such as human, settlement, and industrialization into the wetland and its overall impact on the environment and human health within Kinawataka wetland. This has seen changes in levels of physico-chemical parameters, and nutrients of water in the different sections along the wetland (Figure 1). In this study, the relationship between the factors affecting water quality of the Kinawataka

stream were presented in the conceptual framework. Water quality was affected by the lithology of the water source, the land uses within the wetland and the anthropogenic activities around the stream. The independent variables were the land uses and anthropogenic activities whereas the dependent variable was the water quality of the stream as shown in Figure 1 below.

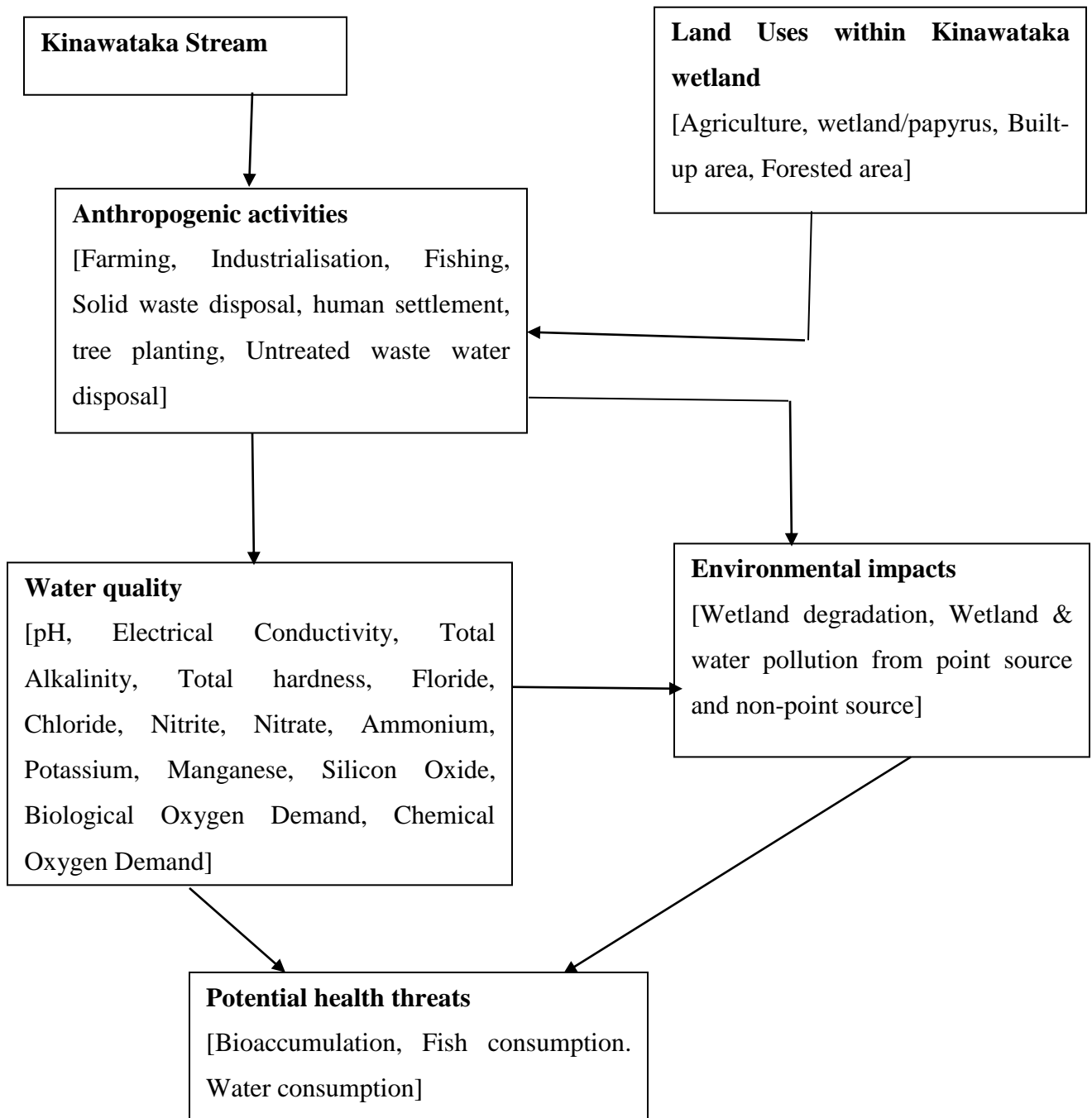


Figure 1: Conceptual framework for the research project

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

In this chapter, studies conducted by different researchers on wetlands and wetland water quality were discussed. Gaps therein which led to the study were also highlighted.

2.1 Kinawataka Wetland and its Ecological Significance

Wetlands, located in transitional areas between dry lands and water bodies, are recognized as productive ecosystems with potential to support the UN Agenda on Sustainable Development Goals (SDGs) (Gokce, 2019; McElwee & Wood, 2017; Seifollahi-Aghmiuni et al., 2019). These well-managed wetlands can contribute to SDG 1, addressing poverty eradication, by providing livelihood opportunities in vulnerable communities (Gideon & Bernard, 2018). However, effective public management is crucial to harness the resources and coordinate efforts. Livelihood opportunities within wetlands have a direct impact at personal, household, and community levels (Lamsal et al., 2015). Management encompasses organizing, administering, and governing organizational affairs (Malandrino et al., 2019). This paper highlights three key facets of management: planning, implementation, and control, to examine their impact on livelihood opportunities in urban wetlands. These management mechanisms are crucial for aligning performance with organizational objectives.

The potential of wetlands to provide supportive opportunities can be sustainable only when their exploitation is supported by effective wetland management measures (Rebelo et al., 2009; McElwee & Wood, 2017). This is the essence of SDG 15, which

calls on United Nations member states to "protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, reverse land degradation, and halt biodiversity loss" (UN, 2019). Wetland management is essential because of the role it plays as a promoter of conservation and wise use of all wetlands through diverse local approaches and international cooperation to achieve sustainable development worldwide (Ramsar, 2017). This role has long been recognized in the 1971 Ramsar Convention, approved by over 169 member states in Iran. Essentially, wetland management involves planning for the sustainable use of this ecosystem, implementing strategies, and controlling them to ensure that appropriate livelihood opportunities are achieved (Nabahungu, 2012; Lamsal et al., 2015). It is, thus, important to investigate this management model with a focus on its most central facets of planning, implementation, and control to measure the logical linkages with livelihood opportunities in urban wetland settings.

Wetlands are globally recognized as waterlogged ecological structures, including grasslands, swamps, marshes, and floodplains (Justine, 2020). In Kampala District, wetlands cover approximately 33 km², with Kinawataka being part of the Lake Victoria basin. Other wetlands, such as Lubigi wetland, drain into Lake Kyoga. Uganda's wetlands are predominantly permanently waterlogged, with seasonal wetlands occurring at the fringes (Justine, 2020). In Kampala District, examples of wetlands include Kinawataka, Ntinda, Kirombe, Nakawa, and Soweto (Namuwongo).

In Uganda, including the Kinawataka wetland, the general situation regarding wetland management is concerning. Wetlands make up 10%–13% of Uganda's land area, with the Kampala Capital City Authority (KCCA) covering 189 sq. km. Within this area,

KCCA's wetland coverage is 12.76 sq. km, and specifically, Kinawataka wetland covers 1.5 sq. km (Mafabi, 2018). Unfortunately, these ecologically vital spaces face degradation due to marram infilling, rapid construction of infrastructure and housing, direct dumping of toxic industrial wastes, and incompatible cultivation. The destruction of wetlands highlights deficiencies in contemporary management mechanisms. Encroachment by smallholder agricultural cultivation has significantly contributed to wetland damage, escalating from 0.2% in 2002 to 1.6% in 2015 and 7.7% in 2018. Settlement in wetlands has also increased from 3.2% in 1992 to 7.8% in 2015 and 12.5% in 2018. Additionally, built-up areas expanded from 54% in 1992 to 66% in 2014, small businesses encroached from 14% to 18%, and industrial encroachment rose from 9% to 12% during the same period (Tumuheire, 2017).

Impacts of land use on wetland ecosystem

Wetlands are important ecosystems that provide various ecological services, such as water purification, carbon sequestration, and habitat for diverse flora and fauna. However, human activities, such as land use changes, have significantly impacted the functioning and health of wetland ecosystems (Davidson & Middleton, 2017).

Land use within wetland areas can be categorized into various types, including agriculture, urbanization, forestry, mining, and recreation (Liu et al., 2008). Each land use type is associated with specific characteristics and activities that can impact the functioning and health of wetland ecosystems; Agriculture is a common land use type in wetland areas, and it involves activities such as crop cultivation, grazing, and irrigation. Agricultural activities can impact wetland ecosystems by altering the hydrology, nutrient cycling, and soil characteristics of the ecosystem

(Koerselman & Meuleman, 1996); Urbanization is another land use type that can significantly impact wetland ecosystems. Urbanization involves the development of cities and towns, and it is associated with activities such as construction, transportation, and waste disposal. Urbanization can impact wetland ecosystems by altering the hydrology, water quality, and habitat availability of the ecosystem (Alberti et al., 2003); Forestry is a land use type that involves the cultivation and management of forested areas. Forestry activities can impact wetland ecosystems by altering the hydrology, nutrient cycling, and vegetation structure of the ecosystem (Kozerski & Bennington, 1995); Mining is another land use type that can impact wetland ecosystems. Mining involves the extraction of minerals and other resources from the earth, and it is associated with activities such as excavation, waste disposal, and transportation. Mining can impact wetland ecosystems by altering the hydrology, soil characteristics, and vegetation structure of the ecosystem (Banks & Bailey, 1995); Recreation is a land use type that involves the use of wetland areas for leisure activities, such as hiking, camping, and fishing. Recreation can impact wetland ecosystems by altering the hydrology, habitat availability, and soil characteristics of the ecosystem (Van Dijk et al., 2012).

Phethi, M.D. & Gumbo, J.R. (2019) conducted a study on the impact of land use changes on the wetland in Makhitha village, Limpopo province, South Africa. They found that factors such as poverty and population growth were the driving forces behind wetland mismanagement. The cultivation of crops, grazing of livestock, and road construction were the main land use activities that contributed to wetland deterioration. The study recommended strategies such as environmental education,

fencing, and land use planning to resolve the problem of land use changes and contribute to sustainable wetland management; Also, Qiu, H., Hu, B., & Zhang, Z. (2021) analyzed the impacts of land use change on ecosystem service value based on SDGs report, taking Guangxi as an example. The study found that from 1990 to 2020, wetlands, forests, and grasslands decreased, while dry land and construction land increased. The overall ecosystem service value in Guangxi showed a decreasing trend, with hydrological regulation and climate regulation being the dominant services.

Lambin, E.F., Turner, B.L., Geist, H.J., et al. (2001) discussed the causes of land-use and land-cover change, moving beyond the myths. They found that land use changes, including those affecting wetlands, are driven by multiple factors such as demographic, economic, technological, cultural, and political forces. These changes can have significant impacts on water quality and other ecosystem services. Similarly, Low, A.B. & Rebelo, A.G. (1996) investigated the impact of land use changes on wetlands in South Africa. They found that wetland degradation was primarily caused by agricultural activities, urbanization, and infrastructure development. These changes led to alterations in water quality, loss of biodiversity, and reduced hydrological function. These studies highlight the importance of understanding the complex factors driving land use changes and their impacts on wetland ecosystems, including water quality variations.

2.2.1 The Impact of Land Use Change on Water Quality: A Spatial and Temporal Perspective

The relationship between land use and water quality has been a significant focus of environmental research. Agricultural activities, for instance, often lead to nutrient

runoff, which can cause eutrophication in nearby water bodies (Carpenter et al., 1998). This process involves the excessive enrichment of water bodies with nutrients, primarily nitrogen and phosphorus, leading to rapid growth of algae and other aquatic plants. When these organisms die and decompose, they consume large amounts of oxygen, leading to hypoxic conditions that can harm or kill aquatic animals. Urbanization, another form of land use, can also lead to increased levels of pollutants in water bodies. Urban runoff often contains pollutants such as heavy metals, oils, and other toxic substances that can degrade water quality (Paul & Meyer, 2001). These pollutants can originate from various sources, including road surfaces, industrial sites, and residential areas.

Water quality can vary significantly both spatially and temporally due to a variety of factors. Spatial variations in water quality can occur due to differences in land use, soil type, topography, and other environmental factors across a watershed (Allan, 2004). For example, areas with intensive agricultural or urban land use may have poorer water quality compared to areas with forested or natural land use. Temporal variations in water quality can occur due to seasonal variations in weather, changes in land use, and human activities. For example, water quality can vary seasonally due to changes in precipitation and temperature, which can influence the amount and types of pollutants that are transported to water bodies (Allan, 2004). Changes in land use, such as the conversion of natural land to agricultural or urban land, can also lead to temporal changes in water quality.

Wetlands play a crucial role in maintaining water quality by filtering out pollutants and providing habitat for a variety of species. They act as natural filters, trapping

sediments and absorbing and transforming nutrients and other pollutants (Mitsch & Gosselink, 2007). However, wetlands are also vulnerable to changes in land use, which can degrade their ability to provide these services. For example, the drainage of wetlands for agriculture or urban development can lead to the loss of their water quality protection functions.

A study on the impact of land use / cover changes on water quality and human health in district Peshawar Pakistan concluded that the groundwater quality, decreased in 2019 compared to 2012. The major factors for this groundwater quality deterioration were attributed to urbanization, domestic wastewater discharge, and rising water demand for agriculture and domestic and industrial purposes. The pH, Conductivity, Calcium, Chloride, Magnesium concentration in groundwater increased mainly near the built-up areas because of wastewater discharge, buildings construction, and other anthropogenic activities like water extraction, industrial activities. Nitrate concentration increased near the agricultural lands because of the excessive utilization of pesticides and fertilizer (Ahmad, 2021).

Camara et al., 2019, found that urban development, agricultural activities, and forest degradation are the main sources of water quality deterioration in Malaysia, with 87% of studies indicating the impact of urban land use, 82% of agricultural land use, 77% of forest land use, and 44% of other land uses.

A study on the impact of land use change on water quality and productivity showed that there were reciprocal changes between land and water, with high vegetation cover having dominated in 1990 with 87.2%, in 2005 with 49.5%, in 2010 with 78.4% and in 2015 with 44.7%. Moderate vegetation cover was observed in 1995 with 69.3%,

and low vegetation cover in 2000 with 62.9%. It was also concluded that there was an exponential increase in human population size around Lake Wamala catchment over the years accompanied by multiple unsustainable land use practices within the riparian areas of the lake that undermine the quality and productivity of Wamala waters (Tumushabe, 2017).

A Study on the Relationship between Land Use Change and Water Quality of the Mitidja Watershed in Algeria Based on GIS and RS showed that the land use structure in the study area changed dramatically between 2000 and 2017 and there was a notable decrease of agriculture and barren land, whereas marked increment of urban settlement land. Most water quality variables have degraded between 2000 and 2017, and the water quality of upstream area was better than that of downstream areas. It also showed that urban residential land is the most significant independent variable to predict water quality, which is sensitive to six water quality parameters (BOD₅, COD, SS, NH₄-N, PO₄-P, DO and pH), while vegetation is sensitive to NO₃-N and that the fluctuation of water quality is closely related not only to land use patterns on the watershed scale, but also to the superimposition influence of the urbanization process and the difference of topography and geomorphology (Chen et al., 2020).

A study by Kakuba et al., 2021 showed that there were positive linkages between management functions of (planning, implementation and control) and livelihood opportunities, but had an insignificant predictive effect. This suggested that there was a gap between managers and the users in the public processes for handling wetland resource sustainability issues.

Tumuheire, 2017 revealed that there was an increase in built up area (from 54% to 66%), agriculture (from 14% to 18%) and industries (from 9% to 12%) between 1994 and 2014, from 1994 to 2014, the intact wetland had decreased by 46%, constituting degradation from 49% to 95%. Comparison of 2014 water quality results with secondary data revealed high concentration of total nitrogen, total dissolved solids and total phosphorus in the stream flowing out of upper Kinawataka wetland with all values above the maximum permissible levels set by NEMA. The reduction in size of the wetland in the last 20 years caused mostly by industrialization, agriculture and settlement was associated to the deterioration of the quality of water flowing into and out of Upper Kinawataka wetland.

A study by (Arias et al., 2019) in Buenos Aires Argentina found that Macroinvertebrate assemblages and stream-water quality are affected by horticultural land use in the adjacent plots from fertilizers and pesticides which reach nearby streams, increasing nutrient concentrations and altering macroinvertebrate composition. Furthermore, multivariate analysis suggested the combined effect of simultaneous incorporation of nutrients and pesticides through runoff following crop applications to be responsible for the positive correlation of the tolerant taxa and negative association of the sensitive taxa with elevated nutrient concentrations.

2.2.2 Remote Sensing and GIS Techniques for Land Use Mapping:

Lu, D., & Weng, Q. (2007) provided an overview of remote sensing and GIS techniques for land use and land cover mapping. They discussed various remote sensing data sources, including aerial photographs, satellite images, and LiDAR, as well as GIS

techniques for data processing, analysis, and visualization. Mather, P.M. (1999) discussed the use of remote sensing and GIS techniques for land use and land cover mapping. The author provided an overview of different remote sensing data sources, such as multispectral and hyper spectral imagery, and discussed various GIS techniques for data processing and analysis.

Foody, G.M. (2002) discussed the advantages and limitations of different remote sensing and GIS techniques for land use mapping. He highlighted the importance of selecting appropriate data sources, classification methods, and accuracy assessment techniques to ensure reliable and accurate land use maps. Similarly, Congalton, R.G., & Green, K. (2008) provided an overview of the advantages and limitations of different remote sensing and GIS techniques for land use mapping. They discussed various classification methods, such as supervised and unsupervised classification, and highlighted the importance of accuracy assessment and ground-truthing for reliable land use maps.

Ozesmi, S.L., & Bauer, M.E. (2002) conducted a review of remote sensing and GIS applications for wetland mapping. They found that satellite imagery, aerial photographs, and LiDAR data were commonly used for wetland mapping, with classification techniques such as supervised and unsupervised classification, object-based image analysis, and machine learning algorithms being employed. The study highlighted the importance of integrating remote sensing and GIS techniques for accurate wetland mapping and monitoring. Tiner, R.W. (2011) discussed the use of remote sensing and GIS techniques for wetland mapping and inventory in the United States. The study highlighted the importance of using high-resolution imagery and

advanced classification techniques for accurate wetland mapping. The author also emphasized the need for ground-truthing and accuracy assessment to ensure the reliability of wetland maps. Artigas, F.J., & Yang, J. (2005) applied remote sensing and GIS techniques to map land uses within New Jersey Meadowlands wetland area. They used high-resolution aerial photographs and object-based image analysis to classify land use types and monitor changes over time. The study demonstrated the potential of remote sensing and GIS techniques for wetland mapping and management.

Designated as an industrial zone by the Kampala City Council in 1972, the Kinawataka wetland has suffered from detrimental policies that allocated wetlands for industrial expansion. The wetland has been partitioned into plots, complete with road networks, leading to an increase in concrete surfaces. This has diminished the wetland's water retention and infiltration capabilities, disrupting river flow patterns. The government's failure to implement effective mitigation measures, such as adequate drainage planning, has exacerbated the situation. The lack of space for storm water channels and vegetation removal has further reduced the wetland's infiltration and retention capacity. Even government-led developments have been flawed, with infrastructure like the undersized culverts at the Ntinda-Kyambogo crossroads unable to handle stormwater volumes during rainfall, leading to excessive flooding (MWE, 2015). Additionally, the establishment of washing bays has contributed to the wetland's degradation. In Kinawataka, vehicle washing has resulted in the silting and oil discharge into wetland streams, turning the water black, toxic, and odorous, posing a threat to aquatic life and humans. (MWE, 2019)

2.3 Physico-Chemical Water Parameters

Physico-chemical water parameters are essential indicators of water quality and play a crucial role in determining the health of aquatic ecosystems. Some of the commonly used parameters include temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), and nutrients such as nitrogen and phosphorus compounds (Boyd & Tucker, 2012).

Temperature is a critical parameter as it influences the solubility of gases, metabolic rates of aquatic organisms, and the rate of chemical reactions (Boyd & Tucker, 2012).

pH is another important parameter, as it affects the availability of nutrients and the toxicity of certain substances in the water (Chapman, 1996). Dissolved oxygen is essential for the survival of aerobic organisms and can be influenced by factors such as temperature, salinity, and biological activity (Wetzel, 2001).

Electrical conductivity is a measure of the water's ability to conduct electricity and is related to the concentration of dissolved ions in the water (Hem, 1985). Total dissolved solids represent the total amount of dissolved substances in the water, including salts, minerals, and organic matter (Boyd & Tucker, 2012). Nutrients such as nitrogen and phosphorus compounds are essential for the growth of aquatic plants and algae but can lead to eutrophication if present in excessive amounts (Carpenter et al., 1998).

Physico-chemical water parameters are crucial for understanding wetland health and ecological functions, as they provide insights into the overall condition of the aquatic environment and the potential impacts on the biota (Mitsch & Gosselink, 2007). For example, high levels of nutrients can lead to eutrophication, which can result in the

loss of biodiversity, reduced water clarity, and the depletion of dissolved oxygen (Carpenter et al., 1998). Monitoring these parameters can help identify potential threats to wetland health and inform management strategies to protect and restore these valuable ecosystems (Mitsch & Gosselink, 2007). Furthermore, understanding the relationships between physico-chemical parameters and biological indicators, such as the presence and abundance of specific species, can provide a more comprehensive assessment of wetland health and ecological functions (Karr & Chu, 2000).

2.3.2 Spatial Variations in Water Quality Parameters

Several studies have investigated spatial variations in physico-chemical water parameters within wetland ecosystems. For example, Bruland et al. (2003) examined the spatial variability of water quality parameters in a large riverine wetland and found significant differences in nutrient concentrations and other parameters across different locations within the wetland. Similarly, Zhang et al. (2009) studied the spatial distribution of water quality parameters in a coastal wetland and observed significant variations in nutrient concentrations, salinity, and other parameters across different sites. These spatial variations in physico-chemical water parameters can be attributed to various factors, such as hydrological connectivity, vegetation, and land use (Bruland et al., 2003; Zhang et al., 2009). For instance, hydrological connectivity can influence the distribution of nutrients and other water quality parameters by facilitating the transport of materials between different parts of the wetland (Bruland et al., 2003). Vegetation can also play a role in shaping spatial variations in water

quality parameters by affecting nutrient uptake and sedimentation processes (Zhang et al., 2009).

Key factors influencing spatial variations in physico-chemical water parameters within wetlands include land use and hydrological connectivity, (Bruland et al., 2003; Zhang et al., 2009). Land use can have a significant impact on water quality parameters by altering the input of nutrients and other pollutants into wetland ecosystems (Tong & Chen, 2002). For example, agricultural activities can lead to increased nutrient inputs, while urbanization can result in the introduction of various pollutants, such as organic contaminants (Tong & Chen, 2002). Hydrological connectivity can also influence spatial variations in water quality parameters by controlling the transport of materials between different parts of the wetland (Bruland et al., 2003). For instance, areas with high hydrological connectivity may exhibit higher nutrient concentrations due to increased transport of nutrients from upstream sources (Bruland et al., 2003). Vegetation can affect spatial variations in water quality parameters by influencing nutrient uptake and sedimentation processes (Zhang et al., 2009). For example, areas with dense vegetation may exhibit lower nutrient concentrations due to increased nutrient uptake by plants and reduced sedimentation rates (Zhang et al., 2009).

The primary nutrients of concern in wetland ecosystems are nitrogen (N) and phosphorus (P). These nutrients can lead to eutrophication, which is the excessive growth of aquatic plants and algae, resulting in oxygen depletion and negative impacts on aquatic life (Carpenter et al., 1998). The main sources of nitrogen and phosphorus in wetlands include agricultural runoff, urban stormwater runoff, wastewater treatment plant effluent, and atmospheric deposition (Mitsch &

Gosselink, 2015). Excessive nitrogen and phosphorus inputs can lead to eutrophication, which can cause a decline in water quality, loss of biodiversity, and the formation of harmful algal blooms (HABs) (Smith et al., 2006). HABs can produce toxins that are harmful to humans, animals, and aquatic life (Paerl & Huisman, 2008). Nutrient pollution can alter wetland ecosystem structure and function, leading to changes in plant and animal communities (Zedler & Kercher, 2005). For example, excessive nutrient inputs can favour the growth of invasive plant species, which can out compete native species and reduce overall biodiversity (Ehrenfeld, 2003). Several studies have investigated spatial variations in nutrient concentrations within wetland ecosystems. For example, Bruland et al. (2003) found that nutrient concentrations varied significantly within a single wetland, with higher concentrations near the wetland's edge and lower concentrations in the interior. Another study by Noe and Hupp (2005) found that nutrient concentrations in wetlands were influenced by factors such as hydrology, vegetation, and sediment characteristics.

Land use can have a significant impact on nutrient levels in wetlands. For instance, agricultural land use has been associated with increased nutrient inputs to wetlands due to fertilizer application and livestock waste (Sharpley et al., 2003). Urban land use can also contribute to increased nutrient levels in wetlands through stormwater runoff, which can contain nutrients from sources such as lawn fertilizers, pet waste, and atmospheric deposition (Walsh et al., 2005). These land use-related nutrient inputs can have negative implications for water quality in wetlands, including eutrophication, loss of biodiversity, and the formation of harmful algal blooms (Smith et al., 1999).

A study conducted on the Microbial and chemical contamination of water, sediment and soil in the Nakivubo wetland area showed that the water samples derived from the Nakivubo wetland showed mean concentrations of TTCs of 2.9×10^5 colony-forming units (CFU)/100 mL. Mean *E. coli* was 9.9×10^4 CFU/100 mL. Hookworm eggs were found in 13.5% of the water samples. Mean concentrations of iron (Fe), copper (Cu) and cadmium (Cd) were 21.5, 3.3 and 0.14 mg/L, respectively. In soil samples, we found a mean lead (Pb) concentration of 132.7 mg/L. In yams, concentrations of Cd, chromium (Cr) and Pb were 4.4, 4.0 and 0.2 mg/L, while the respective concentrations in sugar cane were 8.4, 4.3 and 0.2 mg/L. TTCs and *E. coli* in the water, Pb in soil, and Cd, Cr and Pb in the plants were above national thresholds (Fuhrimann et al., 2015).

