

**THE IMPACT OF URBAN LAND USE PRACTICES ON WATER QUALITY IN
RIVER MPANGA IN FORT-PORTAL MUNICIPALITY, KABAROLE DISTRICT**

BY

AKITE LUCY

2010 /U/ HD/O64/MAG

**DISSERTATION SUBMITTED TO KYAMBOGO UNIVERSITY GRADUATE
SCHOOL IN PARTIAL FULFILMENT FOR THE AWARD OF MASTER OF
ARTS IN GEOGRAPHY DEGREE OF KYAMBOGO UNIVERSITY**

2014

DECLARATION

The researcher declares that this is her original work conducted between 2010 and 2013 for the award of Master of Arts in Geography Degree of Kyambogo University. The researcher undoubtedly reserves all the rights to this work. She therefore, wishes to authenticate that this work has never been submitted in any material form in part or wholly for examination purpose to any University or any examination Board other than Kyambogo University. So, the researcher accepts any inaccuracy or oversight that might have been committed during the process of this study.

Signed.....

Date.....31/02/2015.....

AKITE LUCY

RESEARCHER

APPROVAL

This dissertation has been conducted under the Supervision of Associate Professor Dr. Nabalegwa M. Wambede and Mr. Watsusi Cosmas Nicholas with the assistance of the entire Lecturers of the Department of Geography and Social Studies, Faculty of Arts and Social Sciences, Kyambogo University. It has been approved for submission to the Graduate Board of Examiners for the award of the Degree of Master of Arts in Geography with the approval of:

Signed.......... Date..........

ASSOCIATE PROFESSOR DR. NABALEGWA M. WAMBEDE

PRINCIPAL SUPERVISOR

Signed.......... Date..........

MR. WATSUSI COSMAS NICHOLAS

CO-SUPERVISOR

DEDICATION

I dedicate this work to God the Almighty Father, Jesus Christ and the Holy Spirit, my dearly beloved parents, Late Mr. Constantino Akaca Ogwal and Mrs. Hellen Ichaka Akaca who mattered a lot to me since my child hood, my Congregation of the Daughters of Saint Therese of the Child Jesus and the Catholic Scholarship Program for all the motherly, financial and spiritual support. May the almighty and ever living God bless you abundantly.

ACKNOWLEDGEMENT

Special thanks to the Almighty God who has been so cordial, merciful and loving for having granted me the grace, enthusiasm, resources and astuteness to write this dissertation. May His Most Holy Name forever more be glorified and blessed. In the production of this book, I wish to convey my sincere salutation for the contributions made by the following:

The office of the Academic Registrar, Kyambogo University through the Deputy Registrar and the Dean of Graduate School, for giving me the opportunity to study in this University. I thank the Head of Department Geography and SST Mrs. Turyabanawe Loy Gumisiriza for her motherly encouragement throughout this program. Special thanks go to her for having availed me with the books in the book bank that have made this study successful.

Special thanks also go to the Lecturing Staff of Geography and SST Department; Associate Professor Dr. Nabalegwa. M. Wambede, the Principal Supervisor who guided me throughout this study. He is thanked for availing me his valuable time, energy, text books and encouragement. The role played by Mr. Watusi Cosmas Nicholas, the Co-supervisor is very much acknowledged for the entire guide throughout this study. Mrs. Ssekande Gertrude and Mr. Kinyera Apuke George are remembered for imparting knowledge and reading skills into the researcher. ICT Office of Kyambogo University is thanked for all the technical assistance given towards the production of this book.

The authorities of Kabarole district and Fort-Portal Municipality in particular for the support rendered to me during the whole process. Dr. Muhamed Babu Research Manager Department, NEMA Library and the entire staff of National Water and Sewage Co-operation Central Laboratory-Bugolobi and the staff of National Water and Sewage Co-operation Fort-Portal branch are thanked for providing me the facilities for analyzing my data with them and for all the assistance and guidance during the course of the analysis. A very special thanks to the Catholic Scholarship Program in Kisubi for the Scholarships granted to me. Special thanks to Br. Dr. Ssekate Vincent for all the assistance given during the study. My dearly beloved family members are in a very special way thanked for all the moral, spiritual support and especially for the love manifested in the care they granted to me. Not forgetting my dearly beloved sister Late Josephine Akao Akaca for all the support and prayers while still with us, may her soul rest in eternal peace. May the Almighty God bless all of you abundantly.

TABLE OF CONTENTS

| | |
|--|-------------|
| DECLARATION | i |
| APPROVAL | ii |
| DEDICTAION | iii |
| ACKNOWLEDGEMENT | iv |
| LIST OF TABLES | ix |
| LIST OF PLATES | x |
| LIST OF FIGURES | xii |
| LIST OF APPENDICES | xiii |
| ABSTRACT | xiv |
| CHAPTER ONE: INTRODUCTION | 1 |
| 1.0 BACKGROUND TO THE STUDY | 1 |
| 1.1 Statement of the Problem | 5 |
| 1.2 Objectives of the Study | 7 |
| 1.2.1 General Objective | 7 |
| 1.2.2 Specific Objectives | 7 |
| 1.3 Research Questions..... | 7 |
| 1.4 Justification of the study | 7 |
| 1.5 Significance of the study..... | 9 |
| 1.6 Scope of the Study | 10 |
| 1.7 General description of the study area..... | 10 |
| 1.7.1 Location of the study area..... | 10 |
| 1.7.2 Physical Characteristics of the Study Area | 11 |
| 1.7.2.1 Climate..... | 11 |
| 1.7.2.2 Hydrology | 11 |
| 1.7.2.3 Geomorphology | 13 |
| 1.7.2.4 Geology | 15 |
| 1.7.2.5 Soils..... | 15 |
| 1.7.2.6 Vegetation | 15 |
| 1.7.2.7 Topography | 15 |
| 1.8 Population and Economic Activities..... | 17 |
| 1.8.1 Population | 17 |

| | |
|--|----|
| 1.8.2 Economic Activities | 17 |
| 1.9 Operational Definitions..... | 17 |
| LITERATURE REVIEW | 21 |
| 2.1 Land Use | 21 |
| 2.2 Water Quality | 22 |
| 2.3 The physical characteristics of water | 23 |
| 2.3.1 Total Dissolved Solids (TDS)..... | 23 |
| 2.3.2 Electrical conductivity | 23 |
| 2.3.3 Total Suspended Matter (solids) | 24 |
| 2.4 Chemical characteristics | 25 |
| 2.4.1 Water pH..... | 25 |
| 2.4.2 Nitrate and Total Phosphate..... | 26 |
| 2.4.3 Biochemical oxygen demand (BOD)..... | 28 |
| 2.4.4 Chemical oxygen demand..... | 29 |
| 2.5 Biological characteristics | 29 |
| 2.6 Relationships between urban land use practices and the quality of water | 30 |
| 2.6.1 Residential..... | 31 |
| 2.6.2 Agricultural activities..... | 33 |
| 2.6.2.1 Fertilizers | 33 |
| 2.6.2.2 Biocides..... | 34 |
| 2.6.2.3 Animal Wastes | 35 |
| 2.7 Mining..... | 35 |
| 2.8 Industrial Activities..... | 36 |
| 2.9 Water Transportation | 37 |
| 2.10 Comparison of the water quality before reaching the urban area, and after the urban center..... | 38 |
| CHAPTER THREE..... | 43 |
| METHODOLOGY | 43 |
| 3.1 Research design..... | 43 |
| 3.2 Determining sampling area | 43 |
| 3.2.1 Sampling Techniques..... | 44 |
| 3.3 Data Collection | 45 |
| 3.3.1 Instruments for Data Collection..... | 45 |

| | |
|---|----|
| 3.4 Comparing the quality of water before (inflow), within urban center and after the water in the river has left the urban area (outflow)..... | 45 |
| 3.5 Method used for Data Collection..... | 47 |
| 3.6 Methods used during laboratory analysis of sample of water..... | 48 |
| 3.6.1 Physical parameter..... | 48 |
| 3.6.1.1 Electrometric method for total dissolved solids by use of EC meter..... | 48 |
| 3.6.1.2 Determining electrical conductivity by use of electrometric method and EC meter..... | 48 |
| 3.6.1.3 Determining Total Suspended Solids (Matter) by use of Photometric method and spectrophotometer..... | 49 |
| 3.7.1 Chemical parameters..... | 49 |
| 3.7.1.1 Determining of pH water by use of Electrometric Method..... | 49 |
| 3.7.1.2 Determining BOD by use of Azinde Modification of Wrinkler Method..... | 50 |
| 3.7.1.3 Determining C.O.D by use of closed reflux calorimetric method and spectrophotometer..... | 52 |
| 3.7.1.4 Determining Total phosphate by use of Persulphate Method..... | 53 |
| 3.7.1.5 Nitrate determination by cadmium reduction and spectrophotometric method..... | 54 |
| 3.8.1 Biological parameter..... | 55 |
| 3.8.1.1 Determining Fecal Coli form by use of Membrane Filtration Method (MFM)..... | 55 |
| 3.9 Methods of Data Analysis..... | 56 |
| CHAPTER FOUR..... | 58 |
| PRESENTATION AND DISCUSSION OF THE RESEARCH FINDINGS..... | 58 |
| 4.1 Land use practices and their sizes along Mpanga River in Fort-Portal Municipality..... | 58 |
| 4.2 Different land use practices along Mpanga River in Fort-Portal Municipality..... | 60 |
| 4.2.1 Land uses and water quality in River Mpanga..... | 62 |
| 4.4 Land uses and water quality along River Mpanga..... | 63 |
| 4.5.1 Relationships between unplanned settlement land use and water quality..... | 63 |
| 4.5.1.1 Physical, chemical and biological characteristics of water in unplanned settlement land uses..... | 64 |
| 4.5.2 Car washing bay land use and water quality..... | 68 |
| 4.5.2.1 Physical, chemical and biological characteristics of water at car washing bay land use.. | 69 |
| 4.5.3 Planned settlement land use and water quality..... | 72 |
| 4.5.3.1 Physical characteristics of water in the river within planned settlement land use..... | 73 |
| 4.5.4 Municipal abattoir land use and water quality..... | 75 |
| 4.5.4.1 Physical, chemical and biological characteristics of water within municipal abattoir..... | 76 |

| | |
|--|-----|
| 4.5.6 Commercial land use and water quality..... | 82 |
| 4.5.6.1 Physical, chemical and biological characteristics of water within commercial land use . | 83 |
| 4.5.7 Agro-forestry land use and water quality..... | 86 |
| 4.5.7.1 Physical, chemical and biological characteristics of water within agro-forestry land use | 87 |
| 4.5.8 Animal grazing farm land use and the quality of water | 88 |
| 4.5.8.1 Physical, chemical and Biological characteristics of water within animal grazing land use | 89 |
| 4.5.9 Cultivated land use and the quality of water..... | 91 |
| 4.5.9.1 Physical, chemical and biological characteristics of the water within cultivated farm | 92 |
| 4.5.10 <u>comparing</u> the quality of water in the river from Inflow to Municipality at the border of Bukuku and Fort-Portal Municipality and Outflow in Kijura | 93 |
| 4.5.10.1 Physical, chemical and biological characteristics of water at the outflow and inflow ... | 95 |
| 4.5.10.1. Physical characteristics of water at inflow and out flow | 96 |
| 4.5.10.2 Chemical characteristics of water at inflow and out flow..... | 99 |
| 4.5.10.3 Biological characteristics of water at inflow and out flow | 107 |
| CHAPTER FIVE..... | 109 |
| CONCLUSIONS AND RECOMMENDATIONS | 109 |
| 5.1.0 Conclusion | 109 |
| 5.1.1. Land Use practices along Mpanga River in Fort-Portal Municipality..... | 109 |
| 5.1.2 The Relationships between the different land use practices and their physical, chemical and biological characteristics of the water in River Mpanga, Fort-Portal | 109 |
| 5.1.3 Comparisons of water quality in the river before and after leaving the urban area..... | 114 |
| 5.2 RECOMMENDATIONS | 115 |
| REFERENCES | 121 |
| APPENDICES..... | 126 |

LIST OF TABLES

| | |
|---|----|
| Table 2.1: showing the pH Scale and some examples | 26 |
| Table 4.1: showing an approximation of Land use practices and their sizes in Fort-Portal Municipality | 60 |
| Table 4.2: showing physical, chemical and biological characteristics of water within the unplanned settlement land uses..... | 65 |
| Table 4.3: showing physical, chemical, and biological characteristics of water from car washing bay land use along River Mpanga. | 69 |
| Table 4.4: showing physical, chemical, and biological characteristics planned settlement land use along River Mpanga | 73 |
| Table 4.5: showing physical, chemical, and Biological characteristics of water within Municipal abattoir | 76 |
| Table 4.6: showing physical, chemical, and biological characteristics within the industrial land use along Mpanga River..... | 78 |
| Table 4.7: showing physical, chemical, and biological characteristics within commercial land use along Mpanga River | 83 |
| Table 4.8: showing physical, chemical, and biological characteristics of water within agroforestry land use along Mpanga River | 87 |
| Table 4.9: showing the physical, chemical, and biological characteristics of water within animal grazing land use..... | 89 |
| Table 4.10: showing physical, chemical, and biological characteristics of the river within cultivated land use..... | 92 |
| Table 4.11: showing the physical, chemical and biological characteristics of water at the outflow and inflow | 96 |

LIST OF PLATES

| | |
|--|----|
| Plate 3.1 Photograph showing analysis of pH using the pH meter | 50 |
| Plate 3.2 photographs showing laboratory preparations of BOD test..... | 51 |
| Plate 3.3 Photograph showing the analysis of BOD after 5 days using Azinde Modification of Wrinkler method by use of Dissolved Oxygen Meter | 52 |
| Plate 3.4 photographs showing the laboratory analysis of COD | 53 |
| Plate 3.5 photographs showing the analysis of TP by use of persulphate method. | 54 |
| Plate 3.6 Photographs showing Laboratory preparation, analysis of Fecal Coli form..... | 55 |
| Plate 3.7 Photographs showing the counting and recording of colonies after incubation | 56 |
| Plate 4.1 showing photograph of one of the unplanned settlement land use in Kisenyi Fort- Portal Municipality along Mpanga River..... | 64 |
| Plate 4.2 showing photographs of some activities within the unplanned settlement land use along Mpanga River in Kisenyi which are able to increase TSS and COD..... | 67 |
| Plate 4.3 showing photograph of car washing bay land use along Mpanga River in Nakaseke which are able to increase TSS and COD. | 69 |
| Plate 4.4 showing photographs of planned settlement land use in Booma which is along River Mpanga..... | 72 |
| Plate 4.5 showing photograph of municipal abattoir or slaughtering slab land use within Fort- Portal Municipality at Kabundaire along Mpanga River | 75 |
| Plate 4.6 showing photographs of some of the small scale industries land use in Fort-Portal Municipality along Mpanga River | 78 |
| Plate 4.7 showing photograph of one of the brick making industries in Kabundaire industrial area which are capable of increasing TSS in the river..... | 80 |
| Plate 4.8 showing photographs of one of the grinding mills in Kabundaire industrial area which are capable of increasing TSS in the river..... | 81 |

| | |
|--|----|
| Plate 4.9 showing photograph of commercial land use case study Mpanga market..... | 82 |
| Plate 4.10 showing photographs of some of the activities within Mpanga market capable of increasing EC and TDS in the river. | 84 |
| Plate 4.11 showing photographs of some of the goods sold within Mpanga market able of increasing TSS in the river..... | 85 |
| Plate 4.12 showing photograph of some of the produce sold in Mpanga market able to contribute to BOD in the river | 86 |
| Plate 4.13 showing photograph of people preparing soil for tree nursery bed and containers or bags for transplanting ready seed lings within agro forestry land use..... | 87 |
| Plate 4.14 showing photograph of the animal grazing farm along Mpanga River Fort-Portal Municipality | 89 |
| Plate 4.15 showing photograph of the cultivated land use in Fort-Portal Municipality | 91 |
| Plate 4.16 showing photograph of the sampling point at inflow from the boarder of Bukuku and Fort-Portal Municipality..... | 94 |
| Plate 4.17 showing photograph of the outflow sampling spot from Kijura outside Fort-Portal Municipality..... | 95 |

LIST OF FIGURES

| | |
|--|-----|
| Figure 1.1 showing map of River Mpanga Catchment Area. | 12 |
| Figure 1.2 map showing relief and drainage within Fort-Portal Municipality. | 14 |
| Figure 1.3 showing topographic map of Fort-Portal Municipality. | 16 |
| Figure 2.1 Conceptual Framework of the Research..... | 41 |
| Figure 3.1 schematized map showing selection of sampling stations (spots) along a river ... | 46 |
| Figure 3.2 showing various zones in a river after addition of an organic waste..... | 46 |
| Figure 4.1 showing the map of Fort-Portal Municipality: Land Use..... | 59 |
| Figure 4.2 map showing the Land use practice along River Mpanga in Fort-Portal Municipality | 61 |
| Figure 4.3 showing the mean plot for TDS at inflow and out flow | 96 |
| Figure 4.4 showing the mean plot for EC at inflow and out flow..... | 98 |
| Figure 4.5 showing the mean plot for TSS at inflow and out flow..... | 99 |
| Figure 4.6 showing the mean plot for pH at inflow and outflow..... | 101 |
| Figure 4.7 showing the mean plot for BOD at inflow and out flow | 102 |
| Figure 4.8 showing the mean plot for COD at inflow and out flow | 104 |
| Figure 4.9 showing the mean plot for TP at inflow and out flow | 106 |
| Figure 4.10 showing the mean plot for NO ₃ at inflow and out flow | 107 |
| Figure 4.11 showing the mean plot for FC at inflow and out flow..... | 108 |

LIST OF APPENDICES

| | |
|---|-----|
| Appendix I: Lists of Acronyms and Abbreviations..... | 126 |
| Appendix II: An observation Guides..... | 128 |
| Appendix III: National standards for waste water discharge, NEMA Standards, (2009 Revised)..... | 129 |
| Appendix IV: General table showing the average values on physical, chemical and biological characteristics of water in River Mpangs for each land use under study..... | 130 |

ABSTRACT

This study was conducted in Fort-Portal Municipality, Kabarole District in 2010/2013. Major aims were: identifying and mapping the different land use practices along Mpanga River in Fort-Portal Municipality; to find out the relationships between the different land use practices and the physical, biological and chemical characteristics of the water in River Mpanga in Fort-Portal Municipality in relation to land uses and to compare the quality of water in the river at inflow and outflow. Laboratory analysis of samples of river water taken on the basis of different land uses were done to determine the physical characteristics (parameters included; Total dissolve solids, Total suspended solids and Electrical conductivity). Chemical characteristics (parameters included; Bio-chemical oxygen demand, Chemical oxygen demand, Total Phosphate, pH, and Nitrate). Biological characteristics included; fecal coli form in order to ascertain the degree of the impact of urban land use practices on the quality of water in the river at inflow, within urban center and at outflow. Emphasis was also put to find out whether land uses within urban areas continued to affect water quality in the river when the water had left the Municipality. Survey design and purposive sampling technique were used. Methods of data collection were direct and critical field observations and observation of analysis of samples of water in the Laboratory.

Statistical method of data analysis was standard deviation. Mean results got were presented in constructed tables for each land use and mean plot graphs of the reach which portrayed changes in the quality of water. Conclusively, the land uses in Fort-Portal Municipality have not impacted so much on the river water of Mpanga because most of their average values are below the National Standards with exception of Municipal abattoir where its TP is 18.37 mg/l, COD is 199.50mg/l and Animal grazing farm had a TP average value of 12.34mg/l all are above the National Standards for effluents discharge in water body.

Other land use practices were environmentally friendly. The average values of all the parameters at inflow and outflow presents that there is no pollution. All the urban land uses are recommended along Mpanga River within the Municipality with the exception of animal grazing farm and Municipal abattoir because of their high TP, TSS and COD. Continuous monitoring of water quality at Municipal abattoir by NWSC is required by use of waste Treatment Plant before discharged in the environment. Animal grazing farm need to be far away from the river in order to avoid pollution of river water by their wastes.

CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND TO THE STUDY

Land use according to Food Agricultural Organization (FAO) Guide Line, (1991), is defined as the function of the land determined by natural conditions and human intervention. Land use is therefore the way land is being put into use by man such as land allocated for transportation, residential, markets, agriculture and industrialization. There are other land uses which are natural for example; cover forests, wetlands or swamps and game parks. Cutter et al, (1998), point out that the continents of the world vary considerably in the proportion of land in their uses. For instance, Europe excluding Russia is 30% arable, and Oceania, Africa and South America are only 5 to 7% arable. Ssengendo and Nkunda, (2013), state that over 60% of arable land in Germany is used for the cultivation of grain with wheat, barley and rye being the most important crops while in Uganda 69.7% is for farm land, 21.1% is for grass land, wood land is 16.7%, bush land is 5.9%, wet land is 2.0%, tropical high forest encroached is 1.2%, tropical high forest fully stocked is 2.5%, and open water is 15.3%. In British Columbia, over 50% is covered by productive forest land and 96 % is of coniferous forests.

Enger et al, (2004), point out that in the United State of America, 47% of land is used for forest and natural areas are mostly on the western part of the Mississippi River; nearly 5% of land is intensively used by people in urban centers and transportation corridors. In Canada, 54% is forested and wooded, 8% for crops and livestock, less than 1% of land is in urban centers and transportation corridors and a large percentage of its remaining land is wilderness. These are all allocated according to their suitability for a particular purpose.

Pacione, (2005), noted that urban land use in China in Yang Puzhong include agriculture where fish, livestock, vegetables and fruits are grown. For instance in Shanghai city, vacant spaces near houses are used for agro-forestry systems like orange trees, vegetables and legume plants with the help of fertilizers. National Curriculum Development Centre and Ministry of Education, (1993), point out that, many of the world's largest cities such as New York, London, and Bombay have ports sited on good harbors where ships can unload in sheltered

waters. They also have good hinterlands where large populations have settled and good communication networks like roads, railway lines and water transport which link the ports to their hinterlands.

For the case of New York City, the urban land uses have industries which are over 40,000 and are making different commodities. Examples of heavy industries are; Iron and steel industry which deal in the manufacture of cars, agricultural machinery and railway wagons. Engineering industry deals with ship-building and repairing, production of engines, motor cars, locomotives and aluminum smelting industry. The examples of light industries include; textile industries which deal in the production of clothes, chemical industries dealing in the production of synthetic goods such as; synthetic rubber, plastics, detergents, industrial acids, pharmaceuticals, and fertilizers, printing industry, food processing dealing with brewing, soft drinks, and processing of tea, coffee and cocoa. There are also overwhelming land use practices such as; residential areas in Bronx and Queen's Islands and educational centers like Columbia University, Rockefellers University and New York University.

According to Arber et al, (2001), urban land use in Rio de Janeiro in Southern America is categorized basing on three main divisions within the city, these are:

- The Central Business District (CBD) which is a center with a lot of noise and busy 24 hours a day is full of expensive shops and offices, with high-rise apartments which are also used as residential houses and some factories around Rio's port. The presence of elevated buildings is due to the mountainous and steep nature of the landscape hence no space to expand the buildings horizontally, and since there is no space for road construction, tunnels are cut through the hills.
- Near the CBD is an unplanned area called *a favela* or shanty town in Rochina, with about 100,000 residents, with poorhouses, and poor basic services like garbage collection, running water and sewage disposal.
- In Barra di Tijuca, which is 30 km to the west of Rio, has a population of 150,000, and the land use is similar to that of the CBD.

According to Hickman, (1999), Nairobi which is the largest city and industrial center in East Africa is a good example of the growth of a large town and national capital city which is divided into functional areas of which each is for a purpose. Chief activities or land uses

include government activities such as; offices for the President, parliament and public buildings which are close to each other, to the east of Nairobi city there is Moi Avenue which forms a corridor of important business offices, hotels, entertainment places such as cinema halls and restaurants. Further, in the northern and eastern regions there are mixed developments such as; small shops, workshops, ware houses, residential houses, and markets, Uhuru Highway marks the western edge of the central area, fringed by Uhuru parks and central parks, sports areas, university halls of residence and hotels and there are more government houses on Nairobi hill and tracks of railway lines.

Hickman continues to affirm that Zanzibar which is one of the towns at the East African coast is characterized by many land uses such as; industrial development in the east, residential houses and shops within and out skirt of the town, there are playgrounds on the open lands, places of worship like the Anglican Cathedral which is now built on the site of the former slave market, many mosques and government offices. In Kampala, the dominant land uses within the CBD are; business centers, markets, parks for vehicles, communication networks, and government offices, residential behind commercial houses, open spaces for recreation, industries and institutions. Outside the city there are intensive agriculture on a small scale in Kisaasi, residential, government offices, business centers, urban sprawling like in; Kinawataka, Nakawa, Banda, Acholi Quarters and institutions of learning.

Bowen and Pallister, (2001), assert that, human settlements crowded in towns and cities of Least Economic Developed Countries (LEDCs) such as Cairo and especially Al-Munira in Africa are crowded with 600,000 people into just two square kilometers of land extending up to the fertile irrigated farm land along the banks of River Nile. Bowen continues to claim that heavy settlements in urban centers of Africa have led to the danger of pollution from domestic wastes. For instance, in Nairobi city, piles of garbage are common within residential estates like in Mashia estate and Mathare valley all in Kenya, Mombasa, Dar-as-Salaam, Lagos and several cities in Africa have inadequate garbage storage and collection systems. This is worsened by poor sewage systems which are directed into the river from this crowded settlement informs of human feces, solid wastes from stores are broken down into ammonia by the action of bacteria; large quantities of oxygen are used up in the process of decomposition hence reducing the number of organisms that can survive in the water. These organisms break down the ammonia into nitrates that lead to the eutrophication of rivers and

algal blooms which use more oxygen, reducing light which deoxygenate the river water hence killing all river life.

Manufacturing industries which are often located close to the water sources have caused serious water pollution because water used for cooling industries is often returned to the river with myriads of other by-products that may be emptied in the water course. They also produce heavy metals which are disposed into the rivers, burning of fossil fuels such as; gas, oil, and coal also discharge large quantities of acids in water and oil spills.

Ojungu, (1992), asserts that most of the manufacturing industries and heavy settlements are concentrated at the coastal towns of East Africa such as; Mogadishu, Mombasa, Malindi, Maputo, Port Louis, Victoria and Beira. Examples of industries are; coffee bean roasting, sugar molasses refining, brewing, rice milling, Sisal processing, paper and pulp production. He continues to state that, as a result, large quantities of aquatic discharges which comprise of suspended solids, chemicals, and heavy metals, sludge, and other dissolved substances are disposed in water body. Agro-based industries produced organic wastes hence contributing to the total bio-chemical oxygen demand (BOD) and as a result features of eutrophication appear causing turbidity, toxicity, lowering biological productivities and increasing turbidity in rivers, bays, wetlands and lakes.

Ojungu noted that in Uganda, most of the water resources such as; lakes, rivers swamps and local depressions have been polluted due to human activity such as; dense settlement due to rapid population growth, increased urbanization and industrialization and to some extent by natural factors like runoff eroding sediments from cultivated lands into the water bodies. Even the lake shores of Kyoga are so choked with erosion of sediments from cultivated fields in Namasaale up to the extent that lake water is inaccessible except where there are rocky shores.