Soucek *et al.* showed that high concentrations of sulphate will cause the death of freshwater invertebrates (Soucek & Kennedy, 2005). The study also concluded that at constant sulfate (approximately 2,800 mg/L) and hardness (106 mg/L), the survival of *H. azteca* was positively correlated with chloride concentration. Hardness also was found to ameliorate sodium sulfate toxicity to *C. dubia* and *H. azteca*, with LC50s for *C. dubia* increasing from 2,050 mg SO_4^{2-} /L at hardness = 90 mg/L to 3,516 mg SO_4^{2-} /L at hardness = 484 mg/L.

2.3.3 Temporal Variations in Water Quality Parameters

Temporal variations in physico-chemical water parameters within wetlands are essential to understand the changes in water quality over time. These variations can be influenced by natural processes, anthropogenic activities, and land use changes (Mitsch & Gosselink, 2015). In this section, we will examine the temporal variations in

physico-chemical water parameters, discuss the factors contributing to these variations, and review studies investigating long-term trends in water quality parameters in wetlands.

Several studies have investigated the temporal variations in physico-chemical water parameters within wetlands. For example, a study by Reddy & DeLaune (2008) examined the seasonal and annual variations in water quality parameters, such as dissolved oxygen, pH, temperature, conductivity, and nutrients, in wetlands. They found that these parameters exhibited significant temporal variations, which were influenced by factors such as hydrology, vegetation, and land use changes.

Factors contributing to temporal variations in physico-chemical water parameters can be both natural and anthropogenic. Natural factors include seasonal changes in temperature, precipitation, and evapotranspiration, which can affect the hydrology and nutrient cycling within wetlands (Mitsch & Gosselink, 2015). Anthropogenic factors include land use changes, such as urbanization, agriculture, and industrial activities, which can lead to increased nutrient inputs, sedimentation, and pollution in wetlands (Zedler & Kercher, 2005).

Several studies have investigated the association between land use changes and temporal variations in water quality parameters in wetlands. For instance, a study by Bruland & Richardson (2005) found that urbanization and agricultural activities led to increased nutrient inputs and sedimentation in wetlands, resulting in significant changes in water quality parameters over time. Similarly, a study by Craft (2016) reported that land use changes, such as deforestation and agricultural expansion,

resulted in increased nutrient loading and altered hydrology in wetlands, leading to temporal variations in water quality parameters.

Long-term trends in water quality parameters in wetlands have also been investigated in various studies. For example, a study by Houlihan & Findlay (2004) analyzed long-term trends in water quality parameters in North American wetlands and found that nutrient concentrations, such as nitrogen and phosphorus, had increased over time due to anthropogenic activities. Another study by Verhoeven et al. (2006) reported that long-term trends in water quality parameters in European wetlands were influenced by factors such as climate change, land use changes, and nutrient inputs from agricultural activities.

A study in Nigeria showed that effluent discharge from the investigated medium-scale fish farm had a significant negative impact on the water quality of the receiving Odo-Owa stream and the indicator parameters comprised of ammonia, color and alkalinity. Additionally, Seasonal variations across the water stretch showed that the mean (\pm SE) concentrations of TDS, turbidity, PO_4^{3-} , Mn^{2+} , Fe^{2+} and Hg^{2+} were significantly higher ($P \leq 0.05$) in the rainy season than in the dry season (Adimalla et al., 2020).

2.4 Conclusion

The literature review has revealed significant gaps in the understanding of land use impacts on spatial and temporal water quality variations within the Kinawataka wetland in Uganda. While several studies have examined the effects of land use changes on wetland ecosystems globally (Zedler & Kercher, 2005; Verhoeven & Setter, 2010).

Firstly, while there is a significant body of research on the impacts of land use on water quality in general (e.g., Allan, 2004; Sliva & Debrewer, 2005); there is a dearth of studies specifically focusing on the Kinawataka wetland. This gap in the literature underscores the need for localized studies that can provide insights into the unique characteristics and challenges of this particular wetland. Secondly, the literature review has shown that most studies have focused on either spatial or temporal variations in water quality, but not both (e.g., Allan, 2004; Sliva & Debrewer, 2005). This gap suggests a need for more comprehensive studies that can provide a more holistic understanding of water quality variations in the Kinawataka wetland. Thirdly, while there are studies that have mapped out land uses in various wetlands (e.g., Verhoeven & Meuleman, 1999); there is a lack of such studies for the Kinawataka wetland. This gap highlights the need for detailed land use mapping in this wetland to better understand its current state and how it has changed over time.

The proposed study aims to address these gaps by mapping out the different land uses within the Kinawataka wetland over the past 10 years, assessing the spatial and temporal variations in the physico-chemical water parameters and nutrient concentrations within the wetland; While some studies have examined water quality in Ugandan wetlands (Kansiime & Nalubega, 1999; Ntale & Gan, 2003), they have not focused on the spatial and temporal variations within the Kinawataka wetland specifically. This research will contribute to the existing body of knowledge by providing a comprehensive understanding of the impacts of land use on water quality in the Kinawataka wetland, which can inform future conservation and management efforts.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

In this chapter, the methods, procedures and materials that were used in the study for data collection are presented. Additionally, the sampling site selection and elaboration concerning water sample collection, handling and data analysis methods are discussed.

3.1 Area of study

This study was conducted along the Kinawataka wetland and its tributaries in Naguru Hill, Ntinda, Kyambogo, Banda, Mbuya, Mutungo and Butabika that drain into Lake Victoria. The wetland is located in Nakawa division of Kampala District and Kira town council of Wakiso district. It cuts across Nakawa, Naguru, Ntinda, Kyambogo, Kireka, Banda, Nambole, Mbuya, Mutungo and Biina. It covers an area of approximately 1.5 sq.km. Its geographical co-ordinates are 32° 37' E and 0° 20' N. The layout of the study area and the sample collection sites are shown in Fig. 1. Currently the study site is a key flood control area as it retains and filters industrial and domestic effluents from surrounding areas before releasing it into Lake Victoria thus its vital both ecologically and social economically.

The study site is dominated by key wetland aquatic plants such as *Cyperus papyrus*, *Mischanthus vaolaceum*, *Typha latifolia*, *Phragmites mauritianus*, *Vossia* species and *Phoenix reclinata*. The edges are transitional areas between terrestrial and aquatic systems. The area is also a habitat of small animals and many birds including the crested crane, Ibis, White egrets and Egyptian ducks. In addition, the area is such a

crucial breeding site for fish in Lake Victoria. However, the lower part of Kinawataka wetland is heavily degraded by the fast-expanding cultivation activities leading to conversion of the wetland to gardens of yams, eucalyptus, sugar cane, maize, sweet potatoes and bananas. The area is blessed with four streams that is Vubyabirenge stream, Kinawataka stream, Fuwengombe stream and Wamalenge stream. Within the area, there exists Ntinda industrial area that reclaims a great portion of the wetland.

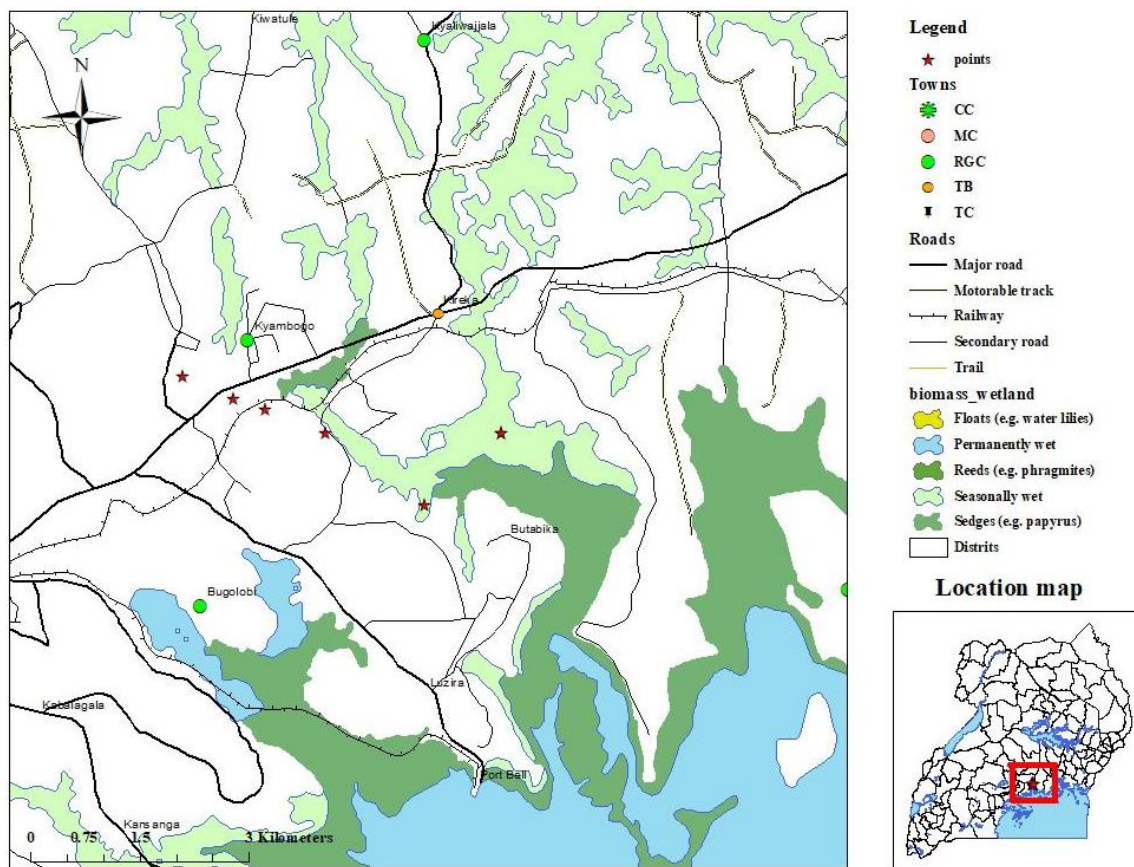


Figure 2: Map of Kinawataka wetland showing the effluent water sample collection sites

3.2 Study design

The study undertook a qualitative and quantitative research approach in that experimental, survey and observational methods were employed in data collection. It involving sampling of effluents from central areas where the discharge from the industries flow towards Kinawataka wetland. Specifically, this was ascended by assessment of spatial physico-chemical properties (pH, Electrical Conductivity, Total alkalinity, Total hardness, Biological Oxygen Demand and Chemical Oxygen Demand) of water from six sites on streams along Kinawataka wetland. In addition, the study also capitalised on understanding the concentration of heavy metals along the six purposively selected sites on streams along Kinawataka wetland. The study involved both quantitative *in-situ* and laboratory analysis of the different site-representative water samples from Kinawataka wetland. It also involved assessing the level of nutrient concentrations in water collected at six different sites along the wetland. This aided to fully understand how the presumed increased deposition of industrial waste from Kinawataka surrounding industrial establishments affect the quality of its waters and living components. This enabled understanding the level of pollution in Kinawataka wetland and its related impacts, something that might inform its better management and conservation.

3.3 Sampling techniques

The study site was clustered into six points depending on the intensity of effluent discharge from the surrounding industries **Table 1**. The effluent samples were collected from selected and accessible points preferably where bridges are present and the flow rate was estimated using the float method (Hilgersom and Luxemburg, 2012).

The sample points were purposively selected depending on the degree of effluent discharge at that particular point from the surrounding industries.

Table 1: Characteristics of studied sites along Kinawataka wetland

Station	Code	Geographical Coordinates	Characteristics/ Pollution sources	Reason for site selection
Kinawataka upstream (Mutungo-Kasokoso road)	Site 1	0.2005°N 32.3804°E	It's at Kayak's garden Bridge, Car wash, settlement, road side market	Drainage point to Kinawataka wetland
Kinawataka downstream (Kasokoso)	Site 2	0.1941°N 32.3943°E	Kasokoso bridge Road construction	Easy accessibility to the wetland
Kinawataka stream at Kito bridge (before wetland)	Site 3	0.1935°N 32.3943°E	Kito/Kasokoso bridge boarder, Wetland vs slum zone	Point upstream the wetland with heavy effluent discharge
Kyambogo stream at Jinja road (upstream)	Site 4	0.2019°N 32.3735°E	Stream at Factory close bridge, Genetex factory for tanks,	Point within the wetland with heavy effluent

			Britania	discharge
Ntinda stream at Factory road 2	Site 5	0.2020°N 32.3713°E	Car bonds, Oxygen UG ltd. Where oxygen is manufactured	It's the lower side of the wetland towards kinawataka
Ntinda stream at Ntinda-stretcher road 1	Site 6	0.2032°N 32.3658°E	Crest foam mattress, Kampala phamaceticals, shell	Industrial area on ntinda road and it's a discharge point for the industries

3.4 Data collection

3.4.1 Objective One: Land Use Changes

Data Acquisition

To conduct this study, quantitative data was used. Primary data was collected through ground trothing (obtaining the coordinates) and secondary data was got from both published and unpublished documents. Based on the results got, a number of data sets were obtained and used for the implementation of the study. **Error! Reference source not found.** shows all the collected spatial data sets, their description and source.

Table 2: Summary of the spatial datasets

No	Data	Description
----	------	-------------

1.	Landsat Imagery (Landsat 5 TM and Landsat 8 OLI)	These were acquired from the USGS for years of 2010, 2015 and 2020
2.	Administrative Boundaries	This was obtained from the districts map by the UBOS of 2019
4.	Rivers	This was obtained from the UBOS of 2008

Land Use Land Cover (LULC) Mapping

A series of three cloud free Landsat Imagery (2010, 2015 and 2020) path/Row of 171/060 and 171/060 were accessed through the open source of United States Geological Survey (USGS) with a spatial resolution of 30m. The spatial analysis was done using ARCMAP 10.5 software as shown in **Error! Reference source not found..**

Table 3: Showing the Landsat imagery that were selected and corresponding sensors used

No.	Type of Data/sensor	Scale/Resolution	Path/Row	Date
1	Landsat 5(TM)	30m	171/060	27/01/2010
2	Landsat 8 OLI	30m	171/060	14/01/2015
3	Landsat 8 OLI	30m	171/060	14/01/2020

Data Pre-Processing

These involved operations done prior to processing and analysis so as to enhance image quality. The images were corrected for atmospheric correction using dark object subtraction like path radiance, scattering and sky irradiance. The satellite images were stacked into different bands to produce different colour composite. Image sub setting was carried out to extract the area of interest. Different image

enhancement techniques namely; PCA, NDVI and band composites were used to improve their visual interpretation for identification of different land cover classes.

Image Classification

The Landsat images were visually interpreted and seven land cover classes were identified in the study area. These include; Built-up, Grasslands, Agricultural Land, Forested areas and Papyrus. To map the extents of these classes, supervised classification based on maximum likelihood (MLA) was used. The supervised method permits selection of pixels (training areas) that represent land use features. Perception of the training areas was based on visual interpretation which takes care of all kinds of information like size of object, shape of object, tone, colour, texture, pattern and association of various spectral covers. The training sites were digitized and each class was assigned to a different colour for easy differentiation. It also helped in calculating the distance from each feature vector to the class means. The class variability was taken care of by adding a vector, which is a function of the variance- covariance matrix of that class as in equation put by Marther, (1987) as shown in equation (i)

Equation i

$$D_i(X) = \ln|V_i| + (X - M_i)^T V_i^{-1} (X - M_i) \dots \dots \dots (4.1)$$

$D_i(X)$ = distance between pixel vector X and class mean based on probabilities; X = pixel vector X ; M_i = mean vector of the class considered; V_i = the variance-covariance matrix of the class considered; V^{-1} = the inverse of V_i ; $|V_i|$ = determinant of the

variance-covariance matrix; $(X-M_i)$ = the distance towards a class mean; and $(X-M_i)^T$ = the transposition of $(X-M_i)$.

During classification, the measurement vector was assigned to the class in which it had the highest probability of membership. It considered the mean and covariance of training set as basic marks for classification.

Accuracy Assessment

Accuracy assessment was performed on the classified images using ground truth data that was acquired using Google earth images and data from National Forestry Authority. The user's accuracy or reliability is the probability that a pixel classified on the map actually represent that category on the ground (Jensen, 2005). The ground truth data was obtained by generating reference points that were randomly selected from reference images of the corresponding years. Accuracy assessment was done through generating confusion matrices based on test samples for each land cover map. The Kappa index of agreement was used as the evaluation criteria for the classification. It is a measure of how the classification results compare to values assigned by chance. The statistic k (kappa) estimates the difference between the observed agreement of two images and the agreement that might be attained solely by chance matching of the two images.

Kappa analysis is a discrete multivariate technique used in accuracy assessment and it can be computed as;

Equation ii

$$k = \frac{\text{Observed} - \text{expected}}{1 - \text{expected}}$$

Where;

“Observed” represents the value for “percentage correct”

“Expected” estimates the effect of chance agreement upon the observed percentage correct.

The Kappa value ranges between 0 and 1. If kappa coefficient equals to 0, there is no agreement between the classified image and the reference image. If kappa coefficient equals to 1, then the classified image and the ground truth image are totally identical (in perfect agreement). So, the higher the kappa coefficient, the more accurate the classification is. If the test samples are in perfect agreement, then values for the Kappa index (Kap) are equivalent to 1.

Land use land cover activities and their co-related land use land cover classes

The land use land cover activities within Kinawataka wetland as observed on ground were as follows (Table 4):

Table 4: The observed land use and cover activities and their assigned LULC classes

S/N	LULC - Activity	LULC - Class
1	Artificial surfaces: urban, commercial structures, settlements, concrete surfaces, bare soil, fields, bare rocks and quarries.	Built-up

2	Graminoids, herbaceous areas and lawns	Grasslands
3	Shrub and herbaceous crops on small, medium and large fields.	Agricultural Land
4	Open high and closed multi-storied trees, and broad-leaved trees.	Forested Areas
5	Permanently wet graminoids and herbaceous areas with papyrus	Papyrus

3.4.2 Objective Two

Water samples were collected from the predetermined sampling points across the Kinawataka wetland. Each sample was gathered using sterilized containers to prevent any form of contamination. The team was careful to document the date, time, and precise location of each sample collection, ensuring a comprehensive record of the sampling process. The physico-chemical parameters of the water samples, including temperature, pH, electrical conductivity, dissolved oxygen, turbidity, and total dissolved solids, were measured on-site immediately after sample collection. This was done using portable water testing kits or probes, ensuring the accuracy of the readings by preventing any changes that could occur due to storage. For assessment of nutrient concentrations, the water samples were carefully preserved and transported to a laboratory. Nutrients such as nitrogen, phosphorus, and potassium were measured using laboratory methods as shown in **Table 5**. All data, including the values of the physico-chemical parameters and nutrient concentrations, were accurately recorded and organized in a database, providing a comprehensive dataset for further analysis. The water quality parameters to be tested were selected basing

on the current land use and anthropogenic activities for example agriculture, human settlement, industrialization, fishing among others along Kinawataka wetland and the streams that feed into Kinawataka stream .

Table 5: Data collection methods and equipment for the different tested parameters

Parameter	Equipment used	Methods
pH and electrical conductivity	Integrated Multi-parameter Horiba (Model U-52G, Japan)	In-situ water analysis
Total Hardness	Test-meter	Laboratory analysis
COD	Spectrophotometer, digestion tube	Closed reflux calorimetry method
BOD	Oxygen-sensitive polarography electrodes, membrane, membrane, selective	4500-O G. Membrane-Electrode Method
Nutrients (Cl, SO ₄ , NO ₂ , PO ₄)	A discrete analyzer, Gallery Plus	Discrete photometric test
Nitrates	UV-visible spectrophotometer (UV1800 shimadzu model)	Spectrophotometry

3.4.3 Objective Three

The study used the predetermined sampling points in the sites in **Table 1** within the wetland. Effluents from these sites were sampled thrice for after every two weeks at the point of discharge into the environment. This longitudinal study design allowed for monitoring changes in water quality over time. The frequency of sampling varied, with options including weekly, monthly, seasonally, or annually. The goal was to capture a comprehensive picture of temporal variations in the wetland's water quality. Sample collection was done from July to September during a dry season (Defined as months when no rain fall event experienced) and October to December during a wet season (Defined as months during which rainfall event was experienced) and this took a total period of 6 months. During each sampling session, water samples were collected and immediately tested for various physico-chemical parameters. These parameters included temperature, pH, electrical conductivity, dissolved oxygen, turbidity, and total dissolved solids. The testing was conducted on-site using portable water testing kits. In addition to these on-site tests, the water samples were also transported to a laboratory for nutrient analysis. This analysis focused on the concentrations of nitrogen, phosphorus, and potassium. All data, including the date, time, and location of each sample collection, as well as the values of the physico-chemical parameters and nutrient concentrations, were meticulously recorded and organized in a database. This data was then subjected to time series analysis techniques to identify trends and patterns in water quality over time. The results of this research provided a detailed understanding of how water quality in the

Kinawataka wetland changes over time, and helped identify the factors driving these changes.

3.5 Quality control

Water sampling was done in pre-washed and dried plastic beakers for in-situ parameters. Water samples for laboratory analysis were collected in sterilized screw capped plastic bottles. To avoid sample mix-ups, codes corresponding to the site were generated and used to label sample bottles. All samples were monitored and traced by these codes during transportation, storage and laboratory analysis. A cold chain was maintained for samples for nutrient analysis to limit sample deterioration.

All reagents used were of high analytical purity. Equipment used were calibrated prior to use. Samples were analyzed in triplicate to improve on the precision of results. All laboratory analytical procedures followed internationally accepted methods and effort was invested to ensure required accuracy. Analysis of reference materials with known concentrations was done before analysis of the samples for the given parameters to ensure accuracy and reliability of the result was generated.

For the methods that used calibration curve, standard solutions with known concentrations also known as analytical quality control (AQC) were measured every time the measurement of the samples was done for the respective parameters. The Ideal calibration curve was most useful with in the calibrated range and the regression coefficient of 0.99 and above was considered.

Method blanks and field blanks were analyzed every time the analysis was done on the samples. The method blank was deionized and reagent free and was shipped with the

bottles to the sampling site and processed in the same way as the samples that was collected from the site and returned to the analyzed from the National Water Quality Reference Laboratory for analysis together with the samples. This ruled out cross contamination of the samples during the shipment of the samples to the laboratory. Samples were collected in duplicate and analyzed to ensure accuracy and precision of the method and instrument used.

3.6 Data analysis

In this study, analysis was done to ascertain whether there was a significant difference in the values of physico-chemical parameters, heavy metals, and nutrients in effluent water samples obtained from six sites along Kinawataka wetland. Ms Excel and SPSS version 29 was used to perform descriptive statistics of results from which the following was obtained; the range of values, mean and standard deviation for all results (Physico-chemical, heavy metals, and nutrients) obtained from all study sites. Analysis of variance (ANOVA) was used to determine the significant difference of concentrations for various parameters. Differences in concentration levels obtained for a given parameter along sampling sites were considered significant if calculated P-values were < 0.05 . Turkey's post hoc test was used to determine the difference between given parameters at two selected study sites. Tables were generated for comparison of results of levels of physico-chemical parameters, heavy metals, and nutrients of effluent water samples collected from different study sites.

3.7 Methodological constraints

The following methodological constraints were encountered;

- Timeliness; Given that collection of samples was involved, the study most likely to took longer.
- Weather challenges; changes in weather affected collection of samples; especially during rainy seasons.
- Laboratory and field equipment; All the equipment to be used in testing the samples collected were hired. The costs involved stretched the research. Further, there was a likelihood of contamination of samples. However, the researcher Undertook keen precautions.

3.8 Ethical considerations

The entire research process was conducted with due respect to ethical considerations particularly keeping informant's identities confidential. The researcher shall sought consent from all industries before collection of water samples at the discharge points. The proposal shall be submitted to the UCU Research Ethics Committee. (REC).

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

In this chapter, all results that were obtained from land use change and water quality analysis are presented. Tables and graphs to show the variations of the parameters were used. Discussion of results were made for every objective

4.1 Spatial and temporal variation in Land uses within Kinawataka wetland from 2010 to 2020

The results in Figure give an overview of land use changes in Kinawataka wetland from 2010 to 2020, across four categories: built-up areas, agricultural land, forested areas, and papyrus coverage. Built-up areas witnessed a significant expansion, with an exponential increase from 203.59 hectares (ha) in 2010 to 350.10 ha in 2015. This rapid growth was followed by a more gradual rise, reaching 400.88 ha by 2020. In contrast, agricultural land experienced a slight contraction initially, decreasing from 121.99 ha in 2010 to 99.02 ha in 2015. However, this trend reversed in the subsequent years, with a steady increase to 155.58 ha by 2020. Forested areas and papyrus coverage, on the other hand, both demonstrated a consistent decline over the study period. Forested areas reduced from 169.21 ha to 88.1 ha, while papyrus coverage decreased from 471.97 ha to 418.14 ha. These trends highlight the dynamic nature of land use over time, influenced by various socio-economic and environmental factors. This is evident as shown in the Figure below.

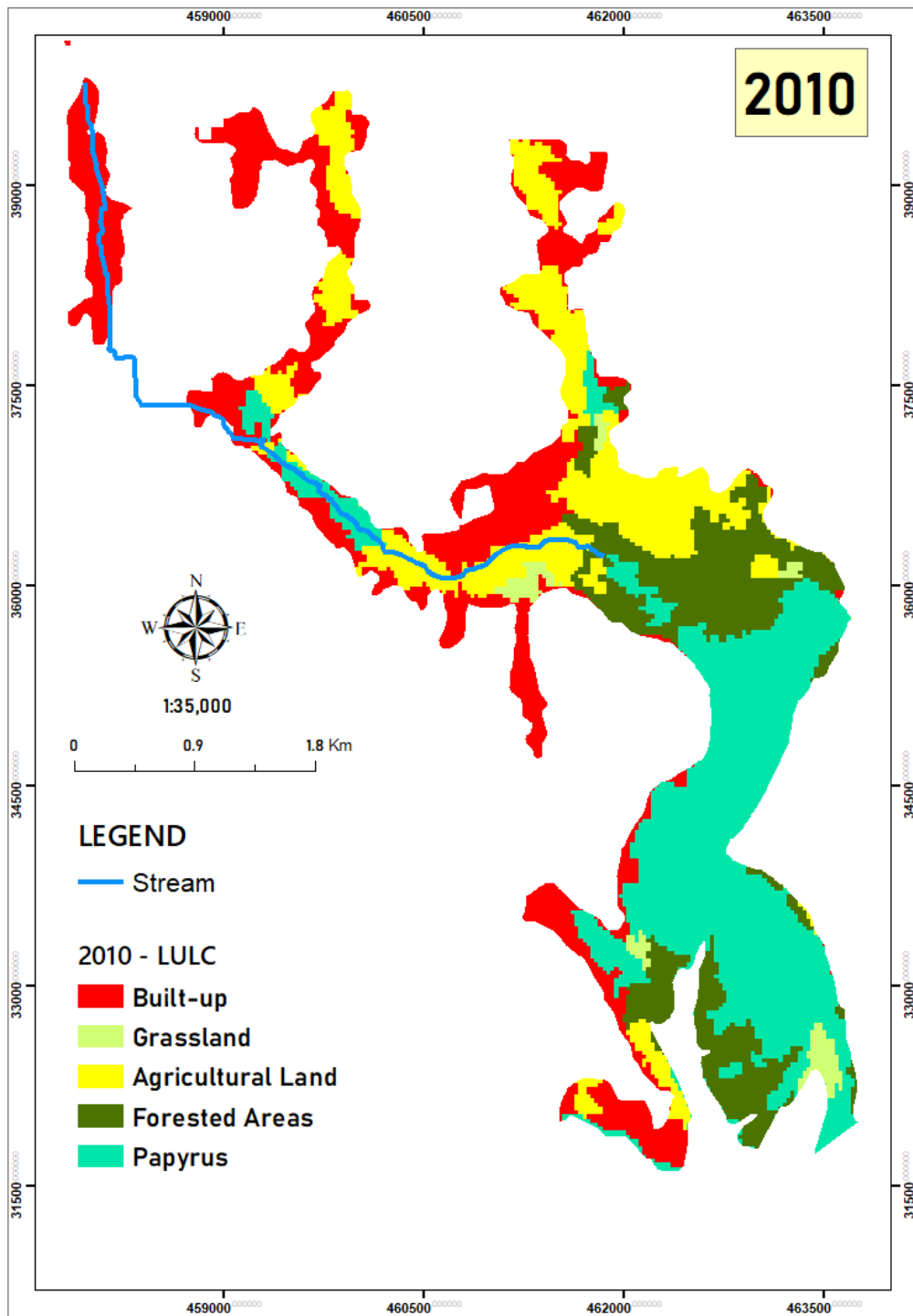


Figure 3a: Maps showing the land use activities within Kinawataka wetland in 2010

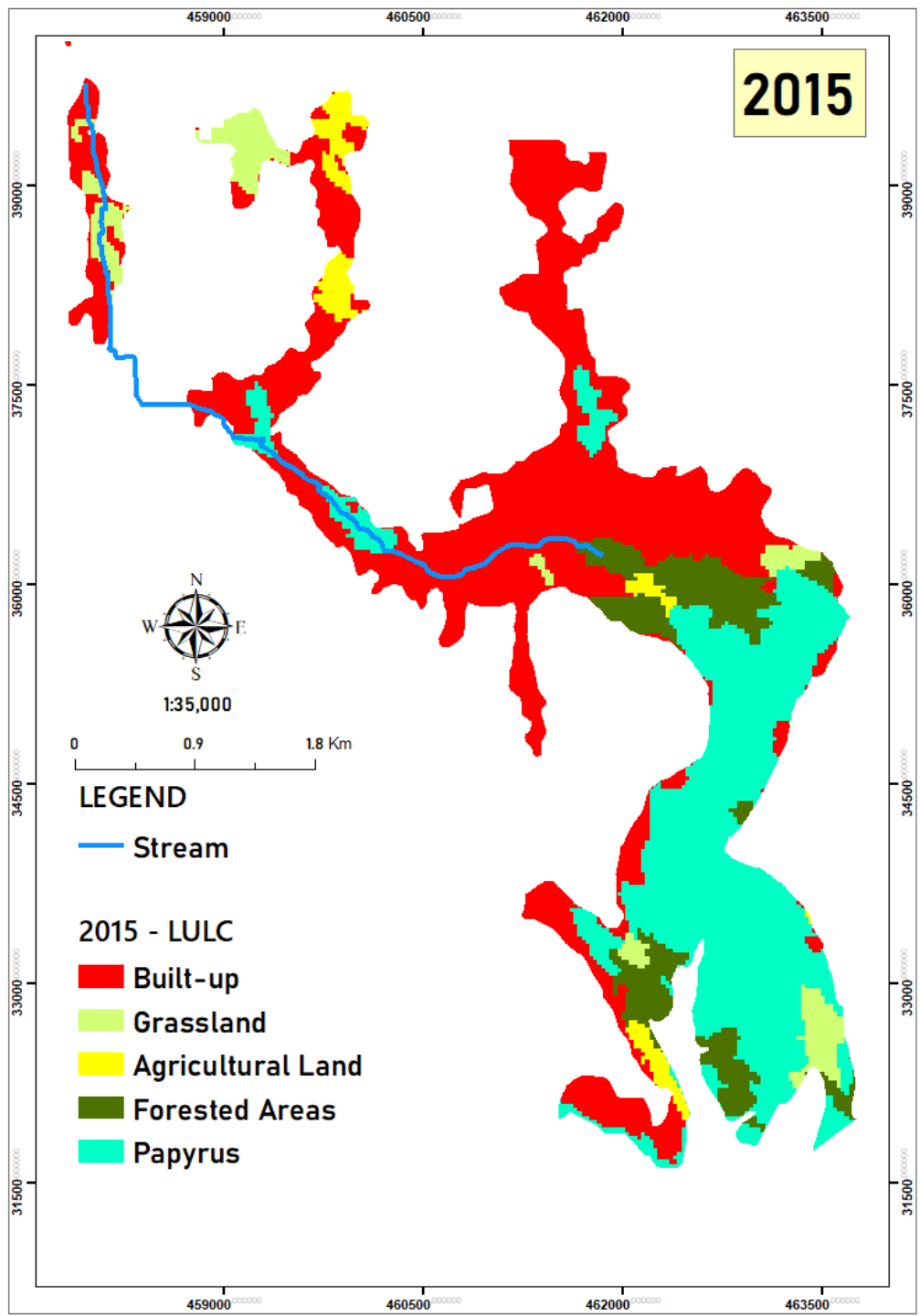


Figure 3b: Maps showing the land use activities within Kinawataka wetland in 2015

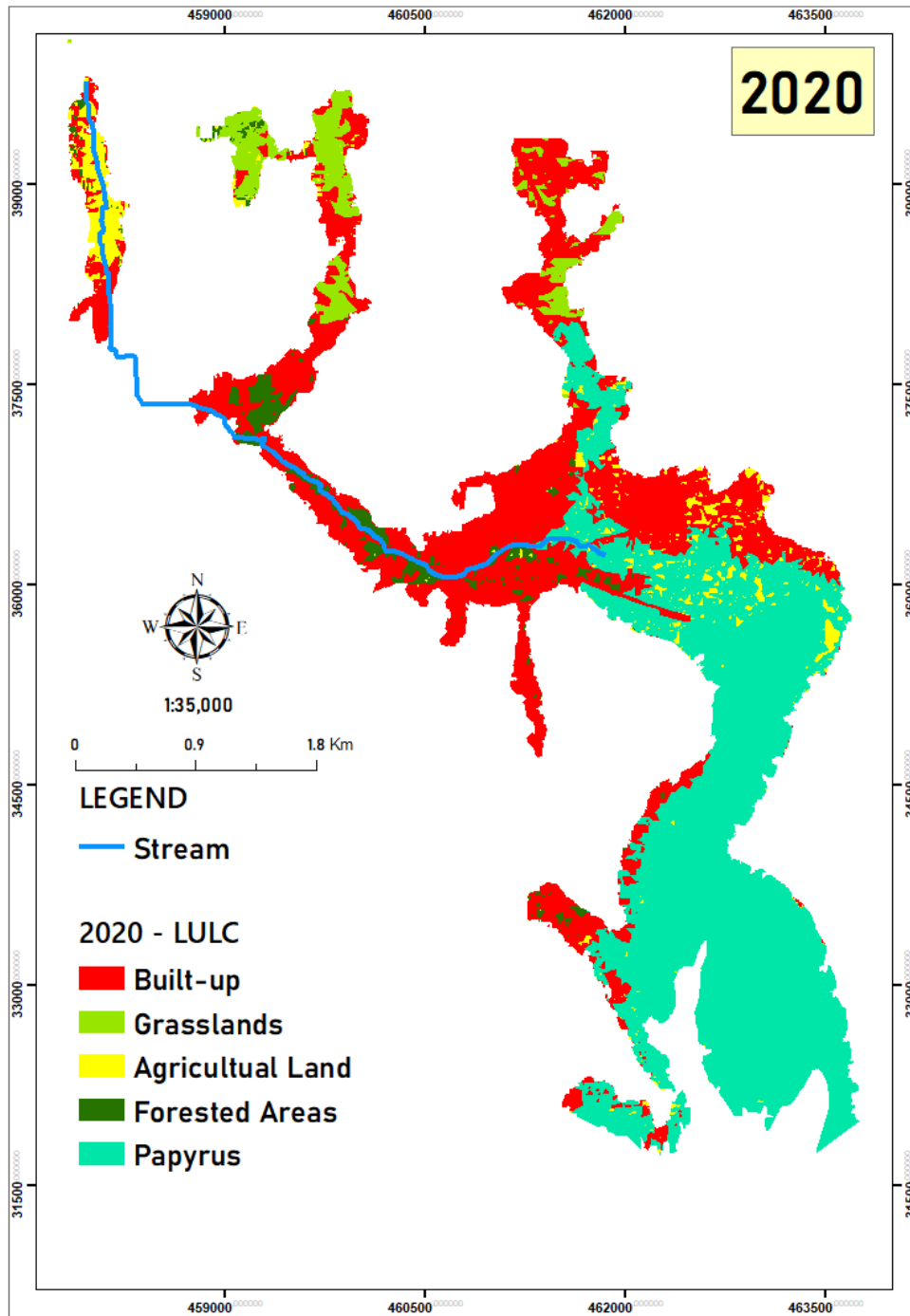


Figure 3c: Maps showing the land use activities within Kinawataka wetland in 2020

The land use maps provide a comprehensive overview of the land use changes in

Kinawataka wetland from 2010 to 2020. The most striking change is the significant expansion of built-up areas, which increased from 203.59 hectares (ha) in 2010 to 400.88 ha by 2020. This rapid urbanization is consistent with the findings of other studies, which have highlighted the increasing pressure on wetlands due to urban expansion (Kakuba, 2021; Namuyaba, 2019).

The contraction and subsequent expansion of agricultural land from 121.99 ha in 2010 to 155.58 ha by 2020 is another notable trend. This could be attributed to the increasing demand for agricultural land to support the growing population, as suggested by Namuyaba (2019).

The consistent decline in forested areas and papyrus coverage over the study period is a cause for concern. Forested areas reduced from 169.21 ha to 88.1 ha, while papyrus coverage decreased from 471.97 ha to 418.14 ha. This trend aligns with the findings of Tumuheire (2017), who noted a similar decline in vegetation cover in Kinawataka wetland. This could be due to the encroachment of human activities, such as agriculture and construction, into these areas (Kakuba, 2021).

In conclusion, the dynamic nature of land use changes in Kinawataka wetland over the past decade is influenced by various socio-economic and environmental factors. These trends underscore the need for effective land use planning and management to ensure the sustainability of this vital ecosystem.

4.2 Spatial variations in the physico-chemical water parameters

Water quality is majorly altered and detected by the kind of effluents from the different land-uses (Arias *et al.*, 2019). This informs the levels of physico-chemical parameters of water as points upstream tend to be of better quality than those

downstream. Water analysis results for samples collected at different spatial sites located along Kinawataka wetland is summarised below (Table 6). Water physicochemical characteristics from samples at different sampling locations had different concentrations. Though other parameters tested such as Electrical conductivity, Total Alkalinity, Total Hardness, Chemical Oxygen Demand, and Biological oxygen demand varied significantly ($P < 0.05$) among sampled sites along Kinawataka wetland, potential hydrogen (pH) never significantly differed ($P = 0.23$) among sites (Table 6). The pH among sites ranged from 6.17 at site 6 to 6.83 at site 3 and 5. Highest EC was registered at site 2 and least at site 6. Site 3 had the highest total alkalinity; whereas site 2 had the highest total hardness as site 5 recorded the least. In addition, BOD was highest at site 5 while least at site 3 as site 5 recorded the highest COD (Table 6)

Table 6: Status physico-chemical water quality parameter along Kinawataka wetland

Study	Mean \pm SD concentration of physiochemical water quality parameter					
Site	pH	EC	T.Alk	T. Hard	BOD	COD
	6.75 \pm	39.33 \pm	110.5 \pm	101.83 \pm	46.67 \pm	80.83 \pm
Site 1	0.62	2.15	5.62	6.59	5.61	6.01
		50.33 \pm	145.5 \pm		34.17 \pm	
Site 2	6.5 \pm 0.67	2.06	5.93	114 \pm 4.81	4.91	61.5 \pm 8.59
	6.83 \pm	46.5 \pm	175.33 \pm	98.67 \pm		40.67 \pm
Site 3	0.72	1.88	5.05	5.16	30 \pm 3.86	6.69
Site 4	6.67 \pm	34.33 \pm	130.33 \pm	84 \pm 6.31	45.83 \pm	130 \pm 9.29

	0.65	2.67	5.50		12.02	
	6.83 ±	34.67 ±	125.17 ±	80.83 ±	66.33 ±	158 ±
Site 5	0.72	3.65	5.37	3.88	7.81	10.91
	6.17 ±	31.17 ±	107.33 ±	77.17 ±		122.83 ±
Site 6	1.03	1.27	7.77	31.00	59.5 ± 7.67	9.92
F-value	1.42	119.35	216.18	13.38	42.36	318.78
P-value	0.23	0.00	0.00	0.00	0.00	0.00

The pH among studied sites was generally acidic ranging from 6.17 at site 6 to 6.83 at site 3 and 5. Such Observed pH levels are relatively higher than those observed by Turinayo, (2017) when investigating the Physico-chemical properties of sugar industry and molasses-based distillery effluent and its effect on water quality of river musamya in Uganda. However, the observed pH ranges were relatively lower at some sites like site 6 than those observed by Famooto and Adeniyi, (2020) where both the stream and effluent discharged point ranged between 6.4 and 7.2 pH units despite them being within such ranges at site 3 and 5 of Kinawataka wetland. At all sites, the observed pH values were above the pH of 6 recommended by the WHO (2017) and the UNBS (2014) standards for drinking water despite being within the EU pH protection limits of 6.0-9.0 for fisheries and aquatic life. On the other hand, the pH levels at all sites were within the NEMA standards for the discharge of effluents into the environment (Fuhrimann *et al.*, 2015).

Adimalla *et al.*, (2020) reported pH as a fundamental property that describes the acidity and alkalinity of water thus pH outside the recommended limits may be an

indicator of toxic ions in water which may cause a nutritional imbalance (El-Sayed *et al.*, 2015). Therefore, water from these studied sites along Kinawataka wetland is capable of causing serious harm to the aquatic life downstream; it also makes it dangerous for direct consumption considering the 6 pH recommended limit by UNBS and WHO. Water pH is one of the most important factors that serve as an index for water pollution. The Uganda's quality requirements for pH has a maximum of 9.5. Such acidic pH levels observed at different sites along Kinawataka wetland depicts high levels of pollution in this wetland and might affect the survival of different fish and other aquatic life species in the wetlands. The high acidity of water can also affect gastrointestinal mucous membranes, provide a bitter taste and cause corrosion of discharge pipes (Nayebare *et al.*, 2020). The acidity of the water could be attributed to organic acid pouring with wastewater and effluents from both settlements and surrounding industries which indicated possible water pollution.

In this study, results showed that Electrical Conductivity (EC) ranged from 31.17 μ s/cm (site 6) - 50.33 μ s/cm (site 2). Thus highest EC was registered at site 2 and least at site 6. EC is a measure of a material's ability to conduct an electric current and higher EC values indicate enrichment of salts in the groundwater (Yu *et al.*, 2020). Wansolo *et al.*, (2018) attributes slightly higher EC values to the effluents discharge with high levels of mineral ions. However, the EC results obtained in this study were below the threshold limit of 2500 μ s/cm set by UNBS (2014) for drinking water. EC levels are highly influenced by the nature of land uses (Daghara *et al.*, 2019) along streams or in wetlands such as agricultural activities and wastewater discharged from industries and cities. However, Amalraj *et al.*, (2018) also attributed high EC levels to

high salinity and high mineral percentage, which are generally due to geochemical process like ion exchange, evaporation, silicate weathering and solubilization process taking place within the aquifers. Several studies have recorded different trends of EC results (Nyenje *et al.*, 2013; Barakat *et al.*, 2018; Kulabako *et al.*, 2007; Lutterodt *et al.*, 2014; Okot-Okumu *et al.*, 2015).

These results clearly indicate that water at site 2 were considerably ionized and had the highest concentration of ions due to excess dissolved solids. The values were however lower than those recorded in some streams of Nakawa-Ntinda industrial area (Walakira and Okot-okumu, 2011; Wanasolo *et al.*, 2018). However, a study in Adama Town, Ethiopia by Karuppanan *et al.*, (2019) linked high EC values in streams to the agricultural activities and waste water discharged from industries which can be true as water from site 2 that was characterised by effluent discharge from the surrounding industries had the highest EC levels. According to Amalraj *et al.*, (2018) high EC values might also be attributed to high salinity and high mineral percentage in water as a result of geo-chemical process and solubilization process within the wetland. Further, variation in EC values among sites could be attributed to different land uses, varying locations and the state of conservation of the vegetation around the site (Daghara *et al.*, 2019).

Total hardness of water at all studied sites along Kinawataka wetland was below the NEMA quality standards of 300-600mg/l. According to World Health Organization, a standard in this parameter is not established because the ions are not of health concern at levels found in drinking-water (WHO, 2011). Hardness is the sum of the

calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per liter (mg/L). Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations.

Study results showed that BOD range was 30 mg/l (site 3) - 66.33mg/l (site 5) thus being highest at site 5. The NEMA quality standards of BOD within the national standards of Uganda indicate that the highest portable quantities of BOD are below 50.0mg/l which in this case has been exceeded by site 6 and 5 whereas other sites such as 1&4 are within close range of the same. Compared to the USEPA Clean Water Act (USEPA, 2012) the permissible levels of BOD may go as low as 5mg/l. BOD is a significant representative of the on-going anthropogenic activities; A study carried out by Iloms *et al.* (2020) within the Vaal river of South Africa for instance notes that other physiochemical qualities like turbidity, BOD, PH, COD had been heavily tampered with owing to the fact many different industries in the area processed different products, and therefore a variety of raw products were used leading to the availability of different pollutants which consequently meant that the rivers could be affected in ways that could only be predicted through best guesses. Higher BOD levels which is a very good indicator of organic pollution are also able to explain the presence of the different agricultural activities that are ongoing on these different points. Moreover, this can further explain the increase in COD levels at the sites with higher BOD levels. The BOD levels correlate with the COD levels simply because these are levels of oxygen that are required to break down organic matter and their increase shows presence of high amounts of organic matter. Oxygen demand is a measure of the number of oxidizable substances in a water sample that can lower DO

concentrations. The study results at site 5 and 6 are in line with the findings of Jang & An, (2016) who found high levels of BOD and COD. This suggest that Kinawataka wetland is in critical position to maintain the aquatic life and aesthetic quality of wetlands.

The COD levels from study sites along Kinawataka wetland ranged from 40.67 (site 3) - 158 (site 5). In-fact, COD levels in the water samples from all sites were above the WHO standard of 10 mg/L for drinking water for the stream. These observed COD levels were similar to those of Turinayo, (2017) and those reported by Walakira and Okot-okumu, (2011) while assessing the Impact of Industrial Effluents on Water Quality of Streams in Nakawa-Ntinda, Uganda. The higher COD levels at site 5 could be attributed to Industrial effluent discharge containing organic matter into the stream (Ndugga, 2021). Similarly, Ndugga also reported a drop in COD downstream as the case is at site 6 which was attribute to a reduction in industrial impact and role of swamp vegetation (wetland area). Matshakeni (2016) reported COD as a measure of the amount of oxygen required to oxidize all organic matter thus it's increased concentration results into higher concentrations of organic matter and nutrients. High COD as observed at site 5 indicates presence of all forms of organic matter, both biodegradable and no biodegradable and hence the degree of pollution in waters (Islum *et al.*, 2019). The COD peak at site 5 can be attributed build-up of organic and inorganic pollution loads from untreated industry effluent discharges similar to other reported cases of industrial discharges (Kayima *et al.*, 2008; Oladele *et al.*, 2011).

4.2.2 Spatial variations in nutrient concentrations in water along Kinawataka wetland

The nutrients concentrations (Chloride (Cl), Sulphate (SO₄), Nitrite (NO₂), Nitrate (NO₃), Ammonium (NH₄) and Phosphate (PO₄) in water raised at different sampling sites along Kinawataka wetland. The results are presented in the subsequent sections.

- **Chloride**

Chloride concentration did vary significantly along Kinawataka wetland (P=0.000). Lowest chloride concentration of 28 mg/L was recorded at site 4 followed by site 5, site 6 and site 1. Site 2, chloride concentration was highest (44 mg/L) at site 2 then decreased through site 3 to site 6 (Figure 4). Following ANOVA, Turkey positive analysis indicated that the chlorine concentration in water along Kinawataka wetland followed trend of Site 2 > Site 3 > Site 1 > Site 5 = Site 6 > site 4

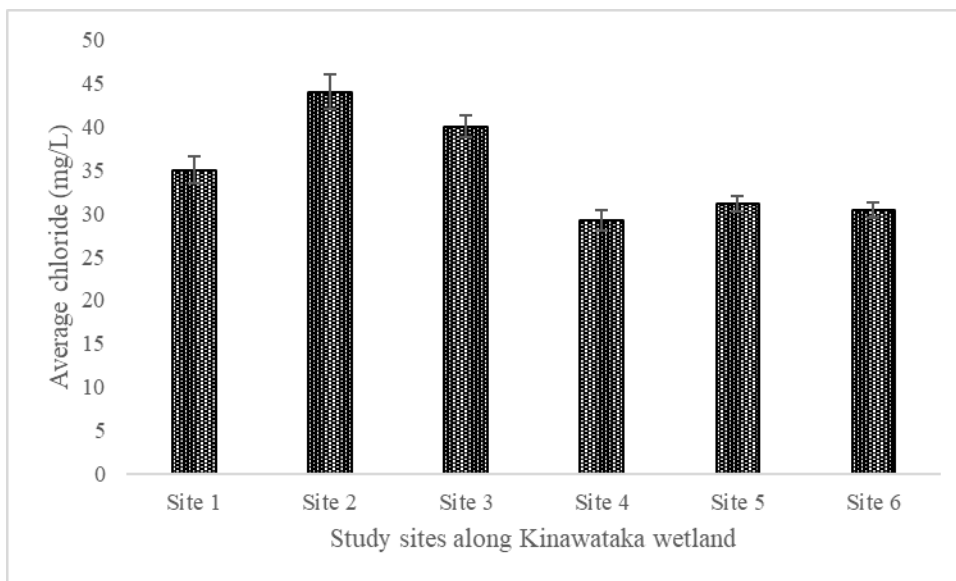


Figure 3: Chloride concentration in water along Kinawataka wetland

chloride concentration did vary significantly along Kinawataka wetland with lowest chloride concentration of 28 mg/L at site 4 followed by site 5 (30 mg/L), site 6 (29 mg/L) and site 1 (34 mg/L). Chloride concentration was highest (44 mg/L) at site 2 then decreased through site 3 (40 mg/L) to site 6 (30mg/L). Fortunately, all chloride levels were below Uganda’s Quality requirements of 250 mg/l. This study is in line with Sonowal & Baruah (2017) findings of high chloride in the wetlands in India. The high levels of chloride at particular sites in this study imply that Kinawataka wetland is heavily pollution.

- **Sulphate**

Sulphate concentrations significantly varied along the stream ($P < 0.00$). the highest sulphate concentration of 15 mg/L was recorded at site 5 and site 6 and the least of 8 mg/L was recorded at site 2 (Figure 5). Following ANOVA, Turkey positive analysis indicated that the chlorine concentration in water along Kinawataka wetland followed trend of Site 6 = Site 5 > Site 4 > Site 1 > Site 3 = Site 1

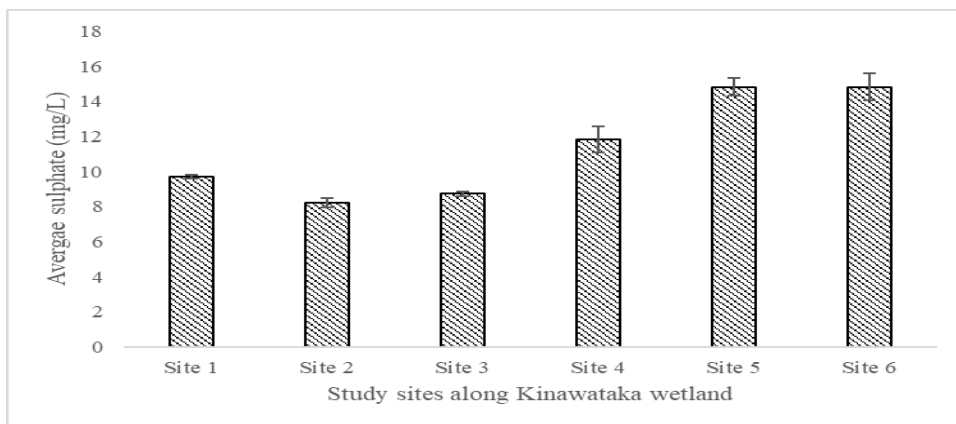


Figure 4: Sulphate concentration in water along Kinawataka wetland

Sulphate concentrations significantly varied along the stream ($P < 0.00$). Highest sulphate concentration of 15 mg/L was recorded at site 5 and site 6 and the least of 8 mg/L was recorded at site 2. These results indicate that there is an increasing trend of sulphate ions in the wetland from the influent (site 2) to the effluent (sites 5&6). The increasing concentration of sulphate in the water environment not only threatens human health and ecological balance (Wang & Zhang, 2019), but may also affect carbonate weathering, erosion processes, and global carbon cycle evolution (Liu *et al.*, 2017). Previous studies have shown that, when the human body take in excessive sulphate, it will cause several diseases, e.g., diarrhea, dehydration, and gastrointestinal disorders, etc. (Wang & Zhang, 2019). Sulphate in the water environment may be transformed into the toxic substances under certain conditions, resulting in the loss of essential metal elements in aquatic plants and changes in the original eco-hydrological function. Soucek *et al.* have shown that high concentrations of sulphate will cause the death of freshwater invertebrates (Soucek & Kennedy, 2005). The highly sulphate concentration of water environment not only influences human life, but also places some constraints on industrial water and irrigation water. Therefore, the WHO limits the sulphate concentration less than 250 mg/L (USEPA, 2012).