NEMA, (2008), stated that Kampala City Council with the participation of Private Solid Waste Collection Firms collected and disposed only 41 per cent of the solid waste per day and the remaining 59 per cent per day is left uncollected and ended up being dumped in storm water, drainage channels, natural watercourses, manholes, undeveloped plots and roadsides. NEMA, (2004), stated that water resources such as; rivers, wetlands or swamps, streams and springs have been polluted by human activities like grazing of cattle, crop farming like

bananas, yams, beans , vegetables and artificial forestry which have led to the dumping of wastes into them either directly or by runoff from heavy rainfall received.

Mugisha, (2013), noted that water hyacinth threatened to choke Lake Victoria again which has been a source of food, drinking water, irrigation, energy, and means of transportation has also become a disposal site for human, agricultural and industrial wastes which destroy it. For example, Mugisha observed that experts suspect the water weed to have been introduced from Rwanda as an ornamental plant for garden ponds due to its beautiful flowers. These entered Lake Victoria via River Kagera and this has threatened to choke a big part of the lake and when they decompose, they lead to oxygen depletion hence death of aquatic lives. The same Vision points out that a fountain of sewage gushing into Nakivubo road opposite the bus terminal after a heavy pour was disposed into streams and swamps in Kampala hence polluting them with both organic and inorganic wastes from restaurants, settlements and industries.

Kasozi, (2007), pointed out that wastes from fish processing industry in Jinja factories are being dumped in Masese wetland which oozes a brown liquid and flows into Lake Victoria hence poisoning it. Wetlands in Bulenga and Busega in Wakiso district and Nateete in Kampala are being polluted by land uses such as construction of roads and houses, brick laying, tree nursery seedlings, car washing bays and settlement with latrines along the swamps.

NEMA, (2004), asserted that land use allocated along Mpanga River in Fort-Portal Municipality are grinding mills for maize which has caused high turbidity in the water especially when runoff drains the wastes into the river. Petrol stations and Garages which produce metals, oil and grease are situated along the river. Runoff from rainfall transport oil and metals into the river hence polluting the river. There are several commercial activities such as; lockups, and markets just near River Mpanga where traders dump solid and liquid wastes at times direct into the river hence reducing the oxygen demand to aquatic lives.

1.1 Statement of the Problem

According to NEMA, (2008), the quality of water in Uganda has been deteriorating over time during the last two decades due to increasing urbanization, population growth and anthropogenic activities which have resulted into significant deterioration of water quality. NEMA, (2004), observed that Fort-Portal municipality is crossed by River Mpanga which

serves the municipality with water for; human and animal consumption, domestic and, hospitals use, provide fish, recreational purposes and support aquatic biota diversity. Fish and Crocodile Act, (1964), as quoted by NEMA, (2004), emphasized that all natural aquatic resources belong to the government, however there is a misconception among communities and individuals especially those with land completely enclosing water resources such as; rivers, lakes and crater lakes that fresh water resources belong to them and therefore they can manage them in the way they wish. As a result, only 20% of these water resources are under control of the department of fisheries with licensed activities.

As a result of the above misconception, there are various land use activities within Fort-Portal municipality. These include; degradation on hillside through ploughing and grazing of animals as a result of expansion of human settlement leading to siltation of the river and swamps because Kabarole is hilly and mountainous. Pollution from slaughtering slabs e.g. in Kabundaire, pit latrines at the banks of River Mpanga, waste from industrial activities like; crude waragi distillation in Kisenyi in southern division, garages which produce wastes like metals, chemicals, and oil, grinding mills, and brick making industry and rampart open car washing bays at the bank of River Mpanga. These are common in Kisenyi, west and south divisions of Fort-Portal municipality which are threats to water resources.

All these have led to contamination of the river because some of the land uses were developed without carrying out Environmental Impact Assessments (EIA'S) contrary to the provisions of The National Environmental Act Cap.153 NEMA, (2004). Even if serious public awareness and law enforcement has been done, it is at a standstill because people are continuing to build haphazardly in unplanned areas because there is no clear structural plan. According to the Structural Plan for Fort-Portal Municipality, (1998-2018), planned settlements are supposed to be established in Kagote, Rwengoma, Booma, Nyabukara and Kitumba. This is opposed to the present situation where some unplanned settlements have also sprung up within the planned settlement area. Case in point, Kisenyi and Rwengoma which are occupied by unplanned settlements were supposed to be occupied by planned settlement. Places where there are car washing bays are supposed to be for open spaces. In other words, the only planned land uses are; Municipal abattoir, small scale industrial areas in Kabundaire, Mpanga and Kabundaire markets and tree nursery beds (River Mpanga Tree Planting Project donated by Tooro Botanical Gardens). Hence there is a need to carry out

research in order to assess the degree of the impact of Nonpoint Sources (NPS) and Point Sources (PS) which involves discharge of substances from; factories, sewage systems, commercial activities and residential which lead to pollution on water in Mpanga River within Fort-Portal Municipality.

1.2 Objectives of the Study

1.2.1 General Objective

The main objective of the study was to examine the impact of land use practices in Fort-Portal Municipality on the quality of water in River Mpanga.

1.2.2 Specific Objectives

The specific objectives of the study were:

1. To identify and map the different land use practices along Mpanga River, in Fort-Portal Municipality.
2. To find out the relationships between the land use practices and the physical, biological and chemical characteristics of the water in river Mpanga, Fort-Portal Municipality.
3. To compare the quality of water in the river before and after leaving the urban area.

1.3 Research Questions

This study was guided by three interrelated research questions as follows:

1. What are the different land use practices along Mpanga River in Fort-Portal Municipality?
2. Is there a relationship between different land use practices and the physical, biological, and chemical characteristics of the water in river Mpanga in Fort-Portal Municipality?
3. What is the quality of water before the water in the river enters the Municipality and after the river has left Fort-Portal urban area?

1.4 Justification of the study

NEMA, (1996), noted that although Uganda depends on water resources in several ways such as; human consumption both in rural and urban areas, industrial use, livestock and wildlife consumption, marine transportation and generation of power, limited research has been carried out to provide necessary information especially on how various land use practices have impacted on the quality of water resources in urban areas. According to NEMA, (1995),

even where previous studies have been made on Environmental Impact Assessments for water quality and discharge of industrial effluents into water; it has excluded other land use practices like; agriculture, residential, markets, car washing bays, commercial activities and animal grazing .

Most studies on water quality have not paid attention on some independent variables which are land use activities such as; agriculture, residential, settlement and commercial activities which impact a lot on the quality of water. For instance a research carried out by Otim, (2008), which assessed the domestic water quality in Peri Urban Settlement of Lira Municipality and a research carried out by De Zaune, (1990), assessed the drinking water quality, standards and control used for ascertaining its quality. The studies emphasized on the hygiene of water basing on parameters like micro-biological, physical and chemical qualities of water at the source, containers for carrying water and its storage in determining the degree of pollution and contamination. These are done with less regards on land use activities which are independent variables.

A study carried out by Kaggwa, (1998), from the International Institute for Infrastructural Hydraulic and Environmental Engineering on the effects of Water Treatment sludge from industries on a papyrus lake swamp in Kampala. The study was intended to investigate as to whether the swamp was able to purify itself after the disposal of the industrial effluents. In other words, this study only looked at industrial activity as the single contributing factor which alters water quality in the swamp living out other land use practices such as; commercial activities, grazing land for cattle, cultivated land, settlement and car washing bays which also contribute to poor quality water. Lwasa and Mwanje, (1997), also conducted a study on the evaluation of cost- effectiveness on water hyacinth control methods in Lake Victoria and Lake Kyoga ecosystems in Uganda. This study was only intended to evaluate how cost-effective the method can be used for controlling water hyacinth in Lake Victoria and Lake Kyoga. In other words, it has not treated the land use activities which contributed to existence of water hyacinth in the two lakes and yet this has been confirmed earlier by Mugisha, (2013), that the water hyacinth in Lake Victoria was suspected by experts as water weeds introduced from Rwanda as an ornamental plant for garden ponds due to its beautiful flowers and entered Lake Victoria via River Kagera and application of fertilizers on agricultural lands which are in turn washed into the lakes providing fertility for the growth of

water hyacinth. In line with this study; it is therefore worth to examine the impact of other land use practices on the quality of water in urban areas.

1.5 Significance of the study

The various uses to which water is put to have important implication for the state of Uganda's environment as does the way water resources are managed. These water resources are used in several ways such as; human consumption in rural and urban areas, industrial use, livestock and wildlife consumption, marine transportation and power generation. They are also home to rich bio-diversity including fisheries resources. This is why The Water Statute, (1996), and the Water Action Plan, (1995), were set by the government of Uganda as the cornerstones of sustainable water resource management policy to ensure that both quantity and quality are preserved.

Despite of the above strategies put in place, NEMA, (1996) and NEMA, (1998), assert that urban populations have more dramatic impact on water resources due to the concentration of population in a relatively small area leading to the existence of several human activities which have direct impact on water quality within urban centers in Uganda. These include; mining, manufacturing industries, housing, commercial activities, and agriculture which lead to soil erosion and suspended matter, and agro-chemicals wastes, sewage and solid wastes from residential which are disposed in water body as mentioned earlier on. The purpose of this study is therefore to enable the researcher to ascertain which land use practices are more detrimental to the quality of water and which land use practices are environmentally friendly. As a result, the study is anticipated to benefit different categories of people;

- The information generated from this research could as well be vital in promoting further research in the field of water quality management in relation to land use activities in urban areas. This data can be used not only within the municipality but beyond.
- The government especially the district policy makers , planners and architectures will use this study to establish policies that will help the land users to apply appropriate land use allocation in the urban centers and regulate its use so as not to pollute the water resources.

- The study will also help the local community to know the impact of irresponsible land use practices on the quality of water and this will enable them to find out appropriate strategies in overcoming the problem.

1.6 Scope of the Study

The study focused on the impact of urban land use practices on the quality of water. This is because land use practices of an area have a close relationship with the quality of the surrounding water resources. The study also investigated the impact of different land use practices on the physical, biological and chemical characteristics of the water. The most significant parameters which gave the researcher a complete idea of what was happening in the study area and to achieve the objective of the study were; Electrical conductivity and total dissolved solids which gave the mineral content of the water, total suspended solids gave the clarity of water, pH and total phosphate specifically gave the organic pollutant, chemical oxygen demand, nitrate and bio-chemical oxygen demand gave a measure of organic, and inorganic pollution and fecal coli form gave the level of microorganisms in the water body .

Geographically, this study was conducted in Fort-Portal Municipality which covered divisions such as; east, west, and south. But the consideration was put in south and west divisions because of the various land use activities which have sprung up along River Mpanga such as; open car washing bays at the river banks, wastes from markets, small scale industries and agriculture. NEMA, (2004), in its report in Kabarole District, states that some of these land uses were developed illegally and without carrying out Environmental Impact Assessments. Hence it is necessary to carry out a study on the degree of how different land uses have impacted on water quality in the area so as to set appropriate strategies on allocation of different activities along the river for a better quality of water.

1.7 General description of the study area

The general description of the study area covered; the location in terms of absolute and relative; physical aspects such as; relief, geology, geomorphology, soils, drainage, vegetation, climate and the human aspects like; demographic characteristics and economic activities.

1.7.1 Location of the study area

Fort-Portal Municipality is found in Kabarole district in Western Uganda and serves as an administrative and commercial center of the district. Fort-Portal lies on the slopes of mount

Ruwenzori commonly known as mountains of the Moon which is 5050 feet above sea level and is dotted with more than ten small hills.

Fort-Portal Municipality covers an area of about 27,820km² with 3 divisions; East, West and south bordered by Mugusu, Kicwamba, Busoro and Karambi Sub-Counties. Fort-Portal town is the district administrative head quarter of Kabarole district, Ang'ienda et al, (2011),

In terms of absolute location, Fort-Portal Municipality is found in Kabarole district in Western Uganda between 0°40' N of the equator and 30° 19'E of Greenwich according to Ssendendo and Nkunda, (2013). According to Ang'ienda et al, (2011), the municipality divisions are being bordered by Mugusu, Kicwamba, Busoro and Karambi Sub-Counties. In terms of relative location, Fort-Portal Municipality is found in western Uganda, Kabarole district. It is bordered by Bundibugyo, Ntoroko, Kyenjojo, Kamwenge and Kasese districts.

1.7.2 Physical Characteristics of the Study Area

The physical background comprise of component that make the whole environment of the area under study. These include: climate, hydrology, geomorphology, soils, vegetation, topography and geology.

1.7.2.1 Climate

The district receives fairly well distributed bimodal annual rainfall averaging between 1200mm a year with temperature averaging between 20-30 degrees Celsius (maximum) in all parts of the district. However temperatures occasionally fall below 19 degrees Celsius because of the hilly nature and dense vegetation in Fort-Portal and Kabarole district in general which influence the climate of the place. This climatic condition is quite favorable for crops, pasture and water availability NEMA, (2004).

1.7.2.2 Hydrology

River Mpanga which crosses Fort-Portal town is part of hydrological system which is drained by small rivers which may be classified as streams examples are; Rivers Mahoma, Igasa and Rwimi. Much of its water originates from the hills of Kicwamba which is its catchment area. According to hydrology map of Uganda, Fort-Portal Municipality lies in the catchments area of Lake George, Ssendendo and Nkunda, (2013) and NEMA, (2004). The Municipality is drained by river Mpanga through its tributaries such as Nyakimya and

Mugunu finally joined by river Katonga up to Lake George. The tributary rivers originate eastwards and flows westwards. River Mpanga also crosses other towns or districts like Kamwenge and Kyenjojo as shown on figure 1.1. As a result of increased urbanization with many land use practices within the towns, the quality of water in River Mpanga has been altered.