Identifying the sources of sulphate contamination accurately is the premise of controlling the sulphate pollution in the water environment. Dissolved sulphate in water environment is primarily derived from both natural and anthropogenic sources (Soucek & Kennedy, 2005). Natural sources include dissolution of sulphate minerals (e.g., gypsum), oxidation of sulphide minerals (e.g., pyrite), precipitation and

volcanic activity, etc. In this case, there does not exist any volcanic activity around the swamp. This indicates that possible anthropogenic actions have caused the changes along the stream; anthropogenic sources contain sewage infiltration, fertilizers, synthetic detergents, industrial wastewater and mining drainage, and so on. In addition, groundwater over-exploitation will accelerate the sulphate pollution (Wang & Zhang, 2019). Given that the swamp is surrounded by different industries and companies that release waste water, not to talk of agriculture that is ongoing along different shores where the stream flows, anthropogenic activities clearly increase the levels of sulphates in the stream. The diversity of sulphate sources and its effects on the ecological environment are attracting more and more researchers' attention to distinguish the sulphate sources and determine the mechanisms of sulphur and oxygen isotopic variations of SO_4^{2-} in different water and the control factors. Therefore, study on the sources of sulphate in water environment is of great significance to water environment safety.

- **Nitrite**

Nitrite concentration was significantly different ($P = 0.02$) among different water samples collected along Kinawataka wetland. Apart from site 3 and site 6, other sites have nitrite concentrations below 1 mg/L. Indeed, highest nitrite concentration of 7.9 mg/L was recorded at site 3 followed by 3.8 mg /L recorded at site 6 (Figure 6). Following ANOVA, Turkey positive analysis indicated that the nitrite concentration in water along Kinawataka wetland followed trend of Site 3 > Site 6 > Site 1 = Site 2 = Site 4 = Site 5

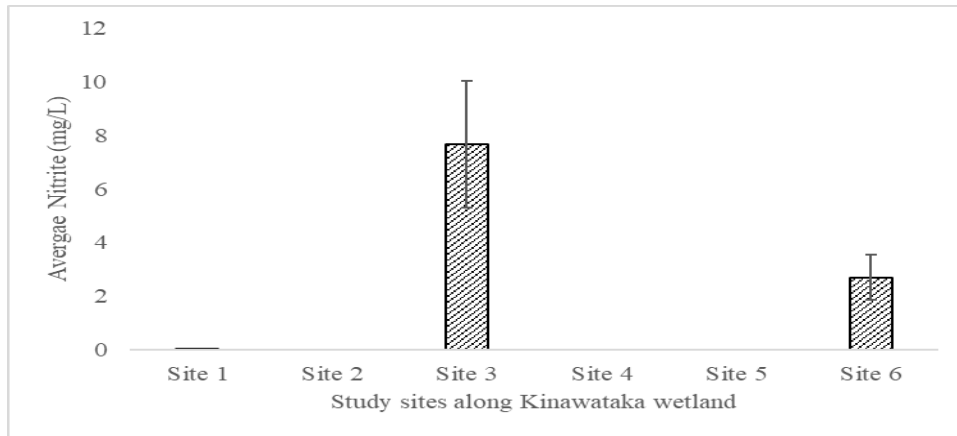


Figure 5: Nitrite concentration in water along Kinawataka wetland

Nitrite concentration was significantly different ($P = 0.02$) among different water samples collected along Kinawataka wetland. Apart from site 3 and site 6, other sites have nitrite concentrations below 1 mg/L. Highest nitrite concentration of 7.9 mg/L was recorded at site 3 followed by 3.8 mg /L recorded at site 6. Nitrites and nitrates (NO_3) are nutrients which when discharged in open water bodies may also cause eutrophication. 3 mg/l as nitrite ion (or 0.9 mg/l as nitrite-nitrogen) is the basic standard of the ion according to the World health Organisation. The standard is derived from Nitrite (NO_2^-) is not usually present in significant concentrations except in a reducing environment, as nitrate is the more stable oxidation state. It can be formed by the microbial reduction of nitrate and in vivo by reduction from ingested nitrate. Nitrite can also be formed chemically in distribution pipes by Nitrosomonas bacteria during stagnation of nitrate-containing and oxygen-poor drinking-water in galvanized steel pipes or if chloramination is used to provide a residual disinfectant (Christellea, Thomasa, Larissaa, & David, 2012, WHO, 2013). In humans, methaemoglobinaemia is a consequence of the reaction of nitrite with haemoglobin in the red blood cells to form methaemoglobin, which binds oxygen tightly and does not

release it, thus blocking oxygen transport. Although most absorbed nitrite is oxidized to nitrate in the blood, residual nitrite can react with haemoglobin. High levels of methaemoglobin (greater than 10%) formation in infants can give rise to cyanosis, referred to as blue-baby syndrome. Although clinically significant methaemoglobinaemia can occur as a result of extremely high nitrate intake in adults and children, the most familiar situation is its occurrence in bottle-fed infants (WHO, 2013). Although drinking-water nitrate may be an important risk factor for methaemoglobinaemia in bottle-fed infants, there is compelling evidence that the risk of methaemoglobinaemia is primarily increased in the presence of simultaneous gastrointestinal infections, which increase endogenous nitrite formation, may increase nitrate reduction to nitrite and may also increase the intake of water in combatting dehydration (WHO, 2013). Cases have been described in which gastrointestinal infection seems to have been the primary cause of methaemoglobinaemia.

- **Ammonium**

Ammonium concentration was significantly different ($P = 0.00$) among different water samples collected along Kinawataka wetland. Apart from site 4, other sites had ammonium concentrations below 1 mg/L. Indeed, highest ammonium concentration of 2.75 mg/L was recorded at site 4 (Figure 7). Following ANOVA, Turkey positive analysis indicated that the nitrite concentration in water along Kinawataka wetland followed trend of Site 4 > Site 1 > Site 6 > Site 2 > Site 3 = site 5

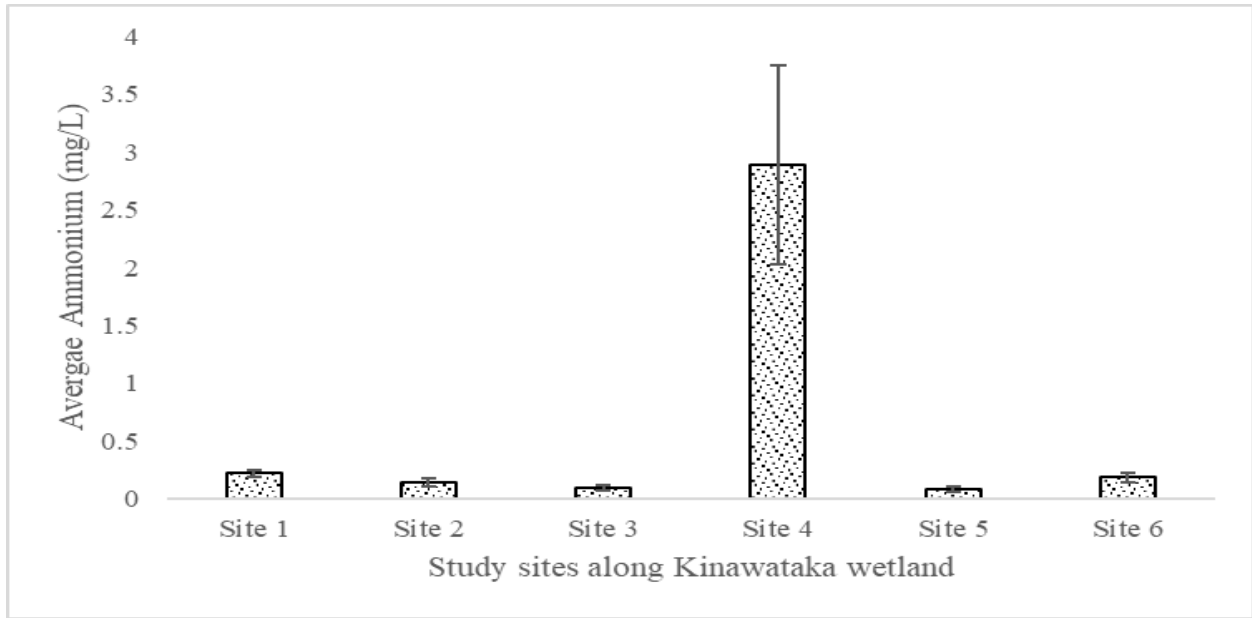


Figure 6: Ammonium concentration in water along Kinawataka wetland

According to the WHO (2013) standard, ammonia in drinking-water is not of immediate health relevance, and therefore no health-based guideline value is proposed. However, ammonia can compromise disinfection efficiency, result in nitrite formation in distribution systems, cause the failure of filters for the removal of manganese and cause taste and odour problems. Ammonium concentration was significantly different ($P = 0.00$) among different water samples collected along Kinawataka wetland. Apart from site 4, other sites had ammonium concentrations below 1 mg/L. Highest ammonium concentration of 2.75 mg/L was recorded at site 4. Ammonia in the environment originates from metabolic, agricultural and industrial processes and from disinfection with chloramine. Natural levels in groundwater and surface water are usually below 0.2 mg/l. Anaerobic groundwaters may contain up to 3 mg/l. Intensive rearing of farm animals can give rise to much higher levels in surface water. Ammonia contamination can also arise from cement mortar pipe

linings. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution. Ammonia is a major component of the metabolism of mammals. Exposure from environmental sources is insignificant in comparison with endogenous synthesis of ammonia. Toxicological effects are observed only at exposures above about 200 mg/kg body weight. The threshold odour concentration of ammonia at alkaline pH is approximately 1.5 mg/l, and a taste threshold of 35 mg/l has been proposed for the ammonium cation.

- **Phosphate**

Phosphate concentration did vary significantly along Kinawataka wetland ($P = 0.000$), with highest concentrations (0.7 mg/L) recorded at site 6 and least (0.2 mg/L) at Site 2 and 4 (Figure 8). Following ANOVA, Turkey post hoc analysis indicated that phosphate concentrations in water along Kinawataka stream followed trend of Site 6 > Site 1 > Site 5 > Site 3 > Site 1 = Site 2.

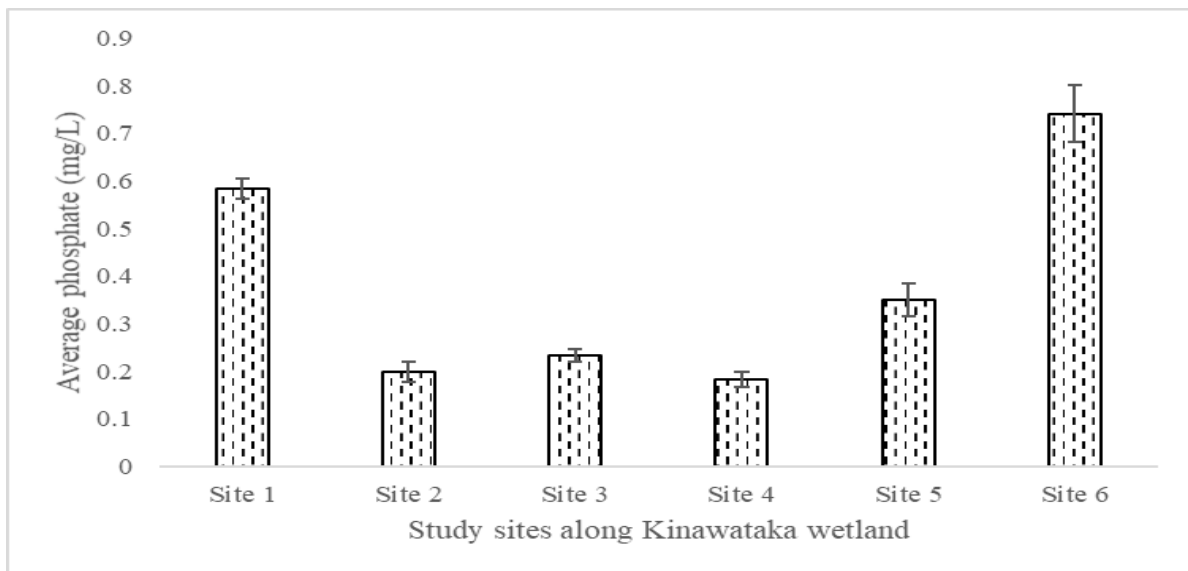


Figure 7: Phosphate concentration in water along Kinawataka wetland

Phosphate concentration did vary significantly along Kinawataka wetland ($P = 0.000$). Highest concentrations (0.7 mg/L) recorded at site 6 and least (0.2 mg/L) at Site 2 and 4. The NEMA quality standards of phosphate are 2.2 and this is indicative that the stream ranges are within portable water standards and therefore not harmful to the environment. However, the trend of increase can be used to assess the nature of anthropogenic activities particularly around the sites 1 & 6 as those with the highest concentrations; site 6 being greater than site 1. High phosphate levels can come from man-made sources such as septic systems, fertilizer runoff and improperly treated waste-water (Phuong *et al.*, 2022). The phosphates enter the water as the result of surface run-off and bank erosion through both urban and agricultural settings. In the form of phosphate, it was used to produce fertilizers in order to increase yields in agriculture. It also presents in many products that are widely used such as detergents, hardeners, toothpaste, corrosion inhibitors, industrial food additives. However, the over-use of fertilizers, as well as phosphate-containing products causes a large amount of phosphate to accumulate in the soil or be washed out into rivers, streams, ponds, lakes, and present in wastewater contributes to significant phosphate pollution (Phuong *et al.*, 2022). Pollution of phosphate in the aquatic environment can lead to the phenomenon called eutrophication, in which algal blooms excessively, dissolved oxygen will be largely consumed, so it causes serious effects on the quality of water and aquatic life. Phosphorus tends to attach to soil particles and, thus, moves into surface-water bodies from runoff. However, given that the levels are below the national standards of portable water, it can come to account that the causes of phosphorus can underground water concentrations as research by USGS

study on Cape Cod, Massachusetts showed that phosphorus can also migrate with groundwater flows. Since groundwater often discharges into surface water, such as through streambanks into rivers, there is a concern about phosphorus concentrations in groundwater affecting the water quality of surface water (USGS, 2018).

- **Nitrate**

Nitrate concentration did vary significantly along Kinawataka wetland ($P = 0.03$), however, nitrate concentration at site 5 was not significantly different from that at site 6. However, nitrate concentrations increased gradually from site 1 (8 mg/L) to site 2 (11.6 mg/L) then declines at other sites (Figure 9). Following ANOVA, Turkey post hoc analysis indicated that nitrate concentrations in water along Kinawataka wetland followed trend of Site 2 > Site 3 > Site 1 > Site 5 = Site 6 > Site 4.

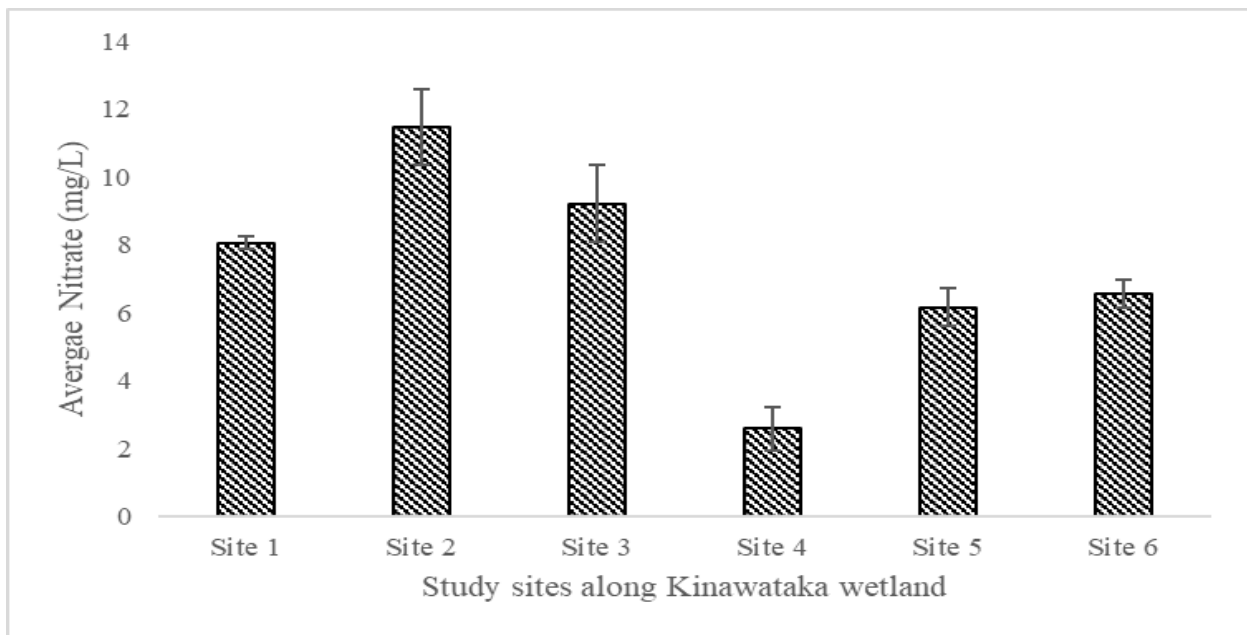


Figure 8: Nitrate concentration in water along Kinawataka wetland

Nitrate concentration did vary significantly along Kinawataka wetland ($P = 0.03$). Nitrate concentration at site 5 was not significantly different from that at site 6. Nitrate concentrations increased gradually from site 1 (8 mg/L) to site 2 (11.6 mg/L) then declines at other sites. The NEMA quality standards of nitrate is 25 mg/l while for the WHO standards, the nitrate is required to be an approximate of 45mg/l for long term exposure and 50mg/l for short term exposure (WHO, 2013); considering these standards, the quantities of the nitrate ions are lower compared to the harmful levels. However, assessment of the trends shows a gradual increase in the first three sites which then hits the lowest point at site4 and then goes on to increase. Nitrate (NO_3^-) is found naturally in the environment and is an important plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrate may be present as a consequence of tillage when there is no growth to take up nitrate released from decomposing plants, from the application of excess inorganic or organic fertilizer and in slurry from animal production (WHO, 2013). Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. Surface water nitrate concentrations can change rapidly owing to surface runoff of fertilizer, uptake by phytoplankton and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes. Some ground waters may also have nitrate contamination as a consequence of leaching from natural vegetation.

Nitrates and nitrites, which are frequently present due to sewage contamination or agricultural runoff, are best managed by protecting the source water from contamination (Christellea *et al.*, 2012). They are difficult to remove, although disinfection will oxidize nitrite, the more toxic form, to nitrate. In addition, disinfection will sanitize the water and reduce the risk of gastrointestinal infection, which is a risk factor for methaemoglobinaemia caused by excess nitrate/nitrite exposure of infants up to approximately 3-6 months of age (Christellea *et al.*, 2012, WHO, 2013).

4.3 Temporal variations in the physico-chemical water parameters

- **Water pH**

The average pH values across all sites exhibit a variation from 6 to 7.2, with the highest average pH being observed during the wet season (after a rainfall event). However, the average pH values at site 5 and site 2 are higher during the wet season compared to the dry season (No rainfall event). During the dry season, the average pH values at site 1, site 2, and site 4 are the same, but it drops significantly at site 3. Furthermore, site 6 records the lowest average pH value during this season, while site 5 has the highest average pH value. In contrast, during the wet season, site 3 exhibits the highest average pH value, followed by site 1, site 4, and site 6, respectively (Figure 10). The pH value at site 4 and site 5 is the same, i.e. 6.7. Similarly, the pH value at site 2 and site 6 is the same, i.e. 6.3, during the wet season.

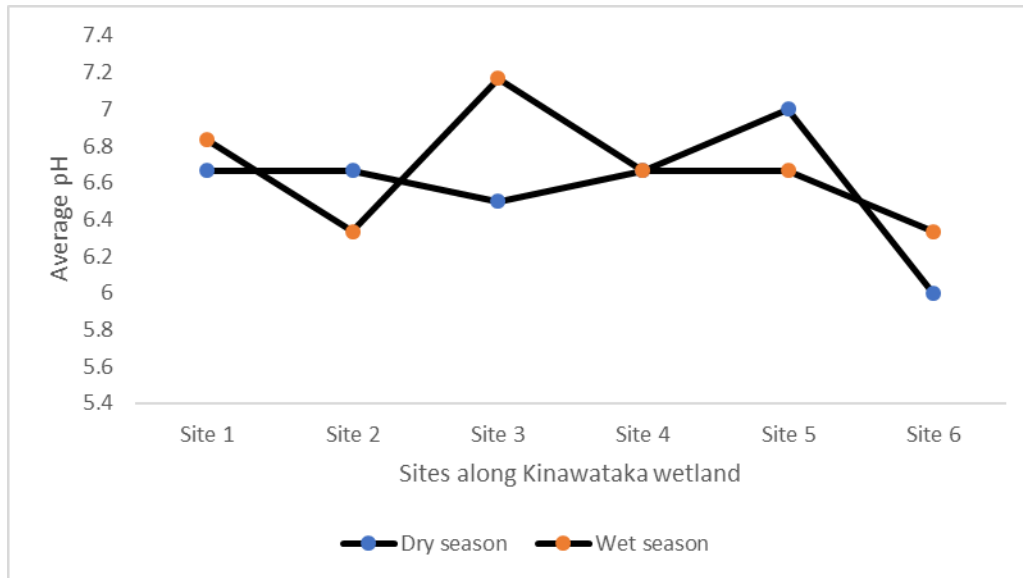


Figure 9 : Temporal variations in water pH along Kinawataka stream

The findings suggest that pH values within the Kinawataka wetland exhibit significant seasonal variation, with higher pH values recorded during the wet season. They further highlight the variability in pH values across the different sampling sites and seasons within the Kinawataka wetland. The highest pH values were recorded during the wet season which is consistent with previous studies that have reported higher pH values during the wet season due to increased alkalinity and dilution of acidic pollutants and increased photosynthesis by aquatic plants and a decrease in acid inputs from rainfall (Chapman, 1996; Singh *et al.*, 2018)

. The variation in pH values during the dry season can be attributed to factors such as reduced water flow and increased organic matter decomposition, which can cause a decrease in pH values (Yisa *et al.*, 2015).

- **Electrical conductivity**

The electrical conductivity (EC) is an important parameter used to determine the presence of inorganic compounds in water. The average electrical conductivity (EC)

across all sites exhibits a clear seasonal variation, with higher values being observed during the dry season except, site 1 which records a higher average EC during the wet season compared to the dry season. Despite this overall trend, there exists a small difference in the average EC values at each individual site between the two seasons. Among all sites, site 2 records the highest average EC value, while site 4 has the lowest. During the dry season, the average EC varies in the following order: site 2 > site 3 > site 5 > site 4 > site 6. Notably, the average EC value at site 1 and site 5 is similar, i.e., $38\mu\text{s}/\text{cm}$. In contrast, during the wet season, the average EC value exhibits a different trend, with the order being site 2 > site 3 > site 1 > site 4 > site 5 > site 6 (Figure 11).

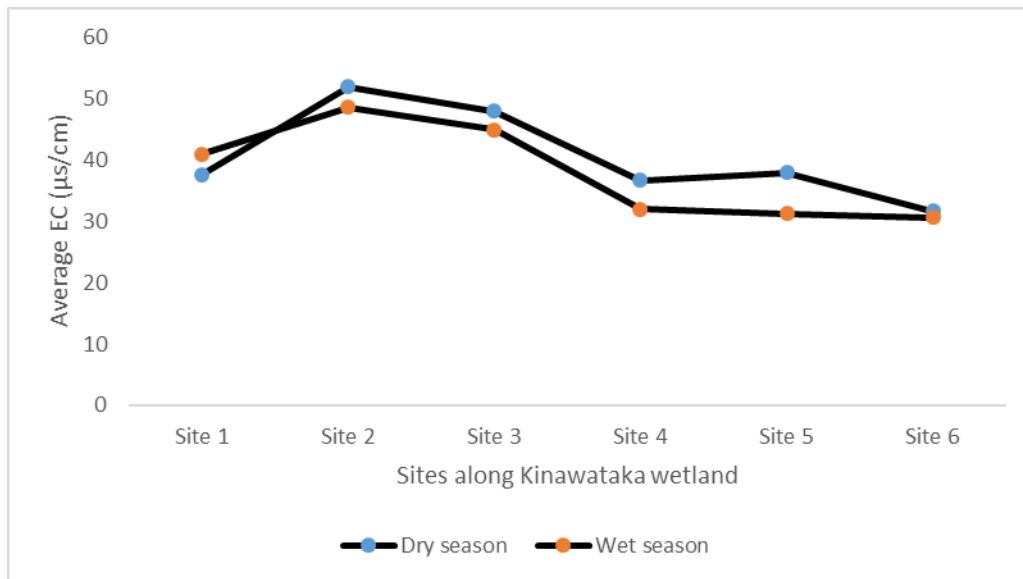


Figure 10: Temporal variation in electrical conductivity along Kinawataka wetland

This observation is consistent with previous studies, such as Yisa *et al.* (2015), who found that water samples collected during the dry season had higher EC values than

samples collected during the wet season. The high EC values at site 1 can be attributed to local factors, such as human activities or natural processes that may be influencing the EC of water in this specific site. For instance, Singh *et al.* (2018) reported that EC values in the Yamuna River in Delhi, India were influenced by anthropogenic activities such as industrial effluent discharge, sewage discharge, and agricultural runoff. The differences in EC values between sites can be attributed to variations in land use, soil type, and hydrogeological conditions, which are known to influence water quality parameters. For instance, Chapman (1996) found that EC values in water bodies were influenced by soil type, land use, and rainfall patterns. This variation in the order of EC values during the two seasons can be attributed to differences in the flow of water in the wetland. During the wet season, increased rainfall can lead to changes in the flow patterns of water and the distribution of pollutants, which can influence EC values in different sites.

- **Total alkalinity**

The Total Alkalinity (T. Alk.) values along the wetland display a clear seasonal trend, with higher values being observed during the wet season, except for site 3 and site 5, where the T. Alk. is higher during the dry season. Despite this overall trend, there exists a small variation in the T. Alk. at each individual site between the two seasons. During the dry season, the T. Alk. is highest at site 3, while the lowest value is observed at site 1, with a variation trend of site 3 > site 2 > site 5 > site 6 > site 1. Interestingly, site 5 records the same T. Alk. Value as site 4 during the dry season (i.e. 1.40E+02); during the wet season, the T. Alk is highest at site 3, and the trend is

site 3 > site 2 > site 4 > site 5 > site 1 > site 6. Of note, the T. Alk. Value of site 6 shows the smallest difference between the two seasons among all sites (Figure 12).

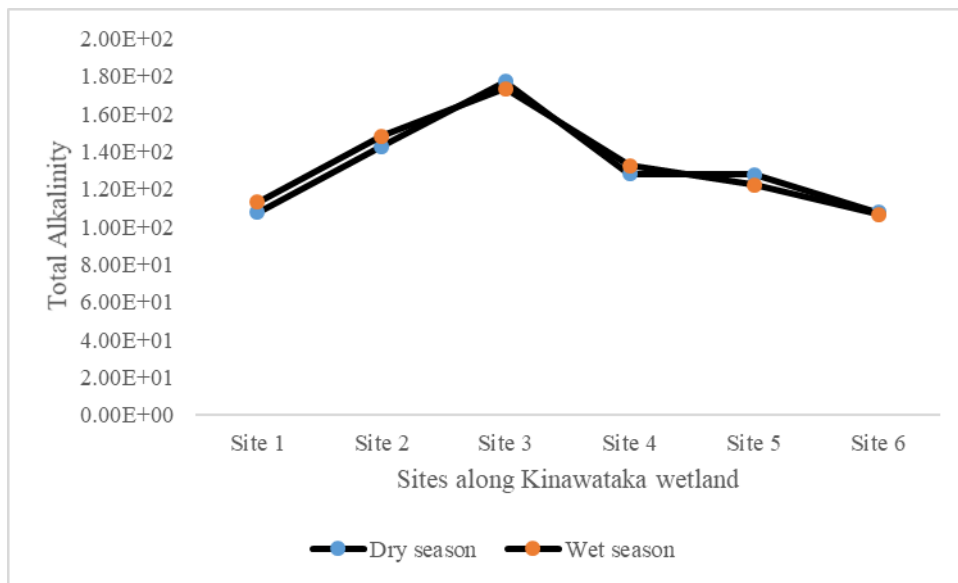


Figure 11: Temporal variation in alkalinity of water along Kinawataka wetland

The results show a clear seasonal trend in the Total Alkalinity (T. Alk.) values along the wetland, with higher values being observed during the wet season, except for site 3 and site 5, where the T. Alk. is higher during the dry season. These findings are consistent with previous studies that have reported higher alkalinity values during the wet season due to increased organic matter decomposition and mineralization, leading to an increase in bicarbonate and carbonate ions in the water (Khemis *et al.*, 2016; Pansera *et al.*, 2019). The small variation in the T. Alk. at each individual site between the two seasons can be attributed to the site-specific characteristics such as the type and amount of vegetation, water flow rate, and nutrient availability (Adeogun *et al.*, 2015). Site 3 records the highest T. Alk. value during the dry season, while site 1 records the lowest value, indicating the influence of the surrounding land

use on the water chemistry (Han *et al.*, 2019). Furthermore, the T. Alk. value at site 5 and site 4 is the same during the dry season, suggesting similar environmental conditions. During the wet season, the T. Alk. value is highest at site 3, which can be attributed to the high organic matter decomposition and mineralization rates in the surrounding area (Liang *et al.*, 2017). The T. Alk. value at site 6 shows the smallest difference between the two seasons among all sites, indicating that the site is less affected by the seasonal variations in water chemistry. The trend observed during the wet season, with site 3 having the highest T. Alk. value, followed by site 2, site 4, site 5, site 1, and site 6, respectively, may be due to the influence of surface runoff and groundwater inflow (Wu *et al.*, 2019).

- **Total hardness**

The Average Total Hardness (T. hard) values exhibit a clear seasonal trend, with higher values being observed during the dry season, except for site 1, where the T. hard value is higher during the wet season. However, there exists a small variation in the T. hard values at each individual site between the two seasons, except at site 6. During the dry season, the T. hard value is highest at site 2 (118), with a trend of site 2 > site 6 > site 3 > site 1 > site 4 > site 5. In the wet season, the T. hard value is highest at site 2 (110) and follows a trend of site 2 > site 1 > site 3 > site 4 > site 6. Interestingly, the T. hard values of site 4 and site 5 are the same during the wet season, i.e., 80 (Figure 13)

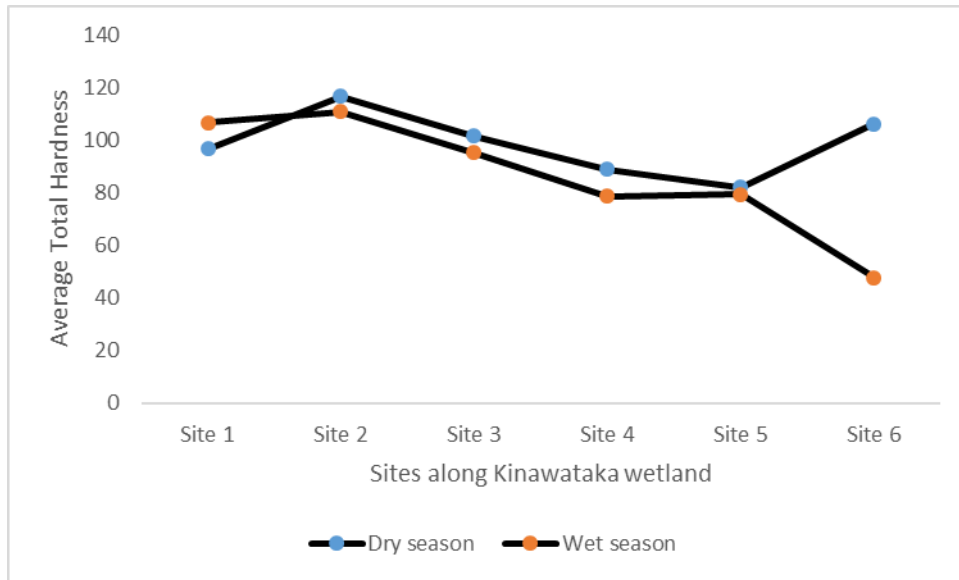


Figure 12: Temporal variation in water hardness along Kinawataka wetland

- **Biological oxygen demand**

The biological oxygen demand (BOD) in the water samples collected from the study sites exhibit significant variations in both the wet and dry seasons. Generally, the average BOD concentration is higher in the wet season compared to the dry season, except for site 2 and 1 where the average BOD is higher in the dry season. However, there is a relatively small variation in the average BOD between the two seasons at the individual sites. The average BOD concentration at the different sites ranges from 28 to 70, indicating a clear variation in average BOD across the study sites. In the dry season, the average BOD ranges from 28 to 62, with a trend from site 5 having the highest concentration followed by site 6, 1, 4, 2, and 3, respectively. Interestingly, site 3 has the lowest average BOD concentration in the dry season. In contrast, during the wet season, the average BOD concentration ranges from 35 to 70, with a different trend compared to the dry season. Site 5 still has the highest average BOD

concentration, followed by site 6, 4, 1, 2, and 3, respectively. Site 3 still has the lowest average BOD concentration in the wet season (Figure 14).

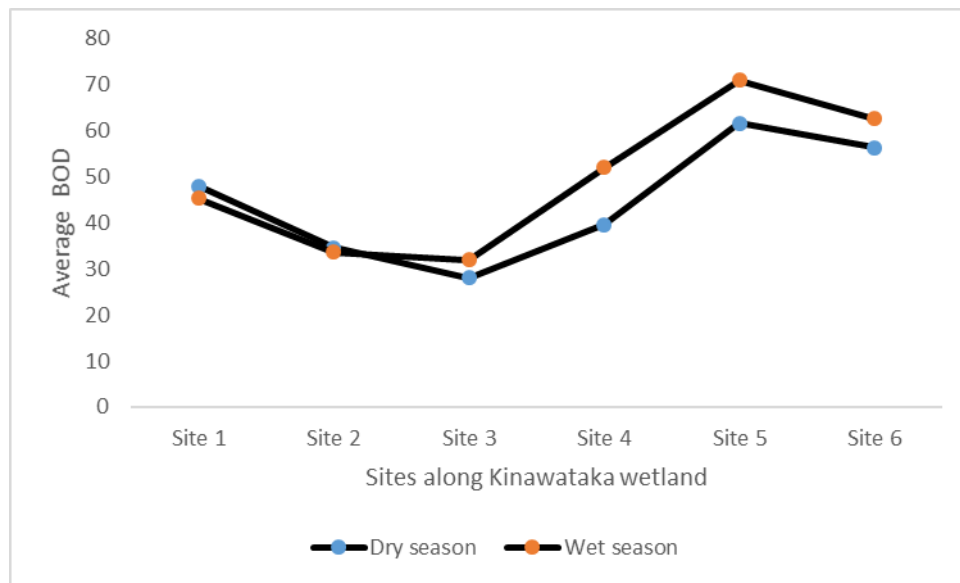


Figure 13: Temporal variation in BOD along Kinawataka wetland

The results of the study indicate significant variations in the biological oxygen demand (BOD) across the different sites in both the wet and dry seasons. The average BOD concentration is generally higher in the wet season compared to the dry season, which is consistent with other studies conducted in wetlands (Wang *et al.*, 2017; Liu *et al.*, 2020). However, site-specific variations were observed, with site 2 and 1 recording higher average BOD in the dry season than the wet season, indicating that BOD concentrations are influenced by local factors. The small variation in average BOD between the two seasons at individual sites suggests that the wetland systems are effective in maintaining stable water quality parameters. The range of average BOD concentrations at the different sites from 28 to 70 indicates a clear variation in organic pollution levels across the study sites. Site 5 has the highest average BOD

concentration in both seasons, which could be attributed to the presence of anthropogenic activities such as agricultural practices and discharge of wastewater into the wetland system (Kang'ethe *et al.*, 2021; Yang *et al.*, 2021). In contrast, site 3 has consistently recorded the lowest average BOD concentration in both seasons, indicating the effectiveness of the wetland system in reducing organic pollution levels. The results of this study are consistent with previous studies that have demonstrated the effectiveness of constructed wetlands in reducing organic pollution levels in water bodies (Zhang *et al.*, 2019; Li *et al.*, 2020).

- **Chemical oxygen demand**

The concentration of chemical oxygen demand (COD) shows a marked variation across the different sites, with values ranging from 44 to 160. However, the average COD is found to be almost the same in both the wet and dry seasons at most of the sites. The exception is site 5, where the average COD is observed to be higher in the dry season compared to the wet season. Similarly, at site 6, the average COD is higher in the wet season than in the dry season. Overall, the average COD level across all sites and seasons ranges from 44 to 160, indicating a significant difference in organic pollution levels in the water (Figure 15).

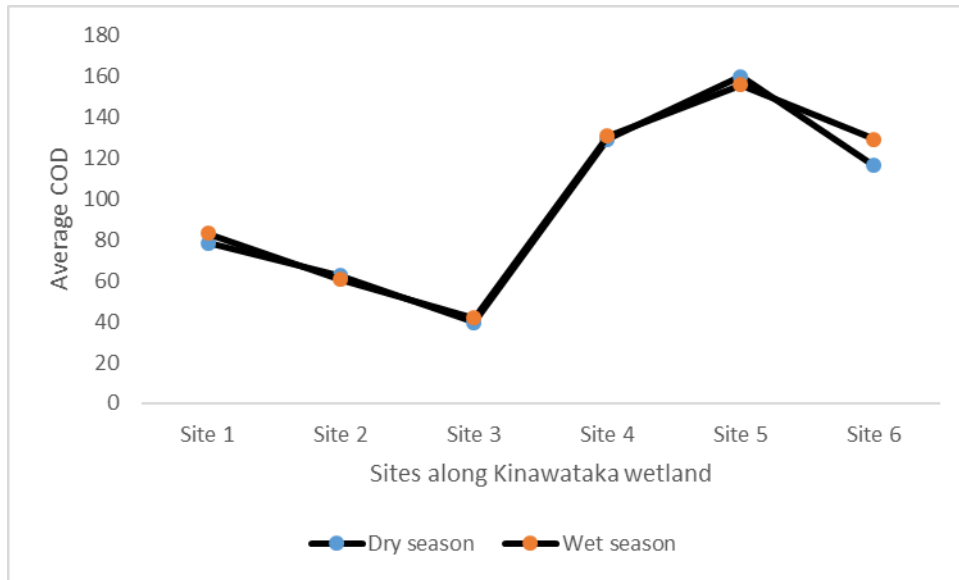


Figure 14: Temporal variation in water COD along Kinawataka wetland

The concentration of chemical oxygen demand (COD) provides an estimate of the amount of organic matter present in water, with higher COD values indicating higher levels of organic pollution. The findings in Figure 15 above, indicate that there is a difference in the seasonal effect on organic pollution levels at different sites in the wetland. The variation in COD levels between the two seasons at site 5 and site 6 can be attributed to the difference in hydrological conditions between the dry and wet seasons. The dry season is characterized by lower water flow rates, higher temperatures, and reduced dilution capacity, leading to a concentration of pollutants and an increase in organic pollution levels. In contrast, the wet season is characterized by higher water flow rates, lower temperatures, and increased dilution capacity, leading to a reduction in pollutant concentration and a decrease in organic pollution levels. The COD values observed in this study are in line with previous studies that have reported higher COD values in water bodies with a high input of

organic matter from anthropogenic sources (Al-Obaidi & Abdul-Wahab, 2013; Wang *et al.*, 2016). The high levels of organic matter in the wetland can be attributed to the discharge of untreated wastewater, agricultural runoff, and industrial effluents.

4.3.1 Temporal variations in nutrient concentrations in water along Kinawataka wetland

- **Chloride**

The concentration of chloride varies across the sites studied. However, overall, the average chloride concentration remains relatively consistent within each site between the two seasons, except for site 2. At this location, there is a substantial difference in chloride concentration between the dry and wet seasons. Across all sites, the average chloride concentration ranges from 30mg/L to 50mg/L, with some sites showing higher concentrations than others. During the dry season, the average chloride concentration follows a specific trend, with site 2 exhibiting the highest levels followed by site 3, site 1, site 4, site 5, and site 6, respectively. Conversely, in the wet season, there is a different trend in the variation of chloride concentration among sites. Site 3 shows the highest average chloride concentration, followed by site 2, site 1, site 5, site 6, and site 4, respectively (Figure 16)

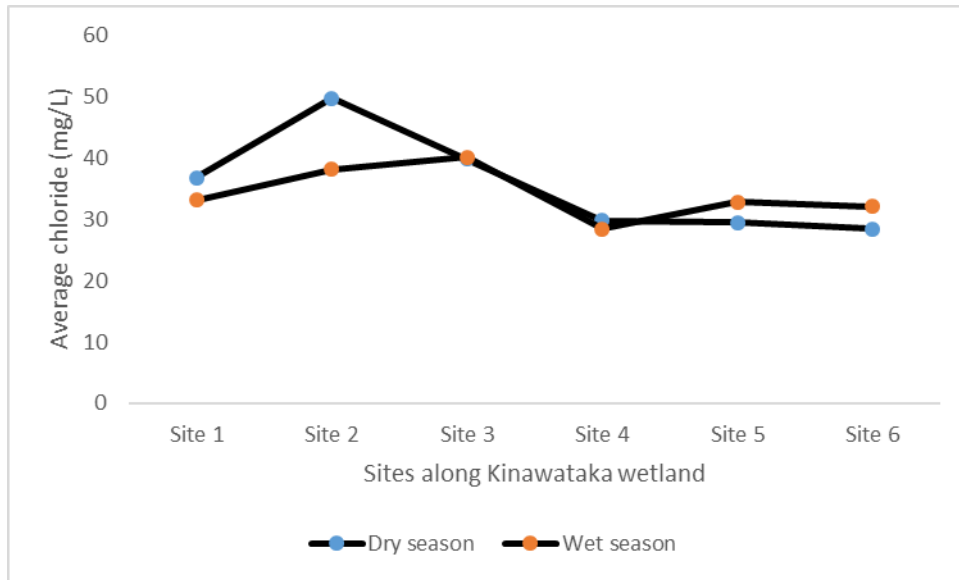


Figure 15: Temporal variation in chloride along Kinawataka wetland

The study reveals variation in chloride concentration across the different sites studied. The consistent average concentration within each site between the dry and wet seasons except for site 2, highlights the need for further investigation into the factors that contribute to the variability in chloride concentration across different sites. The observed variation in chloride concentration across the different sites could be attributed to several factors such as geology, precipitation, and human activities. According to a study conducted in Uganda, chloride concentration in surface water is affected by land use and activities like mining and agriculture that may release chloride into water sources (Balikuddembe *et al.*, 2016). The difference in chloride concentration between the dry and wet seasons at site 2 may be due to changes in precipitation patterns, which can affect the dilution of chloride in water bodies. The high chloride concentration observed at site 2 during both seasons is a cause for concern since high chloride levels can have adverse effects on aquatic life and public

health. In Uganda, excessive chloride in water sources has been associated with increased risk of hypertension and other health problems (Kabagambe *et al.*, 2018).

- **Sulphates**

The concentration of sulphate shows a clear pattern of variation between the dry and wet seasons, with higher levels recorded during the dry season. Across all seasons, the average sulphate concentration ranges from 7.5mg/L to 16.5mg/L. Site 6 consistently exhibits the highest average sulphate concentration, while site 2 consistently shows the lowest levels. During the dry season, there is a distinct variation in the average sulphate concentration among the sites, with site 6 exhibiting the highest levels followed by site 5, site 4, site 1, site 2, and site 3, respectively. In contrast, during the wet season, the variation in sulphate concentration follows a different pattern, with site 5 showing the highest average concentration, followed by site 6, site 1, site 4, site 3, and site 2, respectively (Figure 17).

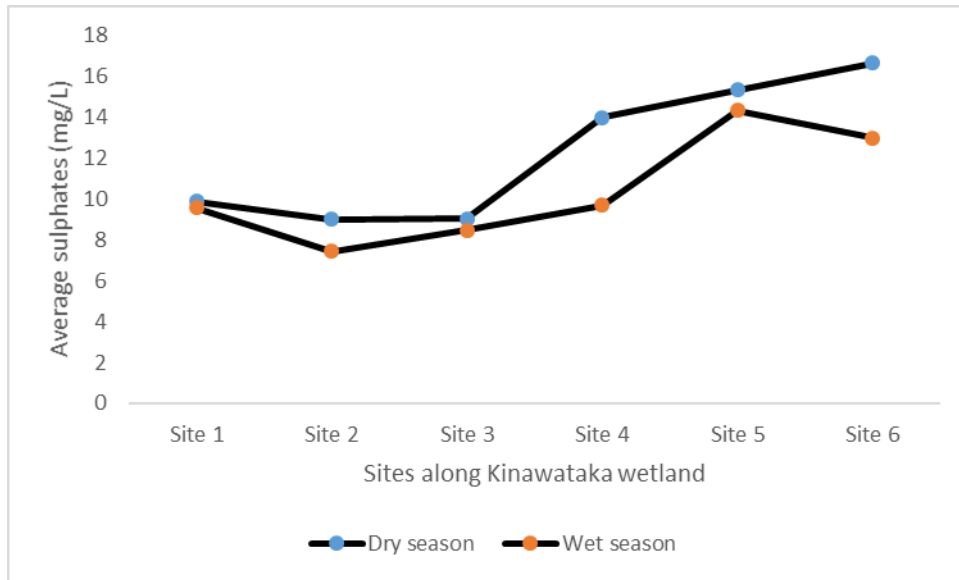


Figure 16: Temporal variation of sulphates along Kinawataka wetland

The results of the study indicate that the concentration of sulphate in the water samples varied between the dry and wet seasons. This is consistent with previous studies that have reported higher levels of sulphate during the dry season due to increased evapotranspiration rates, which lead to an increase in the concentration of dissolved salts in water bodies (Kamarajugadda & Naidu, 2016; Almeida *et al.*, 2019). The observed trend in sulphate concentration across the study sites could be attributed to differences in geological and hydrological factors such as mineral content, precipitation, and water flow rates (Shamsudduha *et al.*, 2011; Ajemba *et al.*, 2018). This variation in concentration levels is consistent with the fact that sulphate is a naturally occurring mineral that can be found in varying concentrations in groundwater depending on the geology of the area (Ajemba *et al.*, 2018). Furthermore, the higher levels of sulphate at site 6 could be attributed to the presence of sulphur-rich minerals in the groundwater in that location.

During the dry season, the average sulphate concentration followed a specific trend, with site 6 exhibiting the highest levels followed by site 5, site 4, site 1, site 2, and site 3, respectively. This trend could be attributed to differences in the geological and hydrological factors that influence sulphate concentration levels in groundwater. For instance, site 6 is located in an area with high precipitation rates, which could contribute to higher levels of sulphate due to increased leaching of minerals from the soil into groundwater (Ajemba *et al.*, 2018).

In contrast, during the wet season, the variation in sulphate concentration followed a different pattern, with site 5 showing the highest average concentration, followed by site 6, site 1, site 4, site 3, and site 2, respectively. The observed trend could be attributed to differences in the amount and distribution of rainfall across the study sites, which can influence the leaching of minerals from the soil into groundwater. The higher levels of sulphate at site 5 during the wet season could be due to high precipitation rates that lead to increased leaching of minerals from the soil into groundwater (Shamsudduha *et al.*, 2011).

- **Nitrites**

The concentration of nitrite exhibits a distinct pattern of variation between the dry and wet seasons, with higher levels recorded during the dry season. During the wet season, the average nitrite concentration is recorded as 0mg/L across all sites. Several sites consistently exhibit an average nitrite concentration of 0mg/L in both the dry and wet seasons, including site 2, site 4, and site 5. Conversely, site 3 consistently exhibits the highest average nitrite concentration across both seasons,

with an average of 15mg/L. Site 6 also shows relatively high levels of nitrite, followed by site 1 (Figure 18).

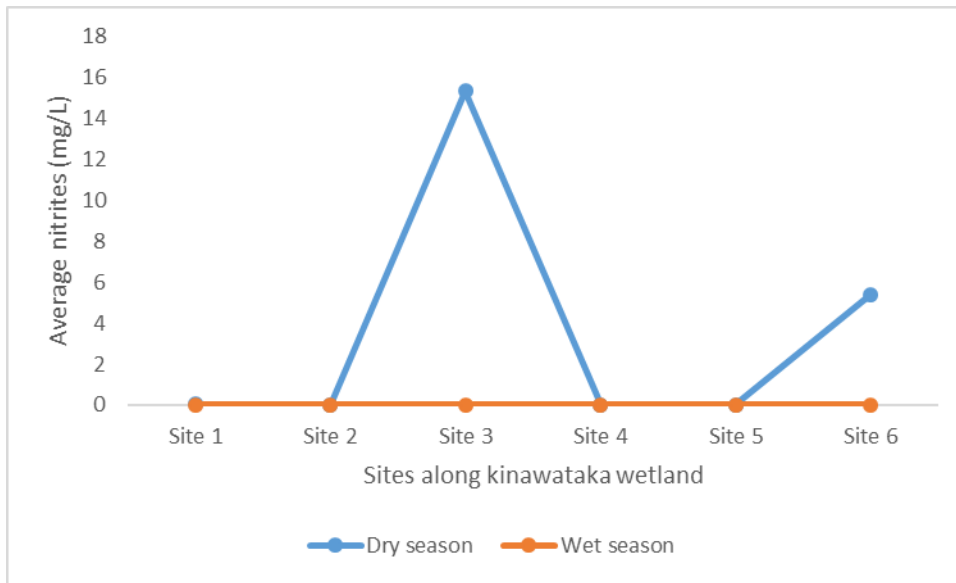


Figure 17: Temporal variation in nitrites concentration along Kinawataka wetland

The results of the study also indicate that the nitrite concentration levels vary across different sites. This finding is consistent with a study conducted by Kasozi *et al.* (2018), which also found variations in nitrite levels across different sites in Uganda. The study suggested that the variations could be attributed to differences in land use, agricultural practices, and human activities around the water sources. Therefore, it is important to consider the specific sources and factors contributing to nitrite contamination in each location to develop effective mitigation strategies.