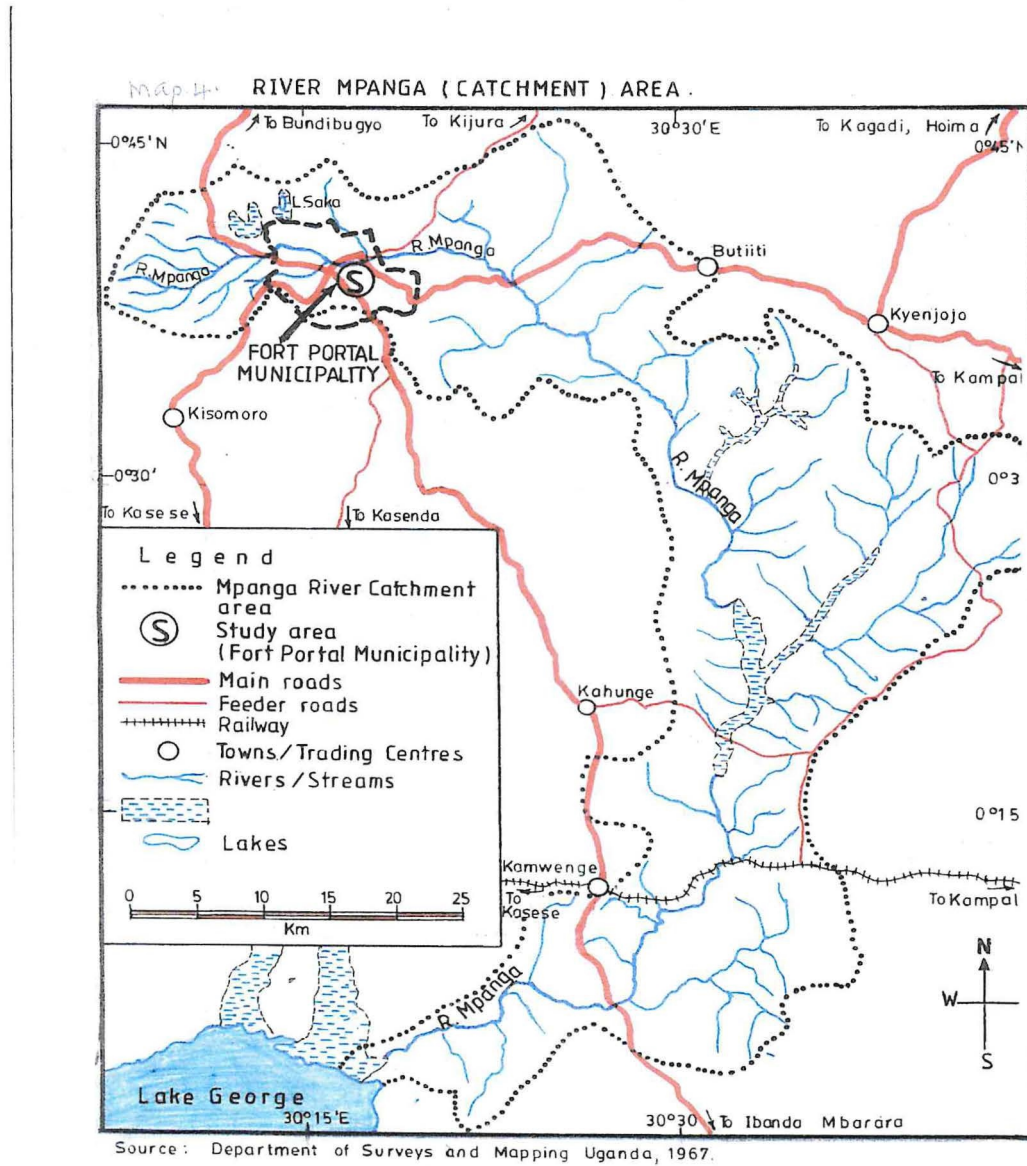


Figure 1.1 showing map of River Mpanga Catchment Area.

1.7.2.3 Geomorphology

This is the study of landforms and the processes which led to their formation. Examples of land forms found in Fort-Portal are; crater lakes, limestone rocks (Amabeere ga Nyinamwiru) such; as stalagmites and stalactites, pillers, hills like Njara and Mwihani and rift valley stretch in Kicwamba as shown on figure 1.2. The origin of the above landforms can be explained under geomorphologic processes such as faulting, volcanicity, warping, fluvial processes and denudation, (Ssengendo and Nkunda, 2013). Fluvial process was affected by up warping in western Uganda which led to the reversal of the direction of the flow of river Katonga eastwards which is joined by Mpanga River and empties its water into Lake George.

Volcanicity and faulting affected north and north east and southern parts of Fort-Portal leading to formations of crater lakes (Saka, Nkuruba, and Rwetera), rift valley stretches in Kicwamba as a result of eastward extension of the Albertine rift valley and hills such as Njara and Mwihani. Adjacent to Lake Saaka are the limestone rocks of Nyakasura. These are formed as a result of chemical weathering process called carbonation. This has resulted into a hilly topography in Fort-Portal. Physical weathering, erosion, transportation and deposition have also led to relatively gently sloping flat land at the foot of the hills as seen on figures 1.2 and 1.3.

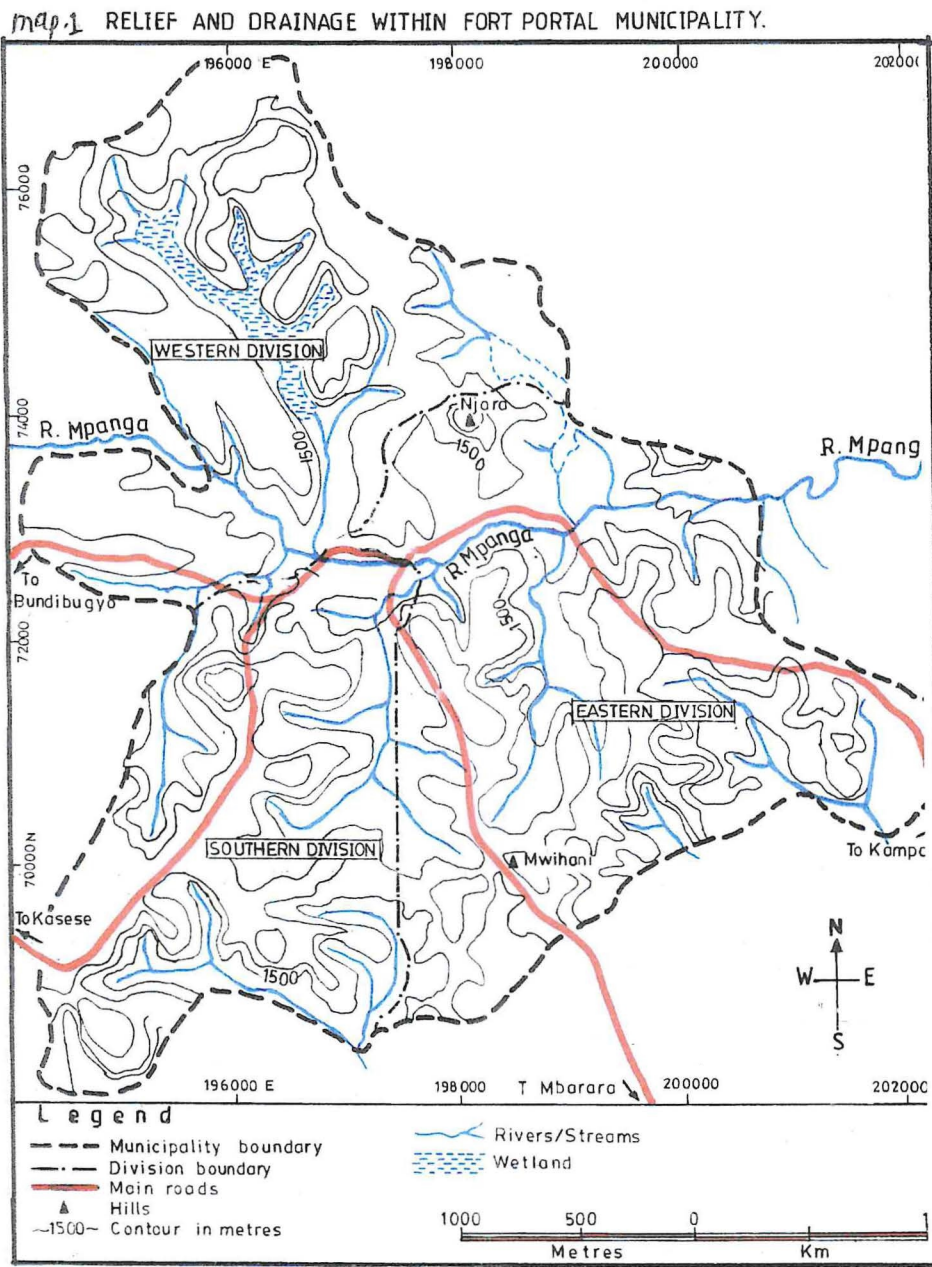


Figure 1.2 map showing relief and drainage within Fort-Portal Municipality.

1.7.2.4 Geology

According to Ssendendo and Nkunda, (2013), Atlas of Uganda, (1962), and NEMA, (1996), the predominant rocks of Uganda are of Precambrian rocks of basement complex formed between 3000-6000 million years ago and these are very old rocks. The younger rocks are of sediments or volcanic origin formed from about 135 million years ago (cretaceous period) to the present. According to map of Uganda in Atlas of Uganda, (1962), the eastern and northern part of Fort-Portal is covered by Pleistocene to recent volcanic rocks and the rest of Fort-Portal is covered by basement complex (Precambrian) mainly of undifferentiated acid gneiss.

1.7.2.5 Soils

Fort-Portal municipality shares the same kind of soil with the rest of the district of Kabarole. For instance the municipality has black loams over red sandy clay loams soils which are volcanic soils. This is shared by west and north of Burahya which include Kicwamba, Maguru, Fort-Portal Municipality, Ruteete and parts of Hakibaale. These are underlain by lateritic soils NEMA, (2004).

1.7.2.6 Vegetation

Within Fort-Portal Municipality, there is a central forest reserve managed by NFA (National Forest Authority). It consists of four blocks of Bihaiga, Mpanga, Nyakimya and Hospital block. Bihaiga is partly planted with eucalyptus trees by a private farmer while the remaining part is being established into a botanical garden with so many different tree species by Tooro Botanical Gardens which is a Non-Governmental Organization (NGO). Mpanga block was encroached by Mpanga Secondary School which erected containers and some houses for teachers while Nyakimya which is a wetland is encroached by some agriculturalists and establishment of dairy farms. Being a town center, all forms of legal and illegal activities take place there due to high population levels with increased demand for forest products, NEMA, (2004).

1.7.2.7 Topography

According to Ssendendo and Nkunda, (2013) and on map on figure 1.3, topographically Fort-Portal Municipality lies on the slopes of mount Rwenzori which is 5050 feet (1250-1500) above sea level dotted with Njara Hill in the northwest and Mwhani hill in the south east as shown on figures 1.2 and 1.3. Fort-Portal Municipality is generally hilly characterized

by steep slopes but western division is gently sloping up to the valley which is occupied by seasonal papyrus swamp. This swamp starts from Booma to Nyabukara up to extreme western division.

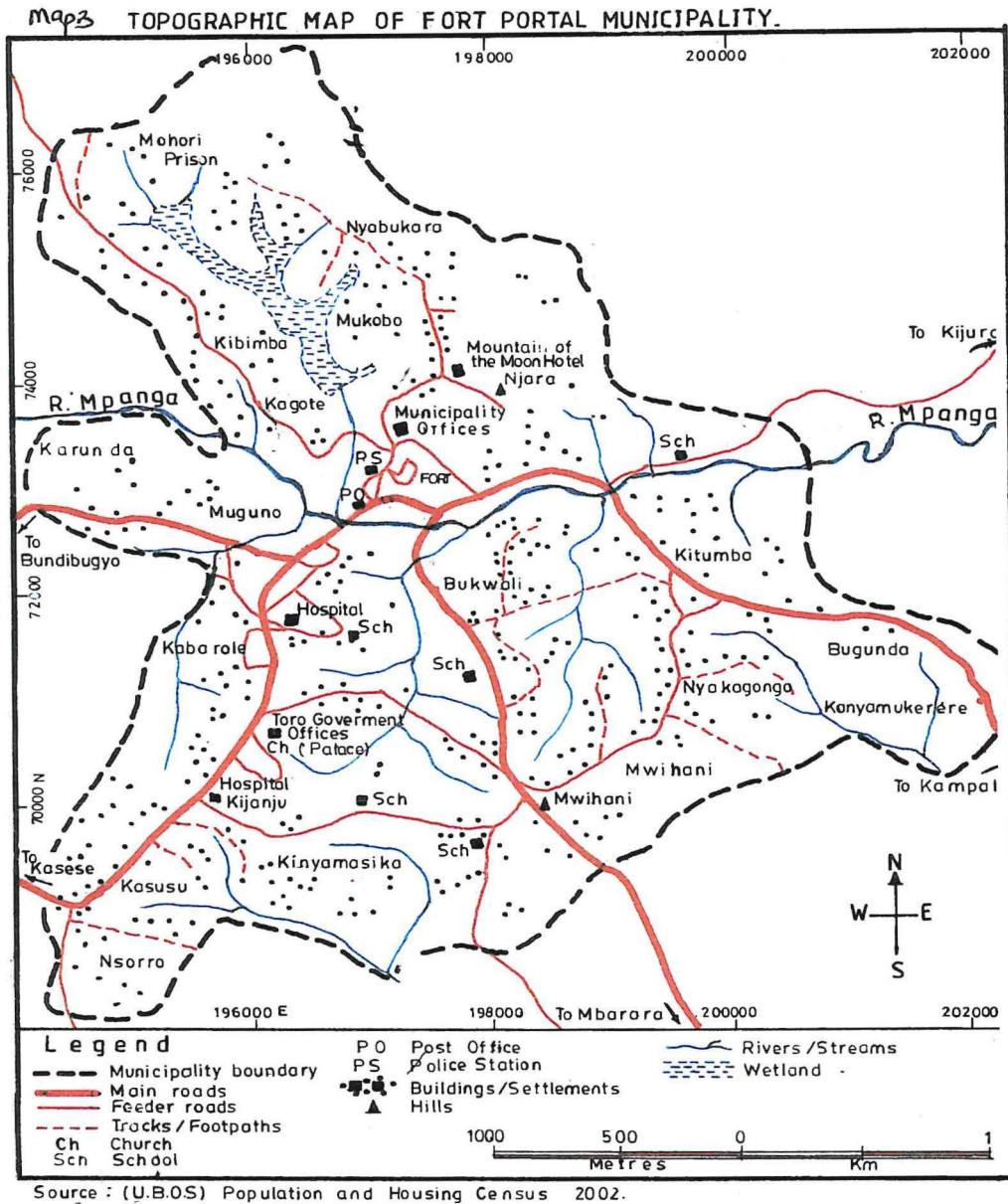


Figure 1.3 showing topographic map of Fort-Portal Municipality.

1.8 Population and Economic Activities

1.8.1 Population

The municipality is projected to be having a total population of about 84,144 persons according to 2010 population census estimate, and is comprised of three divisions; east, west and south with a population of about 2,960, 228,412 and 26,130 respectively basing on the 2002 census, Ang'ienda, et al, (2011).

1.8.2 Economic Activities

The major economic activities within Fort-Portal Municipality are mainly commercial activities, subsistence agriculture through the growing of crops such as; beans, groundnuts, millet, cassava, Irish potatoes, vegetables and fruits. Plantation farming such as; tea, coffee, bananas, and dairy farming. Others include; Nguli or waragi distilling, sand and murrum mining, charcoal burning, brick making, and retail trade with a few small scale industries adjacent to Riversuch as; Mpanga and Kabundaire Markets, medical health services such as; Buhinga, Kabarole hospitals and Virika hospital, Ang'ienda et al, (2011). Basing on the above economic activities, the quality of the water in River Mpanga is altered through wastes disposal either directly or indirectly.

1.9 Operational Definitions

- Land use:** is defined as the function of the land determined by natural conditions and human intervention. Land use is therefore the way land is being put into use by man such as land allocated for transportation, residential, markets, agriculture, grazing and industrialization, Cutter et al, (1998), and FAO, (1991).
- Water quality:** is a measure of chemical content or the amount of dissolved solids and micro-organisms in the water Debora, (1996) and Thompson, (1997).
- Fecal coli form:** these are particularly bacteria that grow in the large intestine (colon) of humans, birds, and mammals and are mostly present in high numbers in feces of animals Kumar, (1979).
- Aerobic bacteria:** refers to bacterial and Microscopic characteristics which require oxygen for their survival Kumar, (1979) and Wright, (2008).

- Facultative bacteria:** are those bacteria which can either survive with or without free oxygen Kumar, (1979) and Wright, (2008).
- Total dissolved solids:** It is an aggregate amount of the entire floating suspended, settleable, and dissolved solids present in the water sample; solid May be organic or inorganic in nature depending upon Volatility of the substances and when they dissolve, They conduct electricity, Trivedi et al, (1997).
- Electrical conductivity:** is defined as the inorganic mineral contents present in the water that can conduct electric current which is measured by specific conductivity test, Trivedi et al, (1997).
- Total suspended solids:** are defined as solids suspended in water and waste Water which consist of silts, clay, fine particles of organic and inorganic matter Debora, (1996) and NWSC, (2009).
- pH:** refers to alkalinity or acidity of water, Dara, (2002), Deborah, (1996) and Kannan, (1997).
- Bio-chemical oxygen demand:** refers to the amount of oxygen required to biologically decay a certain amount of organic matter. This is because the microorganisms present in water break down the organic matter and during this process, they use up the available dissolved oxygen from the water and in case too much dissolved oxygen is removed, aquatic organisms die Chhatwal et al, (1999) and Tripathi, (1993).
- Chemical oxygen demand:** is a measure of the amount of oxygen required by inorganic matter in a sample of water for its oxidation by a strong chemical oxidant called dichromate oxidation, Tripathi, (1993, and Chhatwal et al, (1999).
- Eutrophication:** is the enrichment of water bodies with minerals and organic nutrients such as nitrogen and phosphorous which support proliferation of plant life but can lead to reduced dissolved oxygen

levels and changes in the dominance of plant groups Hugget et al, (2004), Bowen, (2001), Amander et al, and Getis et al, (2006).

Urban areas: these are areas situated in the city or towns that demonstrate an increase both in size and a variety of services and functions with high population density, Getis et al, (2006).

Urban sprawling: is a pattern of unplanned, low density housing and commercial development outside the cities that usually takes place on previously undeveloped land which is characterized by deteriorating infrastructure, poor schools, and poor quality houses, Randolph, (2004), and Enger et al, (2004).

Favela: these are poor houses which are built inside or outside the towns and lived in by people of low income, Getis, (2006), and Arber et al, (2001).

Non-point sources: these are sources of water pollution which are scattered or diffuse, having no specific location where they discharge into a particular water body. They are much harder to trace and Monitor, Cunningham et al, (2004).

Point sources: refers to discharge of pollution or substances from specific locations from; factories, sewage systems, power plants, underground coal mines and oil wells. These sources are discrete and identifiable and easily monitored Cunningham, et al, (2004).

Picho: refers to production of micro or mini hydropower in a small scale on the course of a river which is flowing continuously throughout the year, Banga et al, (1995).

Karst region: this is a region which is dominated by limestone rocks which contain calcium carbonate, Trivedi et al, (1997) and Thornbury, (1969).

Dissolved oxygen: Is a measure of the ability of a water body to support a well-balanced aquatic life, Kannan, (1997) and Wright, (2008).

CHAPTER TWO

LITERATURE REVIEW

2.1 Land Use

Cutter et al, (1998), state that the best data on world land use are provided by FAO, which categorized land uses according to status and employment of the land such as; grazing land, arable, permanent pasture, forest and wood land and others which include; parks, urban areas, roads and other non-agricultural areas which are separated into present and potential land uses. Since land suitability can only be assessed for specified kinds of land use, the description of the land uses are the distinctive focus of land evaluation and once they have been fully described, their requirements can be determined by natural conditions and human intervention basing on their layout as stated by Hugget, (2001), who defined Spatial Pattern as the organization or layout of different activities on the earth's surface be it natural or human phenomena. So in a lay man term spatial patterns may refer to the frequency with which something occurs in the space and geographers are usually interested in the frequency with which something occurs in the terrestrial space.

According to Ang'ienda et al, (2011), Fort-Portal municipality has a number of cottage industries that deal in a variety of products. There are markets that operate during specific days of the week such as Kabundaire farmers market where fresh agricultural produce are found every morning and a general market on Monday and Wednesdays .Ang'ienda continues to point that Mpanga market which is along Mpanga River deals in general merchandise such as; agricultural products, andbutchers, industrial products and Institutions such as; Mountains' of The Moon Universities, Mpanga Secondary School, Fort-Portal Secondary School, Buhinga Primary School, Buhinga and Kabarole Hospitals are all within the urban center. There is tree planting within the municipality and a well utilized road reserved with tree nursery beds (River Mpanga Tree Planting Project by Tooro Botanical Gardens) along Fort-Portal-Kampala highway and along River Mpanga. Other activities in the municipality include; fish farming at a small scale, and the most common ponds are; tilapia, miller cap ponds, the least being Claris pond, and mixed ponds, poultry keeping both exotic, and local chicken, crop growing such as; bananas, cassava, maize, tomatoes, eggplants, avocadoes, cabbages and beans.

Meanwhile the major crops are; bananas which are grown at 34.5%, beans at 22%. Livestock rearing in the municipality include; goats, sheep and cattle rearing. The cattle include both exotic and indigenous breeds. According to the 2002 census, it was found out that majority of the population rear goats, and this was at 54%, followed by indigenous cattle at 18.5%, exotic cattle at 4.5%, rabbits with 2.6%, sheep 7.1% and pigs 3.2%.

2.2 Water Quality

Deborah, (1996), states that it is difficult to provide a simple definition of water quality because of the complexity of factors determining water quality and the large choice of variables used to describe the status of water bodies in qualitative terms. For this reason, Kumar, (1979) and Debora, (1996), have expressed variety of definitions of the quality of aquatic environment as; the set of concentration, speciation, and physical partitions of inorganic or organic substance or else it is composition, and state of aquatic biota in the water body or it is the description of temporal, and spatial variations due to factors internal and external to the water body. While Thompson et al, (1997), state that water quality is a measure of chemical content or the amount of dissolved solids and micro-organisms.

Debora continues to declare that pollution of the aquatic environment is introduced by human directly or indirectly, of which substances or energy which result in such deleterious (toxic) effects are harmful to; living resources, hazard to human health, and hindrance to aquatic activities including fishing or it is the impairment of water quality with respect to its use in; agriculture, industrial and often economic activities. Hence Kumar's definition is more geographical since it covers the temporal and spatial aspects.

Kannan, (1997), points out that chemically pure water consists of two parts i.e. hydrogen and oxygen. According to him, good water should be clear, colorless, odorless, well-aerated, cool, soft, palatable and free from toxic pollutants and suspended matter or sediments but then he asserts that water rarely exists in a pure state because it's always polluted from various sources as will be discussed.

According to Selmes et al, (1995) and Kumar, (1979), the quality of water can be completely defined and estimated by measuring its physical characteristics such as; turbidity, total solids, and suspended solids, color, taste, and odors and specific conductivity of water. Chemical characteristics such as; bio-chemical oxygen demand, chemical oxygen demand, total phosphate, nitrate, pH value of water, hardness of water and sodium content. Bacterial and

Microscopic characteristics which are aerobic bacteria and which require oxygen for their survival then facultative bacteria which can either survive with or without free oxygen.

2.3 The physical characteristics of water

2.3.1 Total Dissolved Solids (TDS)

Trivedi and Gurdeepraj, (1997), noted that TDS content of water is defined as residue left upon evaporation at 103 to 105°C. It is an aggregate amount of the entire floating suspended, settle-able and dissolved solids present in the water sample; the solid may be organic or inorganic in nature depending upon volatility of the substances. Katyal and Satake, (1989), state that dissolved solids for example include not only any organic salts like carbonates, bicarbonates, chlorides, sulphates, phosphates and sometimes nitrates of sodium, potassium and traces of calcium, magnesium, iron and other metal ions but also any non-volatile organic wastes. Thus the term volatile and non- volatile refer respectively to organic and inorganic contents of the water sample, the organic constituent of total solids are responsible for taste, color, gas and biological problems although a few of them in traces produce acute toxicological problems for aquatic dwellers.

2.3.2 Electrical conductivity

According to Trivedi and Guardeepraj, (1997), EC is defined as the inorganic mineral contents present in the water that can conduct electric current which is measured by specific conductivity test. Total dissolved solids are the solids when in solution conduct electricity. These solids are called electrolytes. The electrolytes are sometimes weak or strong. Strong electrolytes ionize in aqueous solution with many free and mobile ions hence have high electrical conductivity examples are sodium chloride, sodium hydroxide and calcium chloride. Conductivity in water is measured in micro Siemens per centimeters ($\mu\text{S}/\text{cm}$). Hence there is a close relationship between TDS and EC (Electrical Conductivity).

Ojungu, (1992), observed that agro-based industries such as cashew nut and copra processing, vegetable oil extraction, coffee bean roasting and grinding, sugar and molasses refining, brewing, rice milling, sisal processing, paper and pulp production and soap production which are concentrated in the major coastal cities of Mogadishu, Mombasa, Dar-as-salaam, Maputo, Baeira including Jinja and Lugazi in Uganda contribute large quantities

of discharge into water bodies which comprise of suspended solids and other dissolved substances.

2.3.3 Total Suspended Matter (solids)

Debora, (1996), asserts that transparency is the limit of visibility in the water and turbidity is a measure of the ability of the water to scatter and absorb light. The type and concentration of suspended matter controls the turbidity and transparency of the water. While in National Water and Sewage Corporation (NWSC), (2009), suspended matter or solids are defined as solids suspended (floating) in water and waste water which consist of silts, clay, fine particles of organic and inorganic matter, soluble organic compounds, plankton and other microscopic organisms. Debora, (1996), continues to assert that both turbidity and suspended matter vary seasonally according to biological activity by the water column and surface runoff from heavy rainfall which carry soil particles. At a given river station turbidity can often be related to total suspended Solids (TSS) especially where there are large fluctuations in suspended matter. Turbidity can be used as a continuous direct measure for TSS. Dara, (2002), asserts that suspended solids and sediments are mostly contributed by soil erosion by natural processes, agricultural development, strip mining and construction activities and suspended solids in water mainly comprise of silts, sand and minerals eroded from the land.