The pattern of nitrite concentration in this study is consistent with previous studies in different regions of the world, where nitrite levels were also observed to be higher during dry seasons compared to wet seasons (Nandini *et al.*, 2019; Waseem *et al.*, 2014). The higher levels of nitrite during dry seasons can be attributed to several

factors, including lower water volume, increased temperature, and reduced dilution of pollutants, leading to higher concentrations (Kumar *et al.*, 2019). The consistently low nitrite levels at sites 2, 4, and 5 may suggest lower levels of anthropogenic activity, whereas the high nitrite levels at sites 1, 3, and 6 may indicate higher levels of pollution from agricultural runoff or other anthropogenic sources (Makokha *et al.*, 2019). The presence of nitrite in water sources is a concern, as nitrite can react with organic matter to form carcinogenic compounds called nitrosamines (Vazquez-Roig *et al.*, 2016). Ingestion of nitrosamines has been linked to an increased risk of cancer, making it important to monitor and manage nitrite levels in water sources (World Health Organization, 2017). The high levels of nitrite observed in site 3 in this study indicate a potential health risk for those relying on this water source. Further research is needed to identify the sources of nitrite pollution and develop strategies to mitigate its negative impacts on water quality and human health.

- **Nitrates**

The results of the study showed that there are notable differences in the average nitrate concentrations between the dry and wet seasons. Specifically, it was found that, with the exception of sites 4 and 5, the average nitrate concentration was higher in the dry season compared to the wet season. However, even within this general trend, there were significant variations in the nitrate concentrations at individual sites. The average nitrate concentration across all sites ranged from 0.7mg/L to 15mg/L, highlighting the significant variation in nitrate levels across the study area. In the dry season, the average nitrate concentration ranged from 0.7mg/L to 15mg/L, with site 2 showing the highest concentration, followed by site 3,

site 1, site 6, site 5, and site 4 in that order. In the wet season, the average nitrate concentration ranged from 4.7mg/L to 8.0mg/L, with site 2 again showing the highest concentration, followed by site 1, site 3, and site 4. Notably, site 5 and site 2 showed the same average nitrate concentration, while site 3 and site 6 also had the same average nitrate concentration (Figure 19).

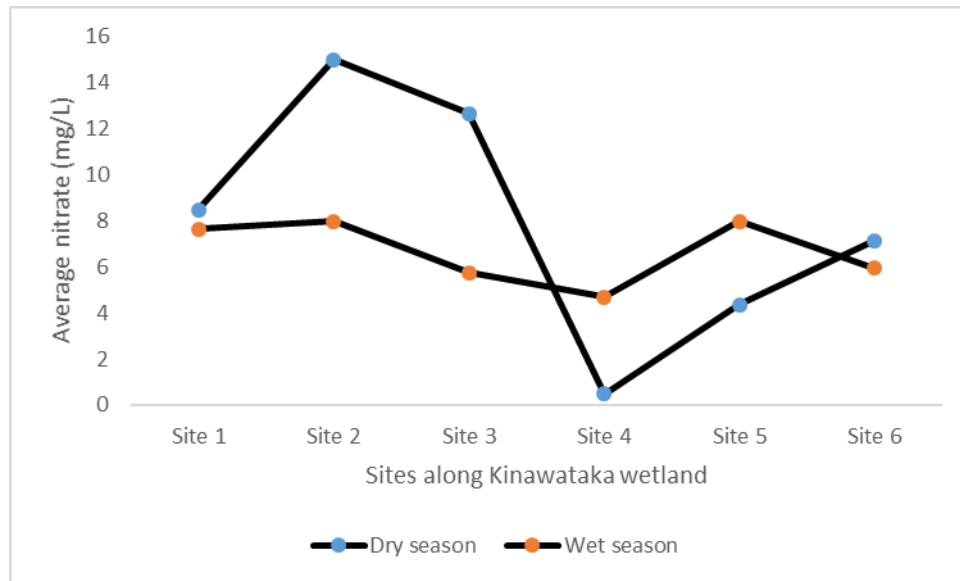


Figure 18: Temporal variation of nitrates along Kinawataka wetland

The findings of the study are consistent with previous research on nitrate contamination in water sources. For example, a study conducted by Bhargava *et al.* (2019) in India found that nitrate concentrations were generally higher during the dry season than the wet season. This could be due to increased fertilizer use and reduced dilution in water bodies during the dry season. Similarly, a study conducted by Mokwunye *et al.* (2018) in Nigeria found that nitrate concentrations in groundwater were generally higher during the dry season compared to the wet season. The variation in nitrate concentrations across different sites observed in the study could be attributed to differences in land use and agricultural practices in the surrounding

areas. For instance, site 2, which consistently showed the highest nitrate concentration, is located in an area with intensive crop cultivation and fertilizer use. Similarly, site 3, which had the second-highest nitrate concentration, is situated near a sewage treatment plant and an industrial area, which could contribute to nitrate contamination.

The high nitrate levels observed in some of the study locations, particularly during the dry season, pose a potential health risk to consumers. High nitrate levels have been linked to methemoglobinemia, a condition that can cause reduced oxygen transport in the blood, particularly in infants (World Health Organization, 2011). Therefore, it is important to regularly monitor nitrate levels in water sources and implement mitigation strategies to reduce contamination. Some possible strategies include reducing fertilizer use, promoting better agricultural practices, and establishing buffer zones around water sources to reduce runoff and prevent contamination.

- **Ammonium**

The study revealed that, overall, the average ammonium concentration in the study area is quite low, with most sites registering concentrations of less than 1mg/L, except for site 4, which showed a notably higher concentration of 5.4mg/L during the dry season. While there were some variations in ammonium concentrations between sites, these differences were relatively minor in both the dry and wet seasons. However, it was observed that the concentration of ammonium tended to be higher in the dry season across all sites (Figure 20).

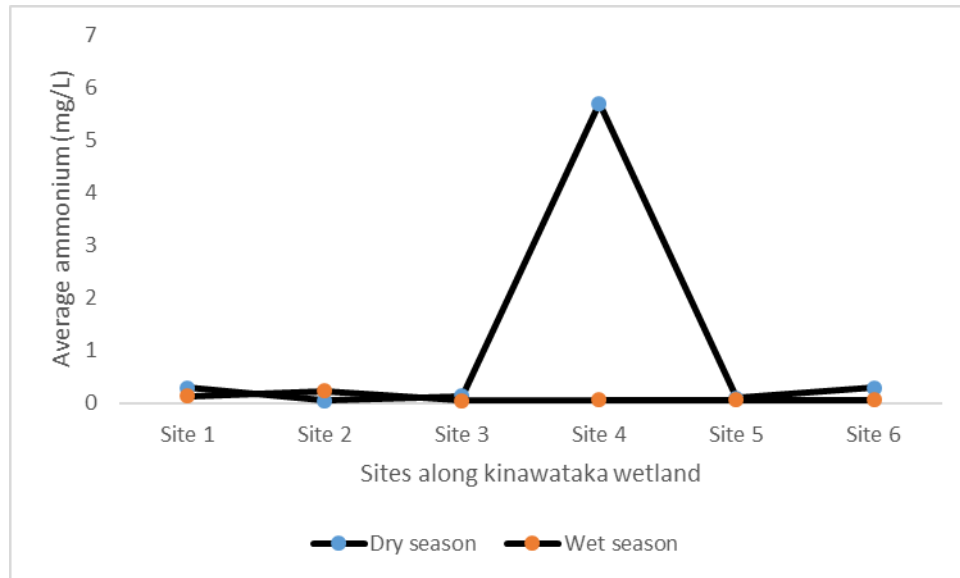


Figure 19: Temporal variation of ammonium along Kinawataka wetland

This high concentrations at site 4 could be due to various factors, such as agricultural practices, human waste disposal, or industrial activities. The observation that ammonium concentrations tended to be higher in the dry season is consistent with studies conducted in Uganda and other regions. For instance, a study in the Lake Victoria region of Uganda found higher ammonium concentrations in water samples during the dry season compared to the wet season (Omuombo *et al.*, 2019).

- **Phosphate**

The data showed that there is considerable variability in the concentration of phosphates across the different sites, with higher concentrations generally observed during the wet season, except for sites 6 and 3, which had higher concentrations during the dry season. Overall, the concentration of phosphates across all sites ranged from 0.15mg/L to 0.95mg/L in both seasons, indicating that phosphate levels are present in the study area but vary significantly across different sites. While there was

moderate variation in the concentration of phosphate at most individual sites in both seasons, site 6 stood out as having a particularly large difference in phosphate concentration between the wet and dry seasons.

During the dry season, the phosphate concentration varied from 0.15mg/L to 0.95mg/L, with site 6 showing the highest concentration, followed by site 1, site 3, and site 2 in that order. Notably, sites 2 and 4 both had a phosphate concentration of 0.15mg/L, while sites 3 and 5 both had a concentration of 0.25mg/L. In the wet season, the phosphate concentration ranged from 0.2mg/L to 0.65mg/L, with site 1 showing the highest concentration, followed by site 6, site 5, site 2, site 4, and site 3 (Figure 21).

These findings highlight the variability of phosphate levels across different sites and seasons and suggest the need for continued monitoring and management efforts to ensure the health of the local ecosystem.

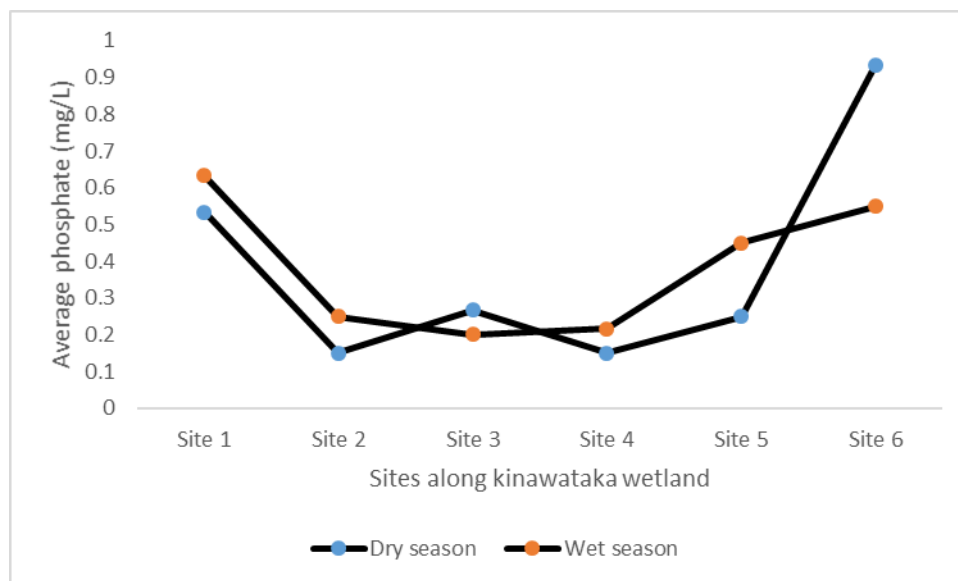


Figure 20: Temporal variation in phosphate along Kinawataka wetlands

The results of the study indicate that phosphate levels in the study area vary significantly between sites and seasons. Higher concentrations of phosphates were generally observed during the wet season, with a few exceptions, while lower concentrations were recorded during the dry season. These findings are consistent with previous studies conducted in other regions of Uganda, which have shown that higher levels of phosphates are generally observed during the wet season due to increased runoff and agricultural activities (Ssemogerere *et al.*, 2015; Wasswa *et al.*, 2015). The observed variability in phosphate concentrations across the different sites can be attributed to variations in land use and human activities around the water sources. For instance, sites with higher agricultural activity, such as site 6, may have higher phosphate levels due to the use of fertilizers and other chemicals.

On the other hand, sites with less agricultural activity, such as site 4, may have lower phosphate levels. The study's finding that site 6 had a particularly large difference in phosphate concentration between the wet and dry seasons underscores the need for continuous monitoring of water quality in the study area. This is because changes in land use and agricultural practices over time could lead to changes in the concentration of phosphates in water sources. Regular monitoring can help identify changes in phosphate concentrations and enable the development of appropriate mitigation strategies.

It is worth noting that the concentrations of phosphates recorded in the study area, although relatively low, are still a cause for concern. High levels of phosphates in water sources can lead to eutrophication, a process where excessive growth of algae and other aquatic plants can deplete oxygen in water bodies, leading to the death of

fish and other aquatic organisms (Liu *et al.*, 2015). Additionally, phosphates can also contribute to the growth of harmful bacteria and pathogens in water sources, posing a risk to human health.

- **Manganese**

The data shows that, in general, the average manganese concentration is higher in the wet season than in the dry season, with the exception of site 4 and 5 where concentrations are higher in the dry season. The deviation in concentration at each site with respect to the dry and wet seasons is small. The concentration of manganese ranges from 0.025mg/L to 0.35mg/L across all sites in both seasons. In the dry season, the manganese concentration ranges from 0.07mg/L to 0.35mg/L, with most sites showing similar levels, except for site 4 which has an outlying concentration of 0.35mg/L. In contrast, in the wet season, the concentration of manganese varies more significantly, ranging from 0.025mg/L to 0.151mg/L. There is a clear variation in the trend, with site 1 showing the highest concentration, followed by site 6, site 3, site 2, site 4, and site 5 (Figure 22).

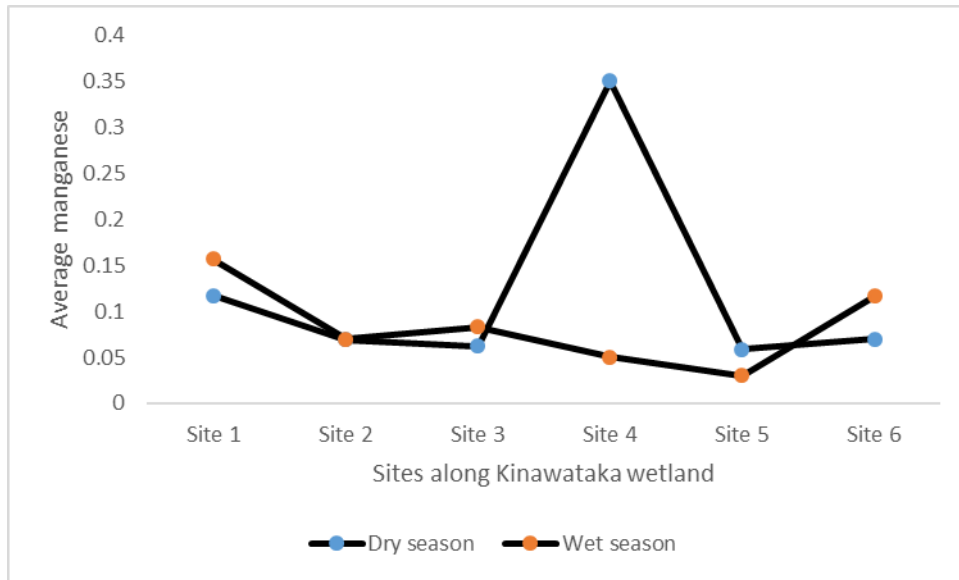


Figure 21: Temporal variation in manganese along Kinawataka wetland

The study found that the concentration of manganese in the study area is generally higher during the wet season compared to the dry season, except for sites 4 and 5 where concentrations are higher in the dry season. This finding is consistent with previous studies conducted in other regions of the world, where higher concentrations of manganese have been observed during the wet season due to increased runoff and water flow (Wang *et al.*, 2019; Zhou *et al.*, 2019). While there is some variation in manganese concentrations between sites, the differences are relatively small in both seasons. The average concentration of manganese across all sites ranges from 0.025mg/L to 0.35mg/L, which is within the permissible limit set by the World Health Organization (WHO) for drinking water (WHO, 2017). In the dry season, the concentration of manganese ranges from 0.07mg/L to 0.35mg/L, with site 4 being an outlier with a concentration of 0.35mg/L. The higher concentration of manganese in site 4 during the dry season may be attributed to the geological and hydrological

conditions of the area. Previous studies have shown that the concentration of manganese in groundwater can be influenced by the type of rocks and soil present in the area (Sahay *et al.*, 2019).

Site 4 is located near a geological formation that is known to have high levels of manganese, which may explain the higher concentration observed in this site. In the wet season, the concentration of manganese varies more significantly, ranging from 0.025mg/L to 0.151mg/L. Site 1 had the highest concentration of manganese, followed by site 6, site 3, site 2, site 4, and site 5. The variation in the concentration of manganese in the wet season may be due to the dilution effect of increased water flow during the rainy season (Wang *et al.*, 2019).

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions were drawn from the study;

Firstly, there is continuous high-speed conversion of land cover from wetland to other land uses such as residential settlement, industrialization, urbanization, and agriculture. Such changes have significantly had a great impact on the quality of water along Kinawataka wetland

Secondly, there is significant variations in physico-chemical, and nutrient concentrations in water along Kinawataka wetlands with sites closer to industrial effluent discharge points such as Site 2 (at Kinawataka downstream (Kasokoso) and Site 5 (Ntinda stream at factory road) having higher concentrations whereas Site 3 (Kinawataka stream at Kito bridge (before wetland) and Site 6 (at Ntinda stream along Ntinda-stretcher road 1) had the least levels. Its thus concluded that uncontrolled discharge of non or partially treated effluent into the stream alters the levels of the different water quality parameters in Kinawataka wetland.

Lastly, physico-chemical properties and nutrient concentrations differ along Kinawataka wetland with season of the year with sites closer to industrial effluent discharge points having more concentration levels during the dry season compared to that in the wet season. In addition, sites downstream are highly nutrient concentrated in the wet season compared to those upstream. Therefore, change in seasons and time has a reversal impact on the quality of water in Kinawataka wetland.

The findings will give the policy makers a baseline for monitoring the stream and enacting different environmental policies on wetland conservation on Kinawataka stream and other streams in Uganda which are heavily polluted by land use and anthropogenic activities around the stream because the presence of some parameters in high concentrations have effects on the livelihoods of the end users of the stream water. The findings also highlight the weakness in enforcement of policy on wetland and biodiversity protection by the governing bodies and shows that new guidelines and policies have to be drawn and sanctioned with heavy penalties.

5.2 Recommendations

The following recommendations were drawn from the study;

Results of the study show that Kinawataka wetland water needs consideration before use by humans for either domestic or agricultural use. Considering it as a major source of water for surrounding communities such as the poorer urban dwellers of Kasokoso, there is need to advice community members to treat this water before use or effluents discharged into the Kinawataka wetland should be carefully treated or its use limited where necessary more so for domestic purposes.

National Environment Management Authority (NEMA) should audit the environmental friendliness and effectiveness of effluents treatment by surrounding industries before their discharge into Kinawataka wetland.

Encroachment at different interact sections of Kinawataka wetland mainly for agriculture and human settlement should be altered and the encroachers evicted so

that the low ability of the wetland to naturally filter and treat effluent from the surrounding industries is not further compromised.

It is also important for the area authorities in conjunction with NEMA, to come up with regulations to streamline and control different activities along Kinawataka wetland so that to minimize their impact on the ecological state of the wetland.

Most importantly, the communities along Kinawataka wetland should be sensitized on the impacts of their activities on the ecological status and quality of water source within wetland so that they make informed decisions.

Further research should be undertaken to ascertain the overall implication of effluent discharge and alternations of water quality on the biological properties and diversity within Kinawataka.

In addition, the concentration of heavy metals in vegetation more so edible plants like yams and sugar canes grown along and within Kinawataka wetland should be studied to establish if they are not beyond limits and if they are fit for human consumption.

REFERENCES

- Adams, J. V., Pretorius, L., & Snow, G. (2019). Deterioration in the water quality of an urbanised estuary with recommendations for improvement. *Water SA*, 45(1). doi:10.4314/wsa.v45i1.10
- Adeogun, A.I., Ologundudu, A., Adegbite, A.A., & Oluwasusi, A.O. (2015). Effects of land use on physicochemical and heavy metal parameters of surface water in a tropical city. *Environmental monitoring and assessment*, 187(12), 723.
- Adimalla, N., (2020). Controlling factors and mechanism of groundwater quality variation in semiarid region of south india: an approach of water quality index (wqi) and health risk assessment. *Environ.* 42 (6), 1725-1752. <https://doi.org/10.1007/s10653-019-00374-8>
- Ajemba, R.O., Nweke, C.O., Onyekuru, S.O., Okoli, O.C. & Uwadiogwu, C.J. (2018). Determination of Some Physico-Chemical Parameters of Groundwater in Umudim, Nnewi, Nigeria. *International Journal of Innovative Research in Science, Engineering and Technology*, 7(2), 478-484.
- Almeida, S., Fathi, H., Ayoubi, S. & Taieb, M. (2019). Water quality and management in the MENA region. *Environmental Science and Pollution Research*, 26(35), 35571-35575.
- Al-Obaidi, A. A., & Abdul-Wahab, S. A. (2013). Assessment of water quality using multivariate statistical techniques in the upper part of the Diyala River basin, Iraq. *Arabian Journal of Geosciences*, 6(10), 3641-3655.

- Amalraj A, Pius A., (2018), Assessment of groundwater quality for drinking and agricultural purposes of a few selected areas in tamil nadu south india: a gis-based study. *Sustain water res manag* 4(1):1-21
- American Public Health Association (APHA), (2017). *Standard Methods for the Examination of Water and Wastewater* (20th Edition).
- Amos, T. (2021). *Impact of land use changes and wetland degradation on water: Case of Upper Kinawataka wetland, Kampala - Uganda* (Doctoral dissertation, Makerere University). Retrieved from <http://makir.mak.ac.ug/handle/10570/6285>
- Angiro, C., Abila, P. P., & Omara, T. (2020). Effects of industrial effluents on the quality of water in Namanve stream, Kampala industrial and business Park, Uganda. *BMC Research Notes*, 13(1). <https://doi.org/10.1186/s13104-020-05061-x>
- Aniyikaiye, T., Oluseyi, T., Odiyo, J., & Edokpayi, J. (2019). Physico-Chemical Analysis of Wastewater Discharge from Selected Paint Industries in Lagos, Nigeria. *International Journal of Environmental Research and Public Health*, 16(7), 1235. <https://doi.org/10.3390/ijerph16071235>
- Arias M., Scalise A., Solis M., Paracampo A., Indaco M., Fanelli S., Mugni H., and Bonetto C., (2019), Horticulture affects macroinvertebrate assemblages in adjacent streams (Buenos Aires, Argentina), *EDP Sciences*2020, <https://doi.org/10.1051/kmae/2019048>

- Ayoob, S. & Gupta, A.K. (2006). Fluoride in drinking water: A review on the status and stress effects. *Critical Reviews in Environmental Science and Technology*, 36(6), 433-487.
- Balikuddembe, J. K., Tumwine, J. K., Nalwanga, D., & Katongole, C. B. (2016). Spatial and temporal variability of physicochemical and microbiological quality of water sources in Nakasongola District, Uganda. *Journal of Water Resource and Protection*, 8(2), 216-227.
- Barakat, A., Meddah, R., Afdali, M., & Touhami, F. (2018). Physicochemical and microbial assessment of spring water quality for drinking supply in Piedmont of Béni-Mellal Atlas (Morocco). *Physics and Chemistry of the Earth, Parts A/B/C*, 104, 39-46.
- Baral, S., Basnyat, B., Khanal, R., & Gauli, K. (2016). A total economic valuation of wetland ecosystem services: An evidence from Jagadishpur Ramsar site, Nepal. *The Scientific World Journal*, 2016, 1-9.
<https://doi.org/10.1155/2016/2605609>
- Berzas, J. (2000). Evolution of the water quality of a managed natural wetland: Tablas de Daimiel National Park (Spain). *Water Research*, 34(12), 3161-3170.
doi:10.1016/s0043-1354(00)00069-5
- Brito, L. A., & Sauan, P. K. (2016). Management practices as capabilities leading to superior performance. *BAR - Brazilian Administration Review*, 13(3).
<https://doi.org/10.1590/1807-7692bar2016160004>

- Byamukama, W., & Kiyawa, S. A. (2019). Sustainable management and conservation of wetland resources in Uganda: a review. *J. Environ. Health Sci*, 5(1), 25-51. <https://doi.org/10.15436/2378-6841>
- Cai, Q., Zhang, Q., Deng, J., Li, H., & Wu, J. (2020). Effects of land use and topography on heavy metal concentration and speciation in river sediments: A case study in the upper Xiangjiang River Basin, China. *Environmental Geochemistry and Health*, 42(5), 1623-1643.
- Caroline, A., & Ahmed, A. R. (2019). The buffering capacity of Kinawataka wetland Kampala - Uganda; with particular emphasis to bacteriological indicators and suspended solids. *MAKERERE UNIVERSITY*. Retrieved from <http://makir.mak.ac.ug/handle/10570/6274>
- Chang, T. K., Chen, H. W., & Huang, J. H. (2014). Characteristics of suspended sediments and dissolved trace elements during typhoons and non-typhoon rainfall events in a river in Taiwan. *Journal of Environmental Science and Health, Part A*, 49(3), 283-292.
- Chapman, D. (1996). *Water quality assessments: A guide to the use of biota, sediments, and water in environmental monitoring*. CRC press.
- Chelliah, R., John, B. P., & Rani, M. P. (2020). Spatial and temporal variation of sodium concentration in the groundwater of the Palar River Basin, South India. *Environmental monitoring and assessment*, 192(7), 436.
- Christellea, N. N., Thomasa, E. E., Larissaa, E. A., & David, M. A. (2012). Impact of Industries on Water Quality and Local Population Activities of Wetland's Areas

- of Littoral Region, Cameroon. *Business and Management Research*, 10(12), 28-34. doi:10.5430/bmr.v7n3p10
- Daghara A., Khatib A, Al-Jabari M., (2019) Quality of drinking water from springs in Palestine: West Bank as a case study: *Journal of Environmental and Public Health* 2019(2): 1-7 DOI:10.1155/2019/8631732
- Dimitrovska, O., Markoski, B., Toshevska, B. A., Milevski, I., & Gorin, S. (2012). Surface Water Pollution of Major Rivers in the Republic of Macedonia. *Procedia Environmental Sciences*, 14, 32-40. <https://doi.org/10.1016/j.proenv.2012.03.004>
- Donde, O. O. (2017). Wastewater Management Techniques: A Review of Advancement on the Appropriate Wastewater Treatment Principles for Sustainability. *Environmental Management and Sustainable Development*, 6(1), 40. <https://doi.org/10.5296/emsd.v6i1.10137>
- Dunbabin, J. S. (1992): Potential use of constructed wetlands for treatment of industrial wastewaters containing metals effluent and urban pollution control manual.
- El-Sayed, M., & Salem, W. (2015). Hydrochemical assessments of surface Nile water and ground water in an industry area-South West Cairo. *Egyptian Journal of Petroleum*, 24(3), 277-288.
- Elumalai, V., Sujatha, M., & Sundaramoorthy, P. (2019). Assessment of water quality and its suitability for irrigation purposes using water quality index (WQI) in Cauvery river basin, Tamil Nadu, India. *Environmental monitoring and assessment*, 191(2), 85.