Dara continues to point out that soil erosion by water, wind and other natural forces are very significant for tropical countries like India for instance it is estimated that out of the total land area of 328 million hectares, 175 million hectares are susceptible to degradation by soil erosion. It is also estimated that the continents are losing 5.8 cm of surface soil every 1000 years and about 6000 metric tonnes of soil are washed away into the sea every year which means that about 5.37 million tonnes of Nitrogen Phosphorous and Potassium (NPK) fertilizers are washed away into the sea. This erosion leads to qualitative and quantitative degradation of soil in land area. This soil may be getting removed from agricultural land area and transported where it is not at all required such as reservoirs, rivers and lakes. Hence TSS and Turbidity cause a significant effect on water quality by changing the aesthetic property of the water and providing avenue for bacteria and sometimes that particle causing turbidity is food to bacteria. Therefore TSS and turbidity is directly proportional to levels of bacterial pollution.

2.4 Chemical characteristics

Goel, (2000), states that other chemical parameters of water quality are nitrite, nitrate, ammonia, sulphate, redox potential, chloride, potassium, iron, heavy metals, calcium, magnesium, hardness, sodium, pesticides and detergents. However the researcher has planned to handle: TSS, TDS, pH, COD, BOD, TP, NO₃ and FC.

2.4.1 Water pH

Debora, (1996) and Kannan, (1997), stated that pH refers to alkalinity or acidity of water. It is a measure of the acid balance of a solution and is defined as the negative of the logarithm to the base of 10 of the hydrogen ions concentration. The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and processes associated with water supply and treatment. Hence when measuring the effects of an effluent discharge, it can be used to help define the extent of effluent plume in water body.

The pH scale runs from 0 to 14 (i.e. very acidity to very alkalinity) whereby 7 is the neutral point for pH. Alkaline water has above 7 pH on the pH meter; whereas acidity of water occurs below 7 on the pH scale. pH is measured on a pH scale. Usually pH measures the concentration of hydrogen ions in the water. The acidity of water is controlled by strong mineral acids, weak acids such as carbonic, humic and folic, and hydrolyzing salts of metals e.g. Aluminum ions, as well as by strong base. It is determined by titration with a strong base, up to pH 4 (free acidity) or to pH 8.3 (total acidity) as shown on the table below where the pH values ranging from 0 (strongly acidic) to 14 (strongly basic).

Table 2.1: showing the pH Scale and some examples

| Behavior | pH Value | Ht concentration in gm /liter | Example |
|----------------------|----------|-------------------------------|-------------------|
| Very strongly acidic | 0 | 1×10^{-1} | 5% Sulphuric acid |
| Strongly acidic | 2 | 1×10^{-2} | Lemon juice |
| Weakly acidic | 4 | 1×10^{-4} | Orange juice |
| Neutral | 7 | 1×10^{-7} | Pure water |
| Weakly basic | 8 | 1×10^{-8} | Body fluid |
| Strongly alkaline | 10 | 1×10^{-10} | Milk of Magnesia |
| Strongly alkaline | 14 | 1×10^{-14} | Caustic Soda |

Source; Kannan, (1997)

On this scale, the pH 7 scale is neutral. The pH range of 6.7-8.6 is generally acceptable. A drop or a rise in pH of water bodies beyond this range would indicate some kind of a pollution stress. Such an alteration could for example be caused by effluents from chemical and fertilizer plants or by acidic rain. Naturally, the pH of a body of water drops as it becomes more acidic with time. This factor should be considered while evaluating the impact of man-made activities. For instance, Munyaradzi, (1996), states that the treatment of bentonite (highly absorbent clay used as a binding and filling or filtering agent) at Boane and Mozambique generates wastes which could contaminate the water of Matola and Umbeluzi rivers making it undrinkable.

2.4.2 Nitrate and Total Phosphate

Hugget et al, (2004), state that nitrogen and phosphorous provide examples of the problems of human enhancement of chemicals in the environment. These nutrients can exist in different forms (or species) for example; nitrogen exists in the form of nitrates, nitrous oxides, and ammonia and nitrogen gas. Sources of these nutrients include sewage effluents, detergents and industrial effluent particularly food processing and agricultural sources as application of fertilizers and animal farming. They are lost from agricultural areas as leachate from water percolate through the soil particles containing absorbed phosphorous and the inefficient return of Slurry over the land. High levels of nitrogen and phosphorous in water bodies can cause eutrophication to occur which refers to the enrichment of water bodies with mineral

and organic nutrients. This initially supports a proliferation of plant life but can lead to reduced dissolved oxygen levels and change in the dominance of plant groups.

Wright, (2008), gives the example of water pollution on River Mississippi which is delivered in the Gulf of Mexico. He states that the Mississippi river watershed encompasses 40% of the land area of the United States and as it collects water from this huge area, it eventually delivers the water to Gulf of Mexico. Because much of the watershed is America's agricultural heartland, the Mississippi is a reflection of what happens on the farm. As U.S farm production experienced tremendous growth during the latter half of the 20th century, more and more fertilizers were spread on agricultural fields and more animals were raised on feedlots. At the same time wetlands bordering river tributaries were drained and no longer intercepted agricultural runoff. The result was a tripling of soluble nitrogen delivered to the river and finally to the Gulf of Mexico. Goel, (2000), also states that apart from the direct discharge of pollutants in the form of domestic and industrial wastes into the river system, the major transport of pollutants from land surface to water system takes place by runoff water which picks up the materials both soluble and suspended from the soil and transports them to receiving waters. Also leaching has been reported to remove huge quantities of pollutants from the soils mainly due to the force of percolation and runoff waters within the cities either causing both ground and surface water pollution.

In case of ground water pollution through leaching due to the force of percolation and runoff waters, surface water will be free from pollution.

The impact of this major flow of nitrogen to the Gulf of Mexico (hypoxic area) was first detected by marine scientists in 1974, who found out that in these areas much of the oxygen had disappeared from bottom sediments and much of the water column above them and they called this a "dead zone". This absence of oxygen is deadly to the bottom-dwelling animals and any oxygen-breathing creatures in the water column that are not able to escape. At first the hypoxic area or "dead zone" as it is called was thought to be similar to other bodies of water, such as the lower Chesapeake Bay that received high nutrients levels which was a minor disturbance that would disappear seasonally but then the hypoxic area suddenly doubled the size following the 1993 flood in the Midwest and it continues to grow.

2.4.3 Biochemical oxygen demand (BOD)

Chhatwal et al, (1999), asserted that the major problem associated with water pollution has been the “bio chemical oxygen demand” or BOD which refers to the amount of oxygen required to biologically oxidize the water contaminants to carbon dioxide and it is a measure of the suspended, colloidal or dissolved organics. The BOD is important in that the higher the BOD, the higher the organic content of the water and the more dissolved oxygen (DO) which will be used to decompose these organics. And a lack of dissolved oxygen in the water- ways kills off fish especially trout. To Wright, (2000), this process of decomposition of organic matters by bacteria consumes dissolved oxygen and eventually the oxygen which would have been in the water is used up. Hence the presence of organic substances can decrease the level of oxygen in the water in another way causing the death of organisms as a result of suffocation. The organics along with the nitrogen and phosphorous primarily can serve as food for algae. These algae are microscopic; greenish-colored plants which live in water although they are not harmful to humans, in fact in limited amounts they are useful for they do create oxygen for other aquatic life by photosynthesis but they do become aesthetically unsightly, a nuisance and a hazard to other aquatic life when they proliferate.

When algae die and decompose, in addition they produce a slimy scum and obnoxious odor; they require oxygen for their decomposition or oxidizations and hence can drastically decrease the dissolved oxygen supply as they decay. For instance manufacturing industries produce large quantities of BOD that is from 20-25 million, or 1 billion annually. The major contributors have been the chemical industry for instance manufactures about 44% of BOD, the pulp and paper industry about 27% and food processing industries about 20%. Ojungu, (1992), stated previously that agro based-industries produce large amounts of organic wastes which contribute significantly to total bio-chemical oxygen demand (BOD). As a result, features of eutrophication (algal growth) are beginning to appear in the sheltered bays and lagoons near the coast of Africa. This pollutant will definitely cause toxic effects, lower biological productivities and increase turbidity of waters in rivers. Otto, Tow leand Bradly, (1981), point out that pollution from residential, commercial and industrial land uses in form of detergents especially true detergents containing large amounts of phosphates and nitrates used by the population. This may also stimulate the growth of algae which upsets the natural balance of aquatic environments. Kannan, (1997) and Debora, (1996), also note that when small amounts of sewage or industrial wastes are dumped into a very large water body, it

would not be badly polluted and that the normal quality of water can be restored in a reasonable period of time. On the other hand when large quantities of domestic sewage, oxygen demanding wastes such as agricultural and industrial wastes are discharged in to a river, the problem can be severe because they tend to deplete the DO of the water body and lead to the development of “septic” conditions.

2.4.4 Chemical oxygen demand

The chemical oxygen demand (COD) is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate. The COD is widely used as a measure of the susceptibility to oxidation of the organic and inorganic materials present in water bodies, and in the effluents from sewage and industrial plants. The test for COD is non-specific. Similarly it does not identify the oxidisable material or differentiate between the organic and inorganic carbon present since some organic compounds are not oxidized by the dichromate method whereas some inorganic compounds are oxidized. Nevertheless, COD is useful and rapidly measured variable for many industrial wastes and has been used for several decades Debora, (1996), Tripathi, (1993) and Kyatal, (1989).

2.5 Biological characteristics

Goel, (2000), asserts that biological parameters include; coli forms, pathogens, planktons (both phytoplankton and zooplankton) and macro-vertebrates. Enger et al, (2004), and Katyal, et al, (1989), state that the wastes from the municipalities, industries, homes and commercial establishments consist of storm water runoff. Wastes from homes consist primarily of organic matter from garbage, food preparation, cleaning of clothes, and dishes and human wastes. Human wastes are mostly undigested food material and consist of concentrated population of bacteria, such as *Escherichia coli* and *Streptococcus faecalis*. These particular bacteria normally grow in large intestine (colon) of humans and are present in high numbers in the feces of humans they are commonly called fecal coli form bacteria.

Kumar, (1979), also points out that those fecal coli forms are also present in the wastes of other warm- blooded animals such as birds and mammals. However, low numbers of these bacteria in water are not harmful to healthy people but because they can easily be identified, their presence in water can be used to indicate the amount of population from the fecal wastes

of humans and other warm-blooded animals. The numbers of these types of bacteria present in water are directly related to the amount of fecal waste entering the water. However the researcher will consider fecal coli form as a parameter intended to generalize fecal bacteria.

For instance in United States, there is high rate of infections caused by fecal contamination for example in 1993, a protozoan pathogen called *Cryptosporidium* was identified in the Milwaukee, Wisconsin, public water system. This resulted in over 400,000 people becoming ill and at least 100 deaths. In Most Economic Developed Countries (MEDCs), sewage is transported via the drainage systems to treatment works where it is cleansed. However, some old treatment works are inefficient and until recently sewage was sometimes emptied direct into the rivers or seas. In United Kingdom (UK) in autumn 2000 people cleaning up after serious flood were warned to wear masks to prevent contracting wies's disease as a result of being in contact with raw untreated sewage.

Another example is given on river Ganges in India where thousands of Hindus flock to the banks of the river to bathe in what they believe to be "Holy water" where cremated corpses float past them and the river nearby drains emit millions of liters of raw sewage. More than 1600 million liters of sewage, industrial waste, agricultural runoff and other pollutants are discharged into the river daily, Enger,et al, (2004).

2.6 Relationships between urban land use practices and the quality of water

The use of land is perhaps the most significant driving force in human impact on natural environment. Randolph, (2004), noted that land development for human settlement and resource production poses critical impact on the land itself and also on water, air, materials and energy use. Conversion of natural and productive lands to human use, sprawling patterns and inappropriate location of development, roads and building construction and land use practices are after development. All have broad impact on human environmental health and natural environment which can be exacerbated by land use decisions and can later cause natural hazards and soil erosion, alter hydrological balance, pollute surface and ground water and destroy wild life. He continues to note that in 1998, about 70% of Americans lived within 10 miles of polluted waters, and 300,000 of rivers and 5 million acres of lakes did not meet water quality standards.

Bowen, (2001), states that in urban areas, the main sources of water pollution in urban areas are: sewage, manufacturing industries and power stations. In addition agricultural areas upstream of urban areas may concentrate excess chemicals in run-off from the application of fertilizers, pesticides and herbicides. Cattle slurry and silage may also leak into rivers and streams. While according to Goel, (2000), the origin of pollution can be traced to their natural occurrences on the earth that is formation by transformation and concentration of natural substances and their man-made synthesis. The examples of naturally occurring pollutants forming the background concentrations are oxides of nitrogen, heavy metals, hydrocarbons and radioactive substances. To Wright, (2008), water pollutants originate from a host of human activities and reach surface water or ground water through an equally diverse host of pathways.

Hence for purposes of regulation, it is customary to distinguish between “point sources” and “Non point sources”. As stated earlier, point sources involve the discharge of substances from factories, sewage systems, power plants, underground coalmines and oil wells. Non point sources of pollutants are agricultural runoff from farm animals and crop lands, storm-water drainage from streets, parking lots, and lawns and atmospheric deposition from air pollutants washed to earth or deposited as dry particles. According to Kannan, (1997), environmental degradation by man is attributed to three major causative factors; over population, urbanization and industrialization. To him, the increasing amount of wastes generated by these phenomena undoubtedly degrades the quality of land, air, food and water in particular.

2.6.1 Residential

Getis and Fellmann, (2006), state that a lot of pollution derives from the activities associated with urbanization in municipalities and residences in most developed and developing countries. Although municipal wastewater treatment is increasing in developed world, there is still cases of pollution from raw sewage for instance a survey of 200 major Russian rivers show 80% of them being polluted by raw sewage and have dangerously high levels of bacterial and viral agents. New York City is reported to be pouring its 65 billion gallons of untreated sewage into Hudson River and Long Island Sound each year.