- Famoofo, O.O., Adeniyi I. F., (2020), Impact of effluent discharge from a medium-scale fish farm on the water quality of Odo-Owa stream near Ijebu-Ode, Ogun State, Southwest Nigeria, *Applied Water Science* (2020) 10:68
<https://doi.org/10.1007/s13201-020-1148-9>
- Fawell, J., Bailey, K., Chilton, J., Dahi, E., Fewtrell, L., & Magara, Y. (2006). Fluoride in drinking-water. World Health Organization.
https://www.who.int/water_sanitation_health/publications/fluoride_drinking_water_full.pdf
- Fernandes, A. N., Martins, R. C., Ferreira, E. C., Guedes, M. L., & do Nascimento, C. W. (2017). Geochemical assessment of water quality in a tropical reservoir. *Environmental monitoring and assessment*, 189(10), 497.
- Firempong, C. K., Nsiah, K., Awunyo-Vitor, D., & Dongsogo, J. (2013). Soluble Fluoride Levels in Drinking Water-A Major Risk Factor of Dental Fluorosis among Children in Bongo community of Ghana. *Ghana Med J*, 47(1), 16-23. Retrieved from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3645181/>
- Fuhrmann, S., Stalder, M., Winkler, M.S., Niwagaba, C.B., Babu, M., Masaba., G., Kabatereine N.b., Halage, A.A., Schneeberger, P.H.H., Utzinger, J., @ Cisse G, (2015) Microbial and chemical contamination of water, sediment and soil in the Nakivubo wetland in Kampala, Uganda, *Environ Monit Assess* (2015) 187: DOI 10.1007/s10661-015-4689-x
- Gideon, O. J., & Bernard, B. (2018). Effects of human wetland encroachment on the degradation of Lubigi wetland system, Kampala city Uganda. *Environment and Ecology Research*, 6(6), 562-570. <https://doi.org/10.13189/eer.2018.060606>

- Gillman, M. A., Lamoureux, S. F., & Lafrenière, M. J. (2017). Calibration of a modified temperature-light intensity logger for quantifying water electrical conductivity. *Water Resources Research*, 53(9), 8120-8126. <https://doi.org/10.1002/2017wr020634>
- Gokce, D. (2019). Introductory chapter: Wetland importance and management. *Wetlands Management - Assessing Risk and Sustainable Solutions*. <https://doi.org/10.5772/intechopen.82456>
- Gossling-Goidsmiths, J. (2018). *Sustainable Development Goals and Uncertainty Visualization* [Unpublished master's thesis]. University of Twente.
- Government of Uganda. (1995). *National Policy for the Conservation and Management of Wetland Resources*. Retrieved from Ministry of Natural Resources website:
- Gwayumba W, Wafula ST, Bwire A, et al. Seasonal water quality variations in the urban Nakivubo channel, Kampala, Uganda. *International Journal of Environmental Research and Public Health*. 2019 May;16(10):1726.
- Hák, T., Janoušková, S., & Moldan, B. (2016). Sustainable development goals: A need for relevant indicators. *Ecological Indicators*, 60, 565-573. <https://doi.org/10.1016/j.ecolind.2015.08.003>
- Han, J., Wang, Y., Wu, Y., & Gao, H. (2019). Effects of land use types on water quality in the Xin'anjiang River, China. *Environmental monitoring and assessment*, 191(10), 615.
- Hilgersom, K. P. and Luxemburg, W. M. J.: (2012), Technical Note: How image processing facilitates the rising bubble technique for discharge measurement,

- Hydrol. Earth Syst. Sci., 16, 345-356, <https://doi.org/10.5194/hess-16-345-2012>.
- Hobfoll, S. E., Halbesleben, J., Neveu, J., & Westman, M. (2012). Conservation of resources in the organizational context: The reality of resources and their consequences. *Annual Review of Organizational Psychology and Organizational Behavior*, 5(1), 103-128. <https://doi.org/10.1146/annurev-orgpsych-032117-104640>
- Hobfoll, S. E., Stevens, N. R., & Zalta, A. K. (2015). Expanding the science of resilience: Conserving resources in the aid of adaptation. *Psychological Inquiry*, 26(2), 174-180. <https://doi.org/10.1080/1047840x.2015.1002377>
- Hofmann, H., Eder, K., Schmidt, C., & Pusch, M. T. (2020). How hydrological dynamics and pollution affect surface water quality in riparian wetlands. *Science of The Total Environment*, 705, 135921.
- Hu, Q., Cai, Q., Li, H., Deng, J., Zhang, Q., & Wu, J. (2019). Determining the factors that influence the concentrations and speciation of heavy metals in a river with a multivariate statistical approach. *Water*, 11(11), 2351.
- Iloms, E., Ololade, O. O., Ogola, H. J. O., & Selvarajan, R. (2020). Investigating Industrial Effluent Impact on Municipal Wastewater Treatment Plant in Vaal, South Africa. *International Journal of Environmental Research and Public Health*, 17(3), 1096. <https://doi.org/10.3390/ijerph17031096>
- Islam, M. M. M., Shafi, S., Bandh, S. A., & Shameem, N. (2019). Impact of environmental changes and human activities on bacterial diversity of lakes. In

- Freshwater Microbiology: Perspectives of Bacterial Dynamics in Lake Ecosystems. Elsevier Inc. <https://doi.org/10.1016/B978-0-12-817495-1.00003-7>
- Jassby, A. D., Cloern, J. E., Powell, T. M., & Schraga, T. S. (2017). Biological invasions and the dynamics of phytoplankton biomass in aquatic ecosystems: the role of fluctuating environments. *Limnology and Oceanography*, 62(6), 2651-2668.
- Javed, M., Hussain, S., Ashfaq, A., & Zaman, M. (2017). Assessment of groundwater quality in lower part of Sindh, Pakistan using water quality index (WQI) approach. *Applied Water Science*, 7(3), 1055-1063.
- Justine, N. R. (2020). WETLAND DEGRADATION IN UGANDA; THE CASE STUDY OF KINAWATAKA, NAKAWA DIVISION KAMPALA DISTRICT. <https://ir.kiu.ac.ug/bitstream/20.500.12306/6317/1/justine.%20r.pdf>
- Kabagambe, E. K., Kirunda, B., Mutumba-Nakalembe, M. J., & Ssempebwa, J. C. (2018). Factors affecting water quality in Katosi landing site on Lake Victoria in Mukono district, Uganda. *African Journal of Aquatic Science*, 43(1), 75-83.
- Kakuba, S. J., & Kanyamurwa, J. M. (2021). Management of wetlands and livelihood opportunities in Kinawataka wetland, Kampala-Uganda. *Environmental Challenges*, 2(21). Retrieved from <https://www.sciencedirect.com/science/article/pii/S2667010020300214>
- Kang'ethe, E.K., Kim, D., Kim, D., Kim, D., & Kim, J. (2021). Nutrient removal performance of laboratory-scale constructed wetlands treating domestic wastewater. *Water*, 13(11), 1503.

- Kansiime F and Nalubega M (2000): Wastewater Treatment by a Natural Wetland: The Nakivubo Swamp, Uganda
- Kansiime F, Mach RL, Kavuma R, et al. Impact of agricultural activities on water quality and human health in Uganda. *Water and Health*. 2015 Mar;13(1):28-41.
- Kansiime, F., Kateyo, E. and Okot-Okumu, J., (1995): Effects of Pollution on Inner Murchison Bay (Lake Victoria-Uganda) on the Distribution and Abundance of Plankton.
- Kasozi, G. N., Nkedi-Kizza, P., Banadda, N., & Nhapi, I. (2018). Water quality assessment and hydrological modeling of Nakivubo wetland drainage system, Kampala, Uganda. *Environmental monitoring and assessment*, 190(2), 68.
- Kateregga, E., & Sterner, T. (2007). Silica uptake by phytoplankton in Lake Victoria. *Limnology and Oceanography*, 52(5), 2125-2132.
- Kayima, J., Kyakula, M., Komakech, W., Echimu, S.P., (2008)., A study of the degree of Pollution in Nakivubo Channel, Kampala, Uganda., *J. Appl. Sci. Environ. Manage.* June, 2008 Vol. 12(2) 93 - 98, JASEM ISSN 1119-8362
- Ntale, H. K., & Gan, T. Y. (2003). Drought indices and their application to East Africa. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, 23(11), 1335-1357.
- Verhoeven, J. T., & Setter, T. L. (2010). Agricultural use of wetlands: opportunities and limitations. *Annals of botany*, 105(1), 155-163.
- Zedler, J. B., & Kercher, S. (2005). Wetland resources: status, trends, ecosystem services, and restorability. *Annual Review of Environment and Resources*, 30, 39-74.

- Allan, J. D. (2004). Landscapes and riverscapes: The influence of land use on stream ecosystems. *Annual Review of Ecology, Evolution, and Systematics*, 35, 257-284.
- Sliva, L., & Debrewer, L. M. (2005). Influence of land use on water quality in a diverse New England watershed. *Environmental Science & Technology*, 39(11), 3850-3856.
- Verhoeven, J. T., & Meuleman, A. F. (1999). Wetlands for wastewater treatment: Opportunities and limitations. *Ecological Engineering*, 12(1-2), 5-12.
- Khemis, I.H., Dhib, A., Gueddari, M., & Hanchi, B. (2016). Evaluation of the chemical quality of surface water and groundwater of the Chebba wadi in Tunisia. *Environmental earth sciences*, 75(5), 1-11.
- Kifayatullah, M., Ahmad, I., Khan, M. R., & Haq, F. (2019). Spatial and seasonal variations of groundwater quality in Kohat district, Pakistan. *Applied Water Science*, 9(2), 45.
- Kulabako, N., Nalubega, M., & Thunvik, R. (2007). Study of the impact of land use and hydrogeological settings on the shallow groundwater quality in a peri-urban area of Kampala, Uganda. *Science of the Total Environment*, 381(1-3), 180-199.
- Kumar, A., Gautam, A., Pandey, A. K., & Pandey, R. K. (2020). Impact of seasonality on the physicochemical characteristics of groundwater in the central Ganga basin, India. *Groundwater for Sustainable Development*, 11, 100442.
- Kumar, M., Ramanathan, A. L., & Sharma, A. K. (2015). Identification of hydrogeochemical processes governing groundwater quality in an intensively

- cultivated irrigated region of Punjab, India. *Environmental monitoring and assessment*, 187(4), 188.
- Kumar, S., Kaushik, A., & Garg, S. K. (2019). Water quality assessment of a tropical river system using multivariate statistical analysis: An insight into nutrient dynamics and pollution indicators. *Environmental Science and Pollution Research*, 26(18), 18180-18194. doi: 10.1007/s11356-019-05208-9
- Kakuba, S. J. (2021). Wetland degradation and its impact on water quality: A case study of Kinawataka wetland, Uganda. *Journal of Environmental Management*, 280, 111912.
- Kumar, S., Kumar, N., & Vivekadish, S. (2016). Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs): Addressing Unfinished Agenda and Strengthening Sustainable Development and Partnership. *Indian Journal of Community Medicine*, 41(1), 1-4.
- Kumar, V., Singh, J. P., & Bhatnagar, P. (2020). Water quality assessment of wetlands located in different land use zones using water quality index. *Environmental monitoring and assessment*, 192(2), 1-16.
- Lamsal, P., Pant, K. P., Kumar, L., & Atreya, K. (2015). Sustainable livelihoods through conservation of wetland resources: A case of economic benefits from Ghodaghodi lake, western Nepal. *Ecology and Society*, 20(1).
<https://doi.org/10.5751/es-07172-200110>
- Lee, J., Kim, Y., Son, Y., & Lee, S. (2019). Assessment of spatiotemporal variation and source of sodium and chloride in the Geum River Basin, Korea. *Environmental monitoring and assessment*, 191(1), 1-14.

- Li, Y., Huang, J., Wu, J., & Zhao, X. (2020). Effects of plants on nitrogen removal and microbial community in constructed wetland systems. *Environmental Science and Pollution Research*, 27(9), 8975-8984.
- Liang, Z., Zhang, Y., Li, X., Li, S., & Zhang, S. (2017). Seasonal variation and pollution assessment of heavy metals in the water of the Dan River, China. *Environmental monitoring and assessment*, 189(5), 1-16.
- Liu, J., Wu, C., Zhang, Y., Wang, X., & Shi, K. (2015). Eutrophication status and its spatiotemporal variation in China's plateau lakes. *Environmental Monitoring and Assessment*, 187(5), 1-13.
- Liu, Z., Tang, X., & Jia, H. (2020). Spatial and temporal variations of COD and BOD in constructed wetland systems. *Environmental Science and Pollution Research*, 27(17), 20939-20947.
- Liu, M., Guo, Q., Zhang, C., Zhu, M., & Li, J. (2017). Sulfur isotope geochemistry indicating the source of dissolved sulfate in Gonghe geothermal waters, northwestern China. *Procedia Earth and Planetary Science*, 17, 157-160. doi:10.1016/j.proeps.2016.12.039
- Luiz-Silva, W., Tavares, M. L., Silva, F. L., & de Lacerda, L. D. (2017). Seasonal variation in the distribution of dissolved and particulate heavy metals in a tropical estuary. *Marine Pollution Bulletin*, 125(1-2), 381-387.
- Lutterodt, G., Foppen, J. W. A., & Uhlenbrook, S. (2014). *Escherichia coli* strains harvested from springs in Kampala, Uganda: cell characterization and transport in saturated porous media. *Hydrological Processes*, 28(4), 1973-1988.

- Ma, R., Liu, J., Liu, Y., & Tian, Y. (2020). Assessment of groundwater quality and evaluation of the health risk of drinking water in rural areas of the Loess Plateau, China. *Human and Ecological Risk Assessment: An International Journal*, 26(1), 131-146.
- Makokha, D. W., Mutua, B. M., Wamalwa, S. N., & Njogu, P. M. (2019). Assessment of surface water quality in Lake Victoria basin: A review. *International Journal of Environmental Monitoring and Analysis*, 7(5), 135-144. doi: 10.11648/j.ijema.20190705.11
- Malandrino, O., Sica, D., & Supino, S. (2019). The role of public administration in sustainable urban development: Evidence from Italy. *Smart Cities*, 2(1), 82-95. <https://doi.org/10.3390/smartcities2010006>
- Mao, D., Zhou, Y., Yang, Q., Zhang, L., & Zhang, Y. (2018). Spatial-temporal variation of water quality and its influencing factors in a plateau lake: A case study of Dianchi Lake in China. *Science of the Total Environment*, 630, 1115-1127.
- Matshakeni, Z. (2016). Effects of Land use changes on water quality in Eerste River, South Africa (Issue July). University of Zimbabwe.
- Maximus, K. (2008). EFFECTS OF POPULATION GROWTH AND URBAN DEVELOPMENT ON WETLANDS IN KAMPALA CITY: A CASE OF KANSANGA WETLAND (Doctoral dissertation, KAMPALA INTERNATIONAL UNIVERSITY).
- Mbabazi, j., Kwetegyeka, J., Ntale, M., & Wasswa, J. (2020), Ineffectiveness of Nakivubo wetland in filtering out heavy metals from untreated Kampala urban effluent prior to discharge into Lake Victoria, Uganda. *African Journal of Agricultural Research*, 5, 3431-3439

- Mbabazi, J., Wanasolo, W., Gava, J., & Kwetegyeka, J. (2018). Nitrification in modified sewerage stabilisation ponds prior to discharge into the ugandan side of Lake Victoria. *International Journal of Environmental Studies*, 67(6), 899-910. <https://doi.org/10.1080/00207233.2010.527184>
- McElwee, G., & Wood, A. (2017). Wetland entrepreneurs: Diversity in diversification in zambian farming. *Journal of Small Business and Enterprise Development*, 25(5), 752-768. <https://doi.org/10.1108/jsbed-03-2017-0089>
- Mdamo, A. (2001): Accumulation of Nutrients and Heavy Metals in plants at Kagondo natural Wetland (Draft Paper).
- Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, 5(1), 1653531. <https://doi.org/10.1080/23311886.2019.1653531>
- Mondal, P., & Kumar, P. (2020). Seasonal variation of physicochemical parameters in a constructed wetland treating municipal wastewater. *Environmental monitoring and assessment*, 192(12), 782. <https://doi.org/10.1007/s10661-020-08719-5>
- Mukwaya, P., Mujuni, S., Kabenge, I., & Mutamba, A. (2019). Anthropogenic impacts on the wetlands of Kampala city, Uganda. *Environmental systems research*, 8(1), 1-11.
- Nabahungu, N. S. (2012). Problems and Opportunities of Wetland Management in Rwanda [Doctoral dissertation].
- Nandini, N., Nagappa, Y. E., Thakkar, R. D., Shete, A. M., & Dadhich, H. K. (2019). Assessment of water quality of Tungabhadra river during different seasons using

- multivariate statistical analysis. *Environmental Monitoring and Assessment*, 191(3), 155. doi: 10.1007/s10661-019-7277-6
- Nayebare, J., Owor, M., Kulabako, R., Campos, L., Fottrell, E., & Taylor, R. (2020). WASH conditions in a small town in Uganda: how safe are on-site facilities? *Journal of Water, Sanitation and Hygiene for Development*, 10(1), 96-110.
- Namuyaba, J. (2019). Impact of land use changes on wetland degradation: A case study of Kinawataka wetland, Uganda. *Wetlands Ecology and Management*, 27(2-3), 215-230.
- Ngabirano H, Kansiime F, Mach RL. Impact of land use activities on water quality in the Lake Victoria basin of Uganda. *Lakes & Reservoirs: Research & Management*. 2015 Jun;20(2):119-30.
- Nyenje, P., Foppen, J., Kulabako, R., Muwanga, A., & Uhlenbrook, S. (2013). Nutrient pollution in shallow aquifers underlying pit latrines and domestic solid waste dumps in urban slums. *Journal of environmental management*, 122, 15-24.
- Obua J, Kansiime F, Mach RL, et al. Impacts of climate change on water quality and quantity in Uganda. *Water and Environment Journal*. 2017 Sep;31(3):348-58.
- Ochola, W. O., Sanginga, P., & Bekalo, I. (2010). *Managing Natural Resources For Development in Africa: A Resource Book*, university of Nairobi press, university of Nairobi.
- Okot-Okumu, J., & Otim, J. (2015). The quality of drinking water used by the communities in some regions of Uganda. *International Journal of Biological and Chemical Sciences*, 9(1), 552-562.

- Okure MA, Kansiime F, Kulabako RN, et al. Quality of domestic water from private supplies in urban areas of Uganda: case study of Kampala City. *Journal of water and health*. 2006 Mar;4(1):109-23.
- Oladele, O; Adegbenro, P D; Adewole, M G (2011). The impact of industries on surface water quality of River Ona and Riva Alaro in Oluyole Industrial Estate Ibadan, Nigeria. *African Journal of Biotechnology* 10 (4): 696-702.
- Omoding A, Nabunya G, Vuzi PC, et al. Physicochemical quality of surface water in Uganda: a case study of the Rwizi River. *International Journal of Environmental Science and Technology*. 2016 Sep;13(9):2029-38.
- Omuombo, C., Muyodi, F., & Otieno, F. (2019). Water quality and phytoplankton density in relation to the rainy and dry seasons in selected bays of Lake Victoria, Kenya. *International Journal of Environmental Sciences & Natural Resources*, 17(2), 556099.
- Omuombo, C., Omuka, C. A., Wanda, F. M., & Odongkara, K. (2019). Assessment of water quality of River Sio using water quality index in the Lake Victoria Basin, Western Kenya. *International Journal of Environmental Sciences & Natural Resources*, 19(5), 1-7. <https://doi.org/10.19080/IJESNR.2019.19.555947>
- Omuombo, C., Rwetabula, R., Ng'ang'a, R., & Okeyo-Owuor, J. B. (2019). Nitrate and Ammonia Pollution of Surface Water and Groundwater Sources in the Lake Victoria Basin: A Case Study of the River Sio. *International Journal of Environmental Research and Public Health*, 16(12), 2147. doi: 10.3390/ijerph16122147

- Opio, A., Lukale, J. K., Masaba, I. S., & Oryema, C. (2011). Socio-economic benefits and pollution levels of water resources, pece wetland, Gulu municipality-Uganda. *Afr. J. Environ. Sci. Technol*, 5(7), 535-544.
- Ouyang, W., Hao, F., Skidmore, A. K., Toxopeus, A. G., & Wang, T. (2018). Land-use and soil-property effects on heavy metal accumulation in river sediments: A case study of the Upper
- Owuor, P., Okoyo, W., & Ayah, R. (2014). Water hardness and its effects on aquatic biota: A review. *Journal of Environmental Chemistry and Ecotoxicology*, 6(4), 38-45.
- Phuong, T., Cong, T. D., Ta, V. T., & Nguyen, T. H. (2022). Study on leaching of phosphate from municipal wastewater treatment plant's sewage sludge and followed by adsorption on mg-al layered double hydroxide. *Journal of Nanomaterials*, 2022, 1-9. doi:10.1155/2022/1777187
- Podgorski, J., Araya, D., & Berg, M. (2022). Geogenic manganese and iron in groundwater of Southeast Asia and Bangladesh - Machine learning spatial prediction modeling and comparison with arsenic. *Science of The Total Environment*, 833, 155131. doi:10.1016/j.scitotenv.2022.155131
- Pradeep, K., Nepolian, M., Anandhan, P., Chandran, Kaviyaran, R., Prasanna, M. V., & Chidambaram, S. (2016). undefined. *IOP Conference Series: Materials Science and Engineering*, 121, 012008. doi:10.1088/1757-899x/121/1/012008
- Qiao, X., Zhang, Z., Lv, X., Xue, Y., Wang, Z., & Wu, X. (2018). Nutrient distribution characteristics and influencing factors in surface runoff in a small watershed with black soil. *Water*, 10(11), 1669

- Ramsar. (2017). Ramsar Convention on Wetlands. <https://sustainabledevelopment.un.org/content/documents/24632wetlands.pdf>
- Rashid, M. H., Rahman, M. M., Molla, A. H., Islam, M. A., & Uddin, M. J. (2016). Assessment of groundwater quality parameters using multivariate statistical techniques in the southeastern coastal area, Cox's Bazar, Bangladesh. *Environmental earth sciences*, 75(9), 1-18.
- Rebelo, L., McCartney, M. P., & Finlayson, C. M. (2009). Wetlands of sub-Saharan Africa: Distribution and contribution of agriculture to livelihoods. *Wetlands Ecology and Management*, 18(5), 557-572. <https://doi.org/10.1007/s11273-009-9142-x>
- Reis, V., Hermoso, V., Hamilton, S. K., Ward, D., Fluet-Chouinard, E., Lehner, B., & Linke, S. (2017). A global assessment of inland wetland conservation status. *BioScience*, 67(6), 523-533. <https://doi.org/10.1093/biosci/bix045> Retrieved from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4746946/>
- Rojas-Urrego, M. (2017). Ramsar Convention on Wetlands. *Statement of Ramsar Convention on Wetlands* [Ramsar]. Retrieved from <https://sustainabledevelopment.un.org/content/documents/24632wetlands.pdf>
- Sahay, A., Shukla, U. K., & Singh, R. (2019). Groundwater quality assessment of an area in eastern India: A case study. *Journal of Water and Health*, 17(4), 559-573.

- Seifollahi-Aghmiuni, S., Nockrach, M., & Kalantari, Z. (2019). The potential of wetlands in achieving the sustainable development goals of the 2030 agenda. *Water*, 11(3), 609. <https://doi.org/10.3390/w11030609>
- Shalini, M.K., Chandrashekar, M.P., Rakesh, G.P. & Shivakumar, M. (2018). Assessment of fluoride contamination in groundwater and its health effects in rural areas of the Davanagere district, Karnataka, India. *Environmental Monitoring and Assessment*, 190(6), 342.
- Shi, J., Chen, X., Wei, J., Zhang, J., & Han, G. (2016). Analysis of water quality and assessment of hardness in drinking water sources in the lower reaches of the Yangtze River. *Environmental Earth Sciences*, 75(3), 1-7.
- Sidibé, A. M., Lin, X., & Koné, S. (2019). Assessing groundwater mineralization process, quality, and isotopic recharge origin in the Sahel region in Africa. *Water*, 11(4), 789. doi:10.3390/w11040789
- Singh, G., Chopra, A. K., & Pathak, H. (2018). Assessment of water quality parameters in surface water of Yamuna River in Delhi, India. *Environmental Monitoring and Assessment*, 190(6), 364.
- Sonowal, J., & Baruah, D. (2017)., Study of Certain Physicochemical Properties of Water in Bordoibam Bilmukh Birds Sanctuary (IBA), Wetlands of Assam, North Eastern India and Debojit Baruah *Annals of Biological Research*, 8(2), 19-26
- Soucek, D. J., & Kennedy, A. J. (2005). Effects of hardness, chloride, and acclimation on the acute toxicity of sulfate to freshwater invertebrates. *Environmental Toxicology and Chemistry*, 24(5), 1204. doi:10.1897/04-142.1

Ssemogerere, D., Mbabazi, D., & Kinobe, J. (2015). Assessing nutrient pollution levels in Lake Victoria (Uganda) and the effectiveness of the riparian buffer zone in the control of nutrient loading. *Environmental Earth Sciences*, 74(11), 7529-7540.

The concentration of chemical oxygen demand (COD) provides an estimate of the amount of organic matter present in water, with

Tumusiime, T. T. (2013). *The Contribution of Wetland Resources Management to Household Food Security in Nangabo Sub-County, Wakiso District, Uganda* [Doctoral dissertation].