Goel, (2000), states that sewage consists of water borne wastes of the community and contains about 99% of water and 1% of solids. Of the solids present in sewage, 70% are organic and 30% are inorganic in nature. Out of the organic constituents, 65% are proteins,

25% are carbohydrates and 10% fats. The inorganic fraction of sewage constitutes grit (shingle, gravels or stones), salts and metals in varying proportions. In most cases domestic sewage is generally discharged from residential in the untreated, treated or partially treated form into the nearby water bodies like rivers, lakes, estuaries or coastal waters where it can cause severe sanitary and other water pollution problems. Sewage is also the production of odors and spread of enteric diseases besides organic pollution which leads to oxygen depletion and death of fish.

Ojungu, (1992), noted that although actual growth in other sectors of the economy of East Africa and Uganda is relatively slow the human population numbers are increasing at an alarming rate. For instance the coastal strip of East Africa supports about 10% of the total national populations. He continues to state that the average population and urbanization growth rates in the coastal region are at 3.0% and 7.6% respectively. Because of much higher rates of growth, several unplanned settlements have sprung up to compound problems within even the planned urban centers. The most serious problems relate to inadequate collection and treatment systems of both sewered and non-sewered domestic wastes. Only the major coastal cities have piped sewerage systems but almost all of them have inadequate capacities to collect non-sewered domestic garbage. Although Mauritius and Seychelles have substantial sewerage services, two third of the coastal urban population in the region discharge their wastes directly to the sea and waste treatment is limited only to removal of coarse suspended materials, (UNEP, 1982).

In Uganda Kasozi, (2007), observed that Lake Victoria Management Programme has found out that those urban centers around the lake contribute to 72% of the pollution which finds their way into the lake. This has been proved by the recent measurement of BOD loads from major towns like Kampala, Jinja, Mukono, and Nansana served by National Water and Sewage Corporations (NWSC) in the country. This showed that the set standards for the BOD discharge were exceeded most of the time in the year 2003-2005 periods. The causes to the above issues were linked to the increased population, urbanization and industrialization which were aggravated by poor sanitation and poor land use management practices examples of such areas include northern parts of Kampala like; Mulago, Kaleerwe, Kyebando and Kawempe which have markets where biodegradable products are sold. These places are known for dumping raw wastes like human wastes, wastes from waragi distilling, vegetables, and fruits wastes from markets and other industries like fruits into water channels, streams

and wetlands which are drained direct in to the lake. This was supported by Ntabadde, (2005), who states that most market vendor's lack latrines hence most of them use polythene bags to dispose most of their wastes even wastes such as feces of animals slaughtered for sale in to the channels and finally direct to the lake.

2.6.2 Agricultural activities

Goel, (2000) and Coble et al, (1981), assert that chemicals which can cause pollution are from agricultural wastes in form of phosphates and nitrates usually originate in the form of runoff from the agricultural fields and animal farms. While Mahajan, (1985) and Gupta, (1997), state that the world population was expected to be 5 billion in 1985 hence more chemicals and fertilizers were required to meet the increased food production requirements caused by this population increase. As a result modern agriculture uses a large number of chemicals called agrochemicals in the form of fertilizers, pesticides, growth hormones, organic manures, nutrients, and solutions in order to increase crop yields. All the residual forms of these chemicals along with organic debris from the remains of the harvested crops are trapped by runoff water causing pollution problems in the receiving waters. Although organic matter is considerably rich in nutrients like phosphorous and pesticides while nutrients create the problem of eutrophication and pesticides are responsible for causing toxicities to aquatic life. Several pesticides have been reported to get bio-accumulated and biomagnified through food chains resulting in the secondary poisoning to man and predatory birds. Getis et al, (2006), states that on a world basis, agriculture probably contributes more to water pollution than does any other single activity. In the United States, agriculture is estimated to be responsible for about two-thirds of stream pollution. Agricultural runoff carries three pollutants; fertilizers, biocides and animal wastes as explained below:

2.6.2.1 Fertilizers

Agriculture is a chief contributor of excess nutrients to water bodies. Getis, et al, (2006), and Amander et al, (2006), state that pollution occurs when nitrates and phosphates that have been used in fertilizers and animal manure from animal farm drain into streams and rivers. In due course they accumulate in ponds, lakes and estuaries. These wastes which are inform of feces, urine plus excess nutrients from animal feeds, pesticides use for killing ticks contribute to high concentration of nitrogen and phosphorous in water body after their disposal.

The nutrients accelerate the process of eutrophication or the enrichment of waters by minerals and nutrients. Eutrophication occurs naturally when nutrients in the surrounding area are washed into the water, but when the sources of enrichment are artificial, as it is true of commercial fertilizers; the body of water may become over loaded with nutrients. Algae and other plants are estimated to grow abundantly, blocking the sunlight that other organisms need. When they die and decompose the level of dissolved oxygen in the water decreases. Fish and plants that cannot tolerate the poorly deoxygenated water are eliminated.

Worldwide, this accelerated eutrophication which is estimated to affect approximately half of all lakes and reservoirs in North America, Europe, and Southeast Asia, some 40% in South America, and 28% in Africa. Symptoms of eutrophication lake are prolific weed growth, large masses of algae, fish kills, rapid accumulation of sediments on the lake bottom, and water that has a foul taste and dour. High levels of nutrients from agricultural run-off in the Mississippi River watershed have helped create a “dead zone”, an area of oxygen depletion in which fish, crabs, and other aquatic creature cannot survive in the Gulf of Mexico off coast of Louisiana. The zone, whose size varies from year to year, reaches its peaks during the summer months, as the water grows warmer and solar radiation increases, causing algal populations to bloom, Getis, et al, (2006).

2.6.2.2 Biocides

The herbicides and pesticides used in agriculture are other sources of the chemical pollution of water bodies. Runoff from farms where such biocide has been applied contaminates both ground and surface waters. One of the problems connected with the use of biocides is that the long-term effects of such usage are not always immediately known. DDT (dichlorodiphenyl trichloroethane), for example, was used for many years before people discovered its effect on birds, fish, and water plant life. Another problem is that thousands of these products, containing more than 600 active ingredients, are now in wide use, yet very few have been reviewed for safety by the Environmental Protection Agency (EPA). Finally, biocides that leach into aquifers can remain there for long after the chemicals are no longer used. Thus DDT is still found in U.S waters even though its use was banned in the late 1960s, Getis et al, and (2006).

2.6.2.3 Animal Wastes

A final agricultural source of chemical pollution is animal wastes, especially in countries where animals are raised intensively. This is a problem both in feedlots, where animals are crowded together at maximum densities to be fattened before slaughter, and on the factory like farms where beef, hog, and poultry production is increasingly concentrated.

American farms and large feedlots produce vast quantities of manure-nearly 3 billion pounds a day but usually lack sewage treatment facilities. The main method for disposing of the waste is to put it into open lagoons (containment ponds) and then spray it onto surrounding fields, from which it can leach into the water tables and rivers. The water pollution that occurs from spreading animal manure on land is suspected by some people to be responsible for recent out breaks of the microorganisms called *Pfiesteriapiscicida* in the Chesapeake Bay. This singled-celled alga proliferates and becomes toxic when exposed to high levels of nitrogen and phosphorous and by-products of animal waste. The manure comes from the large poultry and hog farms of Maryland, Virginia, and North California. *Pfiesteria* have killed millions of fish, and there is some evidence that the organism also sickens human beings, Getis et al, (1999).

2.7 Mining

Land use practices have a big impact in the change of water quality in rivers, streams and lakes. Munyaradzi, (1996), noted that exploitation of coral sand to support Mauritius' construction industry and hotels construction are causing environmental problems in the Indian Ocean Island. Such development have put enormous pressure on the supply of construction aggregates both crushed basalt and coral sand. Inland coral depositions are virtually exhausted resulting into an increase in amount of coral sand extracted from the lagoons inside the reefs. This has led to environmental problems like soil erosion, increased water turbidity, disruption of the food chain in the lagoons, destruction of marine habitat, flora and fauna near dredging sites, loss in production of fish resources and pollution of the lagoons with effluents.

Plummer, et al, (2003), states that extracting and using coal creates environmental problems. The presence of a mine usually lowers the local water table as ground water is pumped out of the mine. The drainage out of the mines tends to be highly acidic, polluting surface streams

and water supplies. Also getting petroleum out of the ground and to the consumer can create environmental problems anywhere along the line. While Prakash and Choubey, (1990), disagree with the above, to them underground mining has little direct impact on surface streams but may have profound long term effects on ground water resources. In case of surface mining like in Singrauli Coal Field noticeably changes in water quality has been seen. These very waters carry various types of waste from the mine into the adjoining rivers and reservoirs.

2.8 Industrial Activities

Goel, (2000) and Debora, (1996), assert that anthropogenic impact on water quality came with the advent of industrialization and increasing populations. This means that the range of requirements for water have increased together with greater demands for higher quality of water. Over time water requirements have emerged for drinking and personal hygiene, fisheries, agriculture, and navigation for transport of goods, industrial production, cooling in fossil fuel, power plants, hydropower generation, and recreational activities such as bathing or fishing. In parallel with these uses, water has been considered since ancient times, the most suitable medium to clean, disperse, transport and dispose both domestic and industrial wastes, mine drainage waters and irrigation returns. Each water use including abstraction of water and discharge of wastes, leads to specific and generally rather predictable impact on the quality of the aquatic environment.

They continue to point out that the industrial wastes have the greatest potential for polluting the receiving waters. The nature and composition of industrial waste vary from industry to industry and even within the same industry depending upon the raw materials, processes and operational factors. The industrial waste may have pollutants of almost all kinds ranging from simple nutrients and organic matter to complex toxic substances. The wastes from the industries like sugar factories, dairies, paper and pulp, tanneries and distilleries are rich in sources of organic matter. Metal plating industries release substantial quantities of heavy metals and cyanide in their wastes. The wastes from fertilizer industries can also be rich source of nutrients causing eutrophication. The chemical industry release wastes with highly variable compositions which are often acidic or alkaline in nature.

The different types of industrial pollution existing in Southern Africa are: organic pollution due to the accumulation of various wastes that de-oxygenate the aquatic environment,

bacterial pollution due to the presence of disease-causing organisms resulting from the discharge of excrement into aquatic environment, accumulation of nutritive salts or certain ions (atoms with an electric charge) leading to eutrophication of lakes or rivers and encouraging the growth of algae, heavy metals such as copper accumulated in algae and macrophytes (large water plants) can inhibit the growth of fish, Munyaradzi, (1996). Also Kasozi, (2007), states that waragi (liquor) industries in Mbale Town disposed their wastes in wetlands. However this permit of disposal of industrial wastes was granted by the Water and Sanitation Sector Performance Report in order to regulate the disposal since wetlands purify the wastes in the water.

2.9 Water Transportation

Dara, (2002), asserts that oil pollution may take place because of losses of oil spills from cargo oil tankers in water bodies or seas during off-shore explorations and production of oil, accidental fires in ships and oil tankers, accidental or intentional oil slick as the event which took place during the Gulf war between Iraq and U.S led by allied forces in the year 1991 and leakage from oil pipelines, crossing water ways and reservoirs. Oil pollution results in reduction of light transmission through surface waters, thereby reducing photo-synthesis by marine plants. Further it reduces the Dissolve Oxygen (D.O) in water which endangers water birds, coastal plants and animals. Thus, Oil pollution leads to unsightly and hazardous condition to marine-life and sea-food.

For instance Plummer, et al, (2003), also points out that in the 1960's, geologists discovered oil beneath the shores of Arctic Ocean on Alaska's North Slope which is the U.S largest oil field. In the process of transporting the oil, there have been some mine oil spills from the pipe line for example in January 1981; 5000 barrels of oil were lost when a valve ruptured. Also when the tanker Exxon Valdez ran aground in 1989, over 240,000 barrels of crude oil were spilled into the waters of Alaska's Prince William Sound and it was the worst ever oil spill in U.S. The spills with its devastating effects on wildlife and fishing industry dramatically highlighted the conflicts between maintaining the energy demand of American economy and conservation of the environment. While the environmental impact statement had singled out marine oil spills as being the greatest threat to the environment and basing on the statistical studies of tanker accidents worldwide, it gave the frequency with which large oil spills could be expected.

2.10 Comparison of the water quality before reaching the urban area, and after the urban center

Cunningham et al, (2004) and Goel, (2000), point out that any physical, chemical, and biological change in water quality that adversely affects living organisms or makes water unsuitable for desired use are caused by human activities like; settlement, industrialization, agriculture and by natural sources from upstream such as; sedimentation from erosion, oil seep, and poison springs. Domestic sewage constitutes 70% of organic wastes of which 65% are proteins, 25% carbohydrates, and 10% of fats. Bowen, 2001, Getis et al, (2006) and Goel, et al, (2000), state that settlement and agricultural practices upstream of urban areas contribute excess chemicals in runoff from application of fertilizers, pesticides and herbicides. All the residual forms of these chemicals along with organic debris from the remains of the harvested crops are trapped by runoff water causing pollution problems in the receiving waters. All these lead to increased total dissolved solids (TDS) and COD of the water body. However Pierre, (2000), asserts that all the eroded particles in a watershed do not reach the watershed outlet because particles detached from bare upland area are trapped in vegetative areas farther downstream hence causing low total suspended solids (TSS) and some materials carried in natural stream is deposited in the channels to cause aggradations.