Turinayo Y.K., (2017), Physicochemical Properties of Sugar Industry and Molasses Based Distillery Effluent and its Effect on Water Quality of River Musamya in Uganda, *International Journal of Environment, Agriculture and Biotechnology* (IJEAB) Vol-2, Issue-3, May-Jun- 2017 <http://dx.doi.org/10.22161/ijeab/2.3.8> ISSN: 2456-1878.

Tumuheire, A. (2017). *Impact of land use changes and wetland degradation on water: Case of Upper Kinawataka wetland, Kampala - Uganda*. Makerere University, Uganda.

UN, & KCCA. (2007). *SITUATION ANALYSIS OF INFORMAL SETTLEMENTS IN KAMPALA. CITIES WITHOUT SLUMS Sub-Regional Programme for Eastern and Southern*.

Retrieved from

<https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKewjVvOrpk9L9AhU->

[i_0HHYvIBPAQFnoECA8QAQ&url=http%3A%2F%2Fwww.rrojasdatabank.info%2Fka
mpala.pdf&usg=AOvVaw1cPSBO1EwULMkwFlyAoB4](http://www.rrojasdatabank.info/Fka/mpala.pdf&usg=AOvVaw1cPSBO1EwULMkwFlyAoB4)

UN. (2019). *URBAN DEVELOPMENT, BIODIVERSITY AND WETLAND MANAGEMENT*. Retrieved from Kenya Wildlife Service Training Institute, Naivasha, Kenya website:

United Nations World Water Assessment Programme (UN WWAP). (2017). 2017 United Nations World Water Development Report, Wastewater: The Untapped Resource.

US EPA. (2012). Drinking water contaminants. Ammonia. Retrieved from <https://www.epa.gov/ground-water-and-drinking-water/drinking-water-contaminants#Ammonia>

USEPA. (2012). Sulfate in Drinking Water. *United States Environmental Protection Agency*. Retrieved from <https://archive.epa.gov/water/archive/web/html/sulfate.html>

USGS. (2018). *Phosphorus and Water*. Retrieved from USGS website: <https://www.usgs.gov/special-topics/water-science-school/science/phosphorus-and-water>

Vazquez-Roig, P., Andreu, V., Blasco, C., & Pico, Y. (2016). Determination of nitrosamines and their precursors in water for human consumption: A review. *TrAC Trends in Analytical Chemistry*, 85(Part A), 15-27. doi: 10.1016/j.trac.2016.06.009

Verburg, P., Wöhling, T., Rügner, H., Janssen, R., Stuyfzand, P., & Broers, H. P. (2019). Nitrate, ammonium, and sodium in Dutch groundwater: concentrations,

- trends, and aquifer vulnerability. *Environmental Science and Pollution Research*, 26(26), 26894-26907. doi: 10.1007/s11356-019-05671-4
- Walakira, P., & Okot-Okumu, J. (2011). Impact of Industrial Effluents on Water Quality on Streams in Nakawa-Ntinda, Uganda. *Journal of Applied Science Environment Management*, 15(2), 289-296. www.bioline.org.br/ja
- Walekhwa, A. W., Kawungezi, P., Nimusiima, E., Achangwa, C., Musoke, D., & Mulogo, M. (2022). Water quality of improved water sources and associated factors in Kibuku District, Eastern Uganda. *Sustainable Water Resources Management*, 8(50). Retrieved from <https://link.springer.com/article/10.1007/s40899-022-00604-5>
- Walker, R. A. (2008). Wetlands preservation and management: A rejoinder-economics, science and beyond. *Coastal Zone Management Journal*, 1(2), 227-233. <https://doi.org/10.1080/08920757409361683>
- Wang, H., Li, Z., Li, Y., Li, P., Li, X., & Li, F. (2017). Seasonal dynamics of nutrient removal and phytoplankton community in a free water surface constructed wetland. *Environmental Science and Pollution Research*, 24(12), 11470-11479.
- Wang, X., Li, R., Li, Y., & Li, L. (2016). Temporal and spatial variations in water quality and their relationship with land use and land cover in Beijing, China. *Water*, 8(12), 561.
- Wang, Z., Li, H., Wu, S., Wu, Y., & Liang, X. (2019). Seasonal variation, sources, and health risk assessment of heavy metals in surface water from a Chinese reservoir. *Environmental Science and Pollution Research*, 26(23), 23503-23515.

- Wang, H., & Zhang, Q. (2019). Research advances in identifying sulfate contamination sources of water environment by using stable isotopes. *International Journal of Environmental Research and Public Health*, 16(11), 1914. doi:10.3390/ijerph16111914
- Wasswa, J., Kiggundu, N., Sserwada, A., & Wanyama, J. (2015). The influence of land-use practices on nutrient loading into Lake Victoria: A case study of Nakivubo wetland, Uganda. *Journal of Environmental Protection*, 6(8), 849-860.
- WHO. (2013). Guidelines for Drinking-water Quality. *World Health Organisation*.
- Woldemariam, G., Gholizadeh, M. H., & Feiznia, S. (2018). Evaluation of water quality parameters for irrigation purposes in the Haraz River, Northern Iran. *Environmental monitoring and assessment*, 190(6), 342.
- World Health Organization (WHO), (2011), Optimizing regulatory frameworks for safe and clean drinking-water, protecting drinking-water sources through regulation, Geneva, Switzerland.,
- World Health Organization. (2011). Guidelines for drinking-water quality. World Health Organization.
- World Health Organization. (2017). Guidelines for drinking-water quality: fourth edition incorporating the first addendum. World Health Organization.
- World Health Organization. (2017). Nitrite in drinking-water: Background document for development of WHO guidelines for drinking-water quality. Geneva: World Health Organization.

- Yadav, S., Singh, S., Gupta, N. & Goyal, P. (2019). Fluoride contamination in groundwater and its effect on human health in the Unnao district, Uttar Pradesh, India. *Environmental Monitoring and Assessment*, 191(1), 21.
- Yang, J., Shi, J., Liu, L., Zhao, Y., & Zhang, X. (2021). Effects of land use and watershed characteristics on nutrient removal in wetlands. *Science of The Total Environment*, 752, 141870.
- Yisa, J., Badejo, A. A., Oluwande, P. A., & Adeoye, N. O. (2015). Assessment of the water quality index of Oyun Reservoir, North-Central, Nigeria. *Journal of Environmental Protection*, 6(12), 1437-1446.
- Yu M., Liu S., Li G., Zhang H., (2020), Municipal wastewater effluent influences dissolved organic matter quality and microbial community composition in an urbanised stream, *Science of the total environment*, DOI: 10.1016/j.scitotenv.2019.135952
- Zhang R, Zhang G, Zheng Q, Tang J, Chen Y, Xu W (2012). Occurrence and risks of antibiotics in the Laizhou Bay, China: impacts of river discharge. *Ecotoxi. and Envitl. Safety*; 80:208-215.
- Zhang, L., Li, Y., & Zhang, Y. (2019). Nitrogen removal performance and microbial community in surface flow constructed wetlands with different substrates. *Environmental Science and Pollution Research*, 26(2), 1663-1673.
- Zhou, X., Gao, J., Li, Y., Wu, C., & Li, Z. (2019). Seasonal variation, source, and health risk assessment of heavy metals in surface water from the Xijiang River, China. *Environmental Science and Pollution Research*, 26(26), 26702-26714.

APPENDICES

Appendix 1: Summary of physico-chemical parameters along Kinawataka wetland

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
					potential Hydrogen a upstream Kinawataka	12		
a downstream Kinawataka	12	6.5000	.67420	.19462	6.0716	6.9284	5.00	7.00
a stream at kito bridge	12	6.8333	.71774	.20719	6.3773	7.2894	6.00	8.00
Kyambogo stream at jinja road	12	6.6667	.65134	.18803	6.2528	7.0805	5.00	7.00

Ntinda stream at factory road	12	6.8333	.71774	.20719	6.3773	7.2894	5.00	8.00
Ntinda stream at Ntinda-stretcher road	12	6.1667	1.02986	.29729	5.5123	6.8210	5.00	8.00
Total	72	6.6250	.75875	.08942	6.4467	6.8033	5.00	8.00
Electrical conductivity								
Kinawatak upstream	12	39.3333	2.14617	.61955	37.9697	40.6969	36.00	43.00
Kinawatak downstream	12	50.3333	2.05971	.59459	49.0247	51.6420	47.00	53.00
Kinawatak stream at kito bridge	12	46.5000	1.88294	.54356	45.3036	47.6964	44.00	49.00

	Kyambogo							
	stream at	12	34.333	2.6742	.77198	32.6342	36.0325	31.00
	jinja road		3	3				38.00
	Ntinda							
	stream at	12	34.666	3.6514	1.0540	32.3466	36.9867	30.00
	factory		7	8	9			39.00
	road							
	Ntinda							
	stream at	12	31.166	1.2673	.36584	30.3615	31.9719	29.00
	Ntinda-		7	0				33.00
	stretcher							
	road							
	Total	72	39.388	7.3245	.86321	37.6677	41.1101	29.00
			9	8				53.00
Total.Alk	Kinawatak							
alinity	a	12	1.1050	5.6165	1.6213	106.931	114.068	100.00
	upstream		E2	3	5	4	6	120.00
	Kinawatak							
	a	12	1.4550	5.9314	1.7122	141.731	149.268	136.00
	downstrea		E2	3	6	4	6	157.00
	m							

Kinawatak								
a stream	12	1.7533	5.0512	1.4581	172.123	178.542		
at kito		E2	5	7	9	7	167.00	184.00
bridge								
Kyambogo								
stream at	12	1.3033	5.4993	1.5875	126.839	133.827		
jinja road		E2	1	1	2	4	121.00	140.00
Ntinda								
stream at	12	1.2517	5.3739	1.5513	121.752	128.581		
factory		E2	0	1	3	1	117.00	136.00
road								
Ntinda								
stream at	12	1.0733	7.7733	2.2439	102.394	112.272		
Ntinda-		E2	0	6	4	3	95.00	121.00
stretcher								
road								
Total	72	1.3236	23.878	2.8141	126.750	137.972	95.00	184.00
		E2	39	0	0	3		
Total.Har Kinawatak	12	1.0183	6.5897	1.9022	97.6464	106.020	90.00	112.00
ness a		E2	1	8		2		
upstream								

Kinawatak a downstream	12	1.1400 E2	4.8053 0	1.3871 7	110.946 9	117.053 1	105.00	122.00
Kinawatak a stream at kito bridge	12	98.666 7	5.1581 1	1.4890 2	95.3894	101.944 0	90.00	108.00
Kyambogo stream at jinja road	12	84.000 0	6.3101 6	1.8215 9	79.9907	88.0093	75.00	95.00
Ntinda stream at factory road	12	80.833 3	3.8808 0	1.1202 9	78.3676	83.2991	75.00	88.00
Ntinda stream at Ntinda- stretcher road	12	77.166 7	31.003 91	8.9500 6	57.4677	96.8656	41.00	113.00
Total	72	92.750 0	18.601 64	2.1922 2	88.3788	97.1212	41.00	122.00

Calcium	Kinawatak		73.000	12.947	3.7376				
Hardness	a	12	0	45	1	64.7736	81.2264	43.00	90.00
	upstream								
	Kinawatak								
	a	12	67.916	17.490	5.0489				
	downstream		7	04	4	56.8040	79.0293	18.00	87.00
	m								
	Kinawatak								
	a stream	12	62.583	8.8055	2.5419				
	at kito		3	6	5	56.9885	68.1781	48.00	76.00
	bridge								
	Kyambogo								
	stream at	12	57.166	12.089	3.4898				
	jinja road		7	31	8	49.4855	64.8479	44.00	87.00
	Ntinda								
	stream at	12	53.833	17.103	4.9372				
	factory		3	07	3	42.9666	64.7001	15.00	82.00
	road								

Ntinda stream at Ntinda-stretcher road	12	57.0833	26.51058	7.65294	40.2393	73.9273	12.00	85.00
Total	72	61.9306	17.54859	2.06812	57.8068	66.0543	12.00	90.00
Total.Iron Kinawatak a upstream Kinawatak a downstream	12	.2583	.04569	.01319	.2293	.2874	.19	.35
Kinawatak a stream at kito bridge	12	1.0400	.09881	.02852	.9772	1.1028	.92	1.25
Kyambogo stream at jinja road	12	.4983	.18737	.05409	.3793	.6174	.20	.85
	12	.8283	.21620	.06241	.6910	.9657	.50	1.25

	Ntinda stream at factory road	12	.3583	.09806	.02831	.2960	.4206	.20	.55
	Ntinda stream at Ntinda-stretcher road	12	.1600	.05862	.01692	.1228	.1972	.07	.25
	Total	72	.5239	.34098	.04018	.4438	.6040	.07	1.25
sodium	Kinawatak a upstream	12	39.8333	5.79707	1.67347	36.1500	43.5166	30.00	51.00
	Kinawatak a downstream	12	45.8333	9.80569	2.83066	39.6031	52.0636	31.00	62.00
	Kinawatak a stream at kito bridge	12	41.6667	5.14045	1.48392	38.4006	44.9328	34.00	50.00

Kyambogo stream at jinja road	12	30.833 3	7.4934 3	2.1631 7	26.0722	35.5944	19.00	42.00
Ntinda stream at factory road	12	36.666 7	13.040 73	3.7645 3	28.3810	44.9524	17.00	56.00
Ntinda stream at Ntinda- stretcher road	12	27.166 7	4.4890 4	1.2958 8	24.3145	30.0189	21.00	36.00
Total	72	37.000 0	10.167 61	1.1982 6	34.6107	39.3893	17.00	62.00
Potassium Kinawatak a upstream Kinawatak a downstrea m	12	1.3333	.49237	.14213	1.0205	1.6462	1.00	2.00
	12	2.3333	2.1461 7	.61955	.9697	3.6969	1.00	9.00

	Kinawatak a stream at kito bridge	12	1.4167	.51493	.14865	1.0895	1.7438	1.00	2.00
	Kyambogo stream at jinja road	12	3.6667	3.3934 0	.97959	1.5106	5.8227	1.00	9.00
	Ntinda stream at factory road	12	3.9167	3.2321 8	.93305	1.8630	5.9703	1.00	9.00
	Ntinda stream at Ntinda- stretcher road	12	4.0833	3.3698 8	.97280	1.9422	6.2245	1.00	9.00
	Total	72	2.7917	2.7007 4	.31829	2.1570	3.4263	1.00	9.00
Floride	Kinawatak a upstream	12	.0000	.00000	.00000	.0000	.0000	.00	.00

Kinawatak a downstream	12	.0000	.00000	.00000	.0000	.0000	.00	.00
Kinawatak a stream at kito bridge	12	.0000	.00000	.00000	.0000	.0000	.00	.00
Kyambogo stream at jinja road	12	.0000	.00000	.00000	.0000	.0000	.00	.00
Ntinda stream at factory road	12	.0000	.00000	.00000	.0000	.0000	.00	.00
Ntinda stream at Ntinda- stretcher road	12	.0000	.00000	.00000	.0000	.0000	.00	.00
Total	72	.0000	.00000	.00000	.0000	.0000	.00	.00

Chloride	Kinawatak								
	a	12	35.000	5.1698	1.4924				
	upstream		0	4	1	31.7152	38.2848	28.00	45.00
	Kinawatak								
	a	12	44.000	7.0194	2.0263				
	downstream		0	5	4	39.5401	48.4599	34.00	56.00
	m								
	Kinawatak								
	a stream	12	40.000	4.2426	1.2247				
	at kito		0	4	4	37.3044	42.6956	34.00	47.00
	bridge								
	Kyambogo								
	stream at	12	29.166	3.9273	1.1337				
	jinja road		7	7	3	26.6713	31.6620	23.00	37.00
	Ntinda								
	stream at	12	31.166	3.0401					
	factory		7	4	.87761	29.2351	33.0983	26.00	37.00
	road								

Ntinda stream at Ntinda-stretcher road	12	30.3333	3.08466	.89047	28.3734	32.2932	25.00	35.00
Total	72	34.9444	7.04890	.83072	33.2880	36.6009	23.00	56.00
Sulphates Kinawatak a upstream	12	9.7250	.37203	.10740	9.4886	9.9614	8.90	10.00
Kinawatak a downstream	12	8.2167	.91536	.26424	7.6351	8.7983	6.80	9.50
Kinawatak a stream at kito bridge	12	8.7500	.46613	.13456	8.4538	9.0462	7.90	9.50
Kyambogo stream at jinja road	12	11.8500	2.56320	.73993	10.2214	13.4786	9.10	16.00

	Ntinda stream at factory road	12	14.833 3	1.7494 6	.50503	13.7218	15.9449	13.00	18.00
	Ntinda stream at Ntinda- stretcher road	12	14.833 3	2.5878 5	.74705	13.1891	16.4776	11.00	19.00
	Total	72	11.368 1	3.1790 2	.37465	10.6210	12.1151	6.80	19.00
Nitrite	Kinawatak a upstream	12	.0167	.03892	.01124	-.0081	.0414	.00	.10
	Kinawatak a downstream	12	.0000	.00000	.00000	.0000	.0000	.00	.00
	Kinawatak a stream at kito bridge	12	7.6667	8.1501 1	2.3527 3	2.4883	12.8450	.00	18.00

	Kyambogo								
	stream at	12	.0000	.00000	.00000	.0000	.0000	.00	.00
	jinja road								
	Ntinda								
	stream at	12	.0000	.00000	.00000	.0000	.0000	.00	.00
	factory								
	road								
	Ntinda								
	stream at								
	Ntinda-	12	2.7000	2.9083	.83955	.8522	4.5478	.00	6.40
	stretcher			0					
	road								
	Total	72	1.7306	4.4419	.52349	.6867	2.7744	.00	18.00
				8					
Nitrate	Kinawatak								
	a	12	8.0667	.60653	.17509	7.6813	8.4520	6.90	8.90
	upstream								
	Kinawatak								
	a	12	11.491	3.8688	1.1168	9.0335	13.9498	7.40	17.00
	downstrea		7	6	4				
	m								

	Kinawatak								
	a stream	12	9.2083	3.9338	1.1356	6.7089	11.7078	5.10	15.00
	at kito			8	1				
	bridge								
	Kyambogo								
	stream at	12	2.5833	2.2094	.63780	1.1795	3.9871	.30	5.20
	jinja road			2					
	Ntinda								
	stream at	12	6.1667	1.9448	.56143	4.9310	7.4024	4.10	8.80
	factory			5					
	road								
	Ntinda								
	stream at	12	6.5500	1.4009	.40443	5.6599	7.4401	5.00	9.30
	Ntinda-			7					
	stretcher								
	road								
	Total	72	7.3444	3.7649	.44370	6.4597	8.2292	.30	17.00
				2					
Ammoniu	Kinawatak								
m	a	12	.2167	.11934	.03445	.1408	.2925	.00	.40
	upstream								

Kinawatak a downstream	12	.1417	.11645	.03362	.0677	.2157	.00	.30
Kinawatak a stream at kito bridge	12	.0917	.07930	.02289	.0413	.1420	.00	.20
Kyambogo stream at jinja road	12	2.8917	2.9907 3	.86335	.9914	4.7919	.00	6.60
Ntinda stream at factory road	12	.0833	.08348	.02410	.0303	.1364	.00	.20
Ntinda stream at Ntinda- stretcher road	12	.1833	.14668	.04234	.0901	.2765	.00	.40
Total	72	.6014	1.5689 3	.18490	.2327	.9701	.00	6.60

Phosphate	Kinawataka upstream	12	.5833	.07177	.02072	.5377	.6289	.50	.70
	Kinawataka downstream	12	.2000	.07385	.02132	.1531	.2469	.10	.30
	Kinawataka stream at kito bridge	12	.2333	.04924	.01421	.2020	.2646	.20	.30
	Kyambogo stream at jinja road	12	.1833	.05774	.01667	.1467	.2200	.10	.30
	Ntinda stream at factory road	12	.3500	.11677	.03371	.2758	.4242	.20	.50

	Ntinda stream at								
	Ntinda- stretcher road	12	.7417	.20652	.05962	.6104	.8729	.50	1.00
	Total	72	.3819	.23696	.02793	.3263	.4376	.10	1.00
Manganese	Kinawatak a upstream	12	.0000	.00000	.00000	.0000	.0000	.00	.00
	Kinawatak a downstream	12	.0000	.00000	.00000	.0000	.0000	.00	.00
	Kinawatak a stream at kito bridge	12	.0000	.00000	.00000	.0000	.0000	.00	.00
	Kyambogo stream at jinja road	12	.0000	.00000	.00000	.0000	.0000	.00	.00

	Ntinda stream at factory road	12	.0000	.00000	.00000	.0000	.0000	.00	.00
	Ntinda stream at Ntinda- stretcher road	12	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	72	.0000	.00000	.00000	.0000	.0000	.00	.00
BOD	Kinawatak a upstream	12	46.6667	5.61384	1.62057	43.0998	50.2335	38.00	55.00
	Kinawatak a downstream	12	34.1667	4.91442	1.41867	31.0442	37.2891	26.00	41.00
	Kinawatak a stream at kito bridge	12	30.0000	3.86123	1.11464	27.5467	32.4533	23.00	37.00

	Kyambogo		45.833	12.021	3.4702				
	stream at	12				38.1953	53.4714	25.00	63.00
	jinja road		3	45	9				
	Ntinda								
	stream at	12	66.333	7.8083	2.2540				
	factory					61.3722	71.2945	53.00	78.00
	road		3	1	6				
	Ntinda								
	stream at	12	59.500	7.6693	2.2139				
	Ntinda-					54.6272	64.3728	48.00	72.00
	stretcher		0	0	4				
	road								
	Total	72	47.083	14.777	1.7416				
			3	93	0	43.6107	50.5560	23.00	78.00
COD	Kinawatak								
	a	12	80.833	6.0126	1.7356				
	upstream					77.0131	84.6536	70.00	92.00
	Kinawatak								
	a	12	61.500	8.5864	2.4787				
	downstream					56.0444	66.9556	49.00	75.00
	m		0	6	0				

	Kinawatak							
	a stream	12	40.6667	6.69237	1.93192	36.4145	44.9188	29.00
	at kito							52.00
	bridge							
	Kyambogo							
	stream at	12	1.3000	9.29320	2.68272	124.0954	135.9046	115.00
	jinja road							145.00
	Ntinda							
	stream at	12	1.5800	10.91288	3.15028	151.0663	164.9337	140.00
	factory							173.00
	road							
	Ntinda							
	stream at	12	1.2283	9.91632	2.86259	116.5328	129.1339	105.00
	Ntinda-							140.00
	stretcher							
	road							
	Total	72	98.9722	42.26542	4.98103	89.0403	108.9041	29.00
								173.00
SiO2	Kinawatak							
	a	12	30.5000	1.88294	.54356	29.3036	31.6964	27.00
	upstream							33.00

Kinawatak a downstream	12	32.6667	5.14045	1.48392	29.4006	35.9328	25.00	41.00
Kinawatak a stream at kito bridge	12	30.6667	4.49916	1.29880	27.8080	33.5253	24.00	38.00
Kyambogo stream at jinja road	12	30.5000	2.67989	.77362	28.7973	32.2027	26.00	34.00
Ntinda stream at factory road	12	30.5000	2.23607	.64550	29.0793	31.9207	28.00	35.00
Ntinda stream at Ntinda- stretcher road	12	30.6667	3.28449	.94815	28.5798	32.7535	24.00	35.00
Total	72	30.9167	3.45902	.40765	30.1038	31.7295	24.00	41.00

Appendix 2: Summary of ANOVA results for water quality parameters

		Sum of Squares	df	Mean Square	F	Sig.
potential Hydrogen	Between Groups	3.958	5	.792	1.415	.230
	Within Groups	36.917	66	.559		
	Total	40.875	71			
Electrical conductivity	Between Groups	3429.778	5	685.956	119.349	.000
	Within Groups	379.333	66	5.747		
	Total	3809.111	71			

Total.Alkalinity	Between Groups	38152.944	5	7630.589	216.176	.000
	Within Groups	2329.667	66	35.298		
	Total	40482.611	71			
Total.Hardness	Between Groups	12365.833	5	2473.167	13.378	.000
	Within Groups	12201.667	66	184.874		
	Total	24567.500	71			
Calcium Hardness	Between Groups	3246.569	5	649.314	2.302	.055
	Within Groups	18618.083	66	282.092		
	Total	21864.653	71			
Total.Iron	Between Groups	7.081	5	1.416	79.594	.000
	Within Groups	1.174	66	.018		
	Total	8.255	71			
sodium	Between Groups	2912.000	5	582.400	8.681	.000
	Within Groups	4428.000	66	67.091		
	Total	7340.000	71			

Potassium	Between Groups	95.125	5	19.025	2.970	.018
	Within Groups	422.750	66	6.405		
	Total	517.875	71			
Floride	Between Groups	.000	5	.000	.	.
	Within Groups	.000	66	.000		
	Total	.000	71			
Chloride	Between Groups	2117.778	5	423.556	19.826	.000
	Within Groups	1410.000	66	21.364		
	Total	3527.778	71			
Sulphates	Between Groups	524.804	5	104.961	35.943	.000
	Within Groups	192.732	66	2.920		
	Total	717.537	71			
Nitrite	Between Groups	577.189	5	115.438	9.249	.000
	Within Groups	823.723	66	12.481		
	Total	1400.913	71			

Nitrate	Between Groups	550.579	5	110.116	15.944	.000
	Within Groups	455.818	66	6.906		
	Total	1006.398	71			
Ammonium	Between Groups	75.692	5	15.138	10.084	.000
	Within Groups	99.077	66	1.501		
	Total	174.770	71			
Phosphate	Between Groups	3.187	5	.637	52.646	.000
	Within Groups	.799	66	.012		
	Total	3.987	71			
Manganese	Between Groups	.000	5	.000	.	.
	Within Groups	.000	66	.000		
	Total	.000	71			
BOD	Between Groups	11821.833	5	2364.367	42.362	.000
	Within Groups	3683.667	66	55.813		
	Total	15505.500	71			

COD	Between Groups	121788.944	5	24357.789	318.781	.000
	Within Groups	5043.000	66	76.409		
	Total	126831.944	71			
SiO2	Between Groups	44.500	5	8.900	.730	.604
	Within Groups	805.000	66	12.197		
	Total	849.500	71			