In comparison of the above, Cunningham et al, (2004), point out that from downstream at a point source such as a municipal sewage plant discharge, a characteristic decline and restoration of water quality can be detected either by measuring D.O content or by observing the types of flora and fauna that live in successive sections of the river. To him the decline can be due to low wastes disposal in the river or dilution from other streams joining the river. He called this downstream decline the 'oxygen sags' and restoration can be due to increased wastes disposal in the river by human activities or natural processes. Tripathi, (1993), who asserted that when wastes containing organic matters are discharged into streams, it create heavy pollution load at some critical points, the DO of the river starts decreasing up to a minimum value. However, Cunningham et al, (2004), also support the above statement by saying that in upstream from the pollution source; oxygen level is high hence supporting the growth of clean water organisms while further downstream the water may become so oxygen depleted that only the most resistant microorganisms and invertebrates can survive.

Tripathi, (1993), further asserted that when wastes containing organic matters are discharged into streams, they create heavy pollution load at some critical points, the DO of the river

starts decreasing up to a minimum value. This means that dilution would have been caused by the stream which joined the main river hence causing low BOD, Bowen, (2001), Getis, et al, (2006), and Goel, (2000), state that agricultural practices upstream of urban areas contribute excess chemicals in runoff from application of fertilizers, pesticides, and herbicides. All the residual forms of these chemicals along with organic debris from the remains of the harvested crops are trapped by runoff water causing pollution problems in the receiving waters. Despite of the usefulness of agricultural runoff as being rich in nutrients like phosphorous, organic matter and pesticides, these nutrients create the problem of eutrophication. And pesticides cause toxicities in aquatic life when they get bio-accumulated and bio-magnified through food chain this result into secondary poisoning to man and predatory birds. And nitrates which are susceptible to runoff with each rainfall enter ground water through infiltration and percolation. And where they are extensively used like feedlots, they appear in wells and streams and rivers.

They continue to point out that those human wastes from residence; cattle slurry and silage from animal feed lots may also leak into the rivers and streams or are disposed directly. For instance Bowen, (2001), states that in Most Economic Developed Countries such as United Kingdom, United States of America and German, sewage is transport via the drainage systems to treatment works where it is cleaned before entering the water courses. However, some old treatment works are inefficient such that they sometimes emptied raw sewage directly into rivers. This may cause pollution in the downstream rendering the water unfit for aquatic life and human consumption because they introduce microorganisms in water. Bowen continues to site the example of pollution of river Thames in Central London in 1841 where there were 270,000 houses and most of them had cesspits that would over flow straight into the river leading to cholera outbreak.

Munyaradzi, (1996), gives the example of pollution of rivers from mining centers in Africa. For instance the stretches of acid which polluted Olifants River in the Eastern Transvaal have been accredited to the coal mines upstream. This is because mining centers in Africa use water as a medium for mineral extraction processes and this water contains toxic chemical compounds such as high level of sulphur and nitric acids. This toxic compound enters into rivers directly by run-off or through seepage. This polluted water with low pH value is more acidic and corrosive and at the same time a high pH value indicates increase alkalinity. They continue to assert that river basins, lakes and coastal areas in Southern Africa are subjected to various mining operations because of existence of products such as; soda ash in

Makgadikgadi in Botswana, gypsum and iron ore in Kafue flats in Zambia, salt in Etosha in Namibia, coral sand along the coast of Tanzania, Mauritius and Mozambique, coal along the Zambezi valley and diamond production around Dundo in north east of Angola has caused a certain amount of pollution to the tributaries of the Kasai river flowing into Zaire basin.

Hence in South Africa, the main effect of mining is the contamination of water by soluble substances and liquid effluents of toxic substances. This has been approved by carrying out regular testing at more than 40 sampling stations or points in the Vaal catchment area upstream where the result show that mine dumps on the East Rand leached into the Rietspuit streams. Among other toxic chemicals that were frightening were sulphate levels that exceeded European standards for water surface.

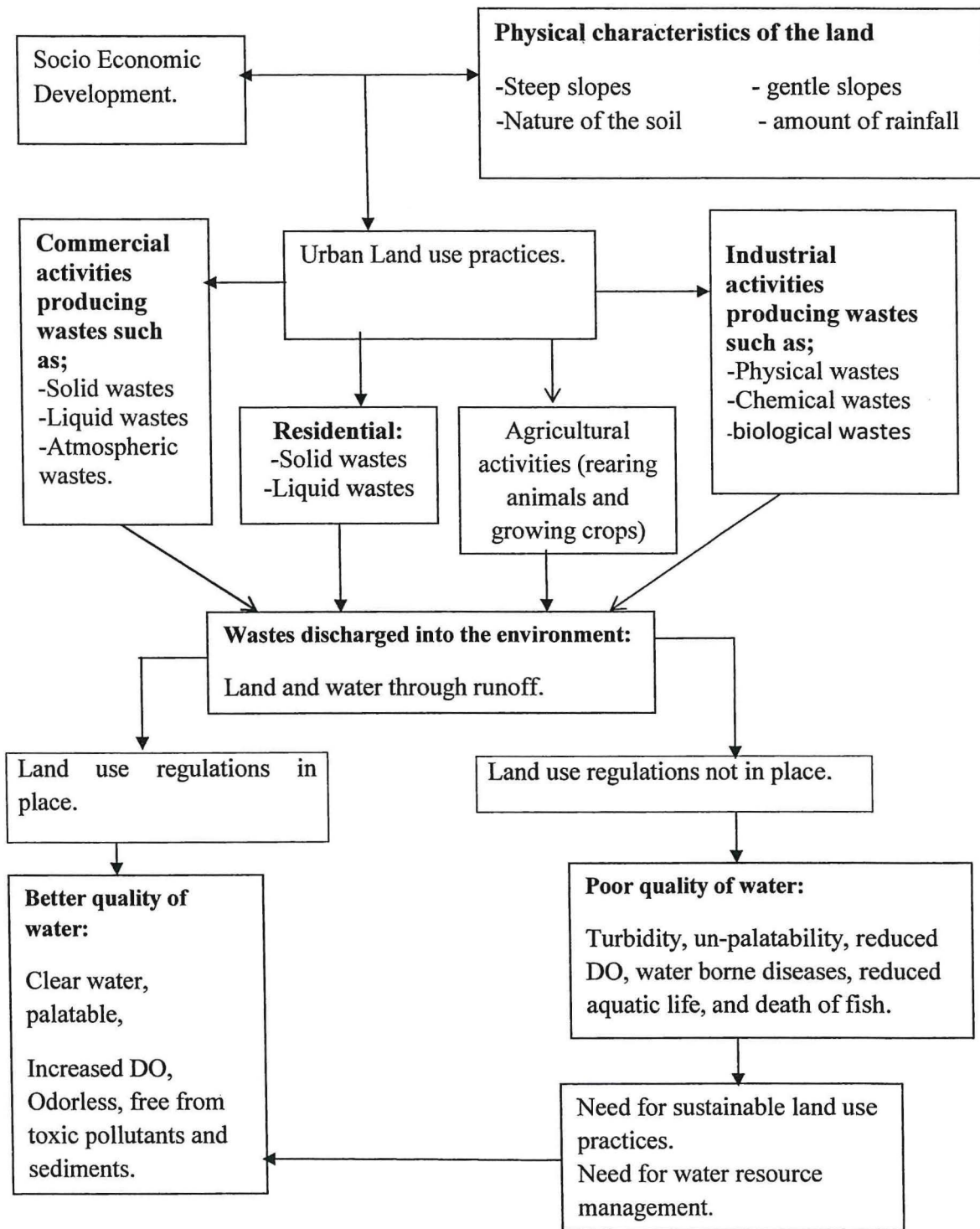


Figure 2.1 Conceptual Framework of the Research

As shown in figure 2.1, increase in socio economic development coupled with physical characteristics of the land such as: steep slopes, gentle slopes, nature of the soil and amount of rainfall determine the type of land use practices in an urban area. These land use practices are inform of; Commercial activities, Residential, Industrial activities, constructions activities of roads and houses, washing bays and agriculture. Land uses like commercial and residential produce wastes such as; solid wastes, liquid wastes and atmospheric wastes while industrial activities produce wastes such as; physical wastes, chemical wastes, atmospheric and biological wastes. These Wastes are later on discharged into the environment that is land and finally in water resources. These wastes later on alter the quality of the water. Where land use regulations have been put in place, better quality of water have been realized such as; clear and palatable water, increased DO in water, odorless water, water free from toxic pollutants and sediments. But where land use regulations have not been put in place, poor quality of water have been realized such as; turbidity, un-palatability, reduced DO, water borne diseases, reduced aquatic life and death of fish. These call for need for sustainable land use practices and need for water resource management strategies such as; prohibiting activities like; washing of vehicles in water resources, excessive use of agro-chemicals in cultivated fields, disposal of untreated wastes from industries into water bodies and disposal of untreated sewage wastes from residential into water bodies. When all these are done, better quality of water can be achieved.

CHAPTER THREE

METHODOLOGY

3.1 Research design

Research design was Survey design and the methods used in collecting factual information were sampling and observation. The study led to mapping the different land use practices along Fort-Portal Municipality and later on samples of water were taken at various intervals on the basis of different land uses for analysis. The samples of water were taken using bottles of 500-1000ml at each land use before the river entered the municipality, within the municipality at different land use and after the water in the river had left the municipality to determine the extent to which the land uses had affected physical, biological and chemical characteristics of the water in the river. This was done with the help of research assistant. Other techniques employed in data collection were taking photographs and use of Global Positioning System (GPS) for allocating the coordinates for each sampling spot of land use.

3.2 Determining sampling area

Fort-Portal Municipality has three divisions these are; East, West and South divisions which have a population of 29,602, 28,412 and 26,130 respectively as estimated by 2010 census. Amongst these divisions, western and southern divisions were selected for study because these parts of the municipality have a variety of land use patterns along River Mpanga. The west division is dominated by residential such as Booma, Nyabukara, Kagote, and Kisenyi. Institutions such as Nyabukara nursery and primary schools, and Kahunga Bunyonyi Primary School, Uganda Pentecostal University, Kabundaire Market which handles agricultural produce, Mountains of the Moon Hotel, Municipality abattoir and small scale industrial land uses such as garages, aluminum can workshops and grinding mills. The southern division comprise of commercial activities such as; shops and markets like Mpanga market, Buhinga Hospital, agricultural activities such as animal grazing farming, and cultivated farm, police station, Mpanga Secondary School , tree plantation and tree nursery beds. So land uses along Mpanga River before, within and after Fort-Portal urban area were sampled. This facilitated a comparative analysis between the different land-use practices and the quality of water. The land use which were sampled were; unplanned settlement, car washing bay, planned settlement, municipal abattoir, industrial land use, commercial land use, agro-forestry,

agricultural activities (cultivated farm, and animal grazing farm). The researcher sampled the above land uses because they are situated along River Mpanga and they are expected to contaminate the river. So the researcher's intention is to determine the degree of pollution by each land use along the river as shown on figure 4.2.

3.2.1 Sampling Techniques

The sampling technique used was purposive in which samples of water in the river were taken exactly where there was a particular land use practices along Mpanga River such as cultivated farms, settlements, sand mining, cattle grazing and brick making were sampled. Samples were also done before the water entered the urban center and also when the water leaves the urban center. The land use practices sampled were car washing bays, abattoir, small scale industrial area in Kabundaire, planned and unplanned settlements, garages, commercial activities (shops and markets), tree planting and tree nursery beds (agro-forestry). Samples were taken when the water in the river left the urban center. This was done in order to find out the degree of the impacts of land use activities on physical, chemical and biological characteristics of the water. The sampling from inflow to municipality and out flow from the municipality helped the researcher to compare the quality of water in the river before and after the urban center physically, biologically and chemically.

According to Selmes et al, (1995), the survey was done by selecting a stretch of a river that includes agricultural land, industrial and urban development, the land use was mapped and at regular intervals along a sample reach. The water samples were taken and measurements of pH, DO and water temperature were done. This study employed a relatively similar method of Goel, (2000), on figure 3.1 and Selmes et al, (1995), whereby a stretch of a river which includes agricultural i.e. animal and cultivation of crops, industrial, commercial, car washing bay, settlement and other urban development as mentioned earlier were selected. Samples of water were taken four times on different dates at determined intervals from upstream (point A) before the river enters the urban center. Samples were also taken from hot spots (point B) where there were a number of land use activities taking place within the urban center such as; agricultural activities, factories, garages, washing bays, markets, schools, hospital, aluminum can workshop, residential, and finally in downstream (point C) after the river had left the Municipality. Key parameters that indicate pollution and contamination were; pH, Suspended matter and transparency, TDS, BOD, COD, DO, TP, Nitrate and F.C (fecal coli form). This

was intended to establish the quality of water before, and after the river has left the urban center.

3.3 Data Collection

Two types of data were collected in this research; primary and secondary data. The primary data were collected from the field by use of observation guides. The primary data included information about land uses and their patterns along Mpanga River, the size of each land use, sampled water, physical, chemical and biological characteristics of water within a particular land use and comparison of the quality of water within the inflow and outflow. Secondary data included information from newspapers, internet and text books.

3.3.1 Instruments for Data Collection

The most suitable tool which was employed was the observation guides. In scrutiny of increasing the exactness of information collected, camera was also used to produce photographs of; land uses along the river and activities being carried out within the different land uses, sampling spots of inflow and outflow were got by use of estimate of distance between land uses. Other instruments in data collection were; bottles for collecting water in the river, tape measures and GPS for establishing coordinates of sampling spots.

3.4 Comparing the quality of water before (inflow), within urban center and after the water in the river has left the urban area (outflow).

Goel, (2000), states that the sampling stations in a river are usually decided after a preliminary survey of the stretch of the basin taking following aspects into consideration:

- Points on entry of waste waters along the river.
- Points of entry of fresh water tributaries.
- Points where there is significant changes in width, velocity, slope, or depth of the river.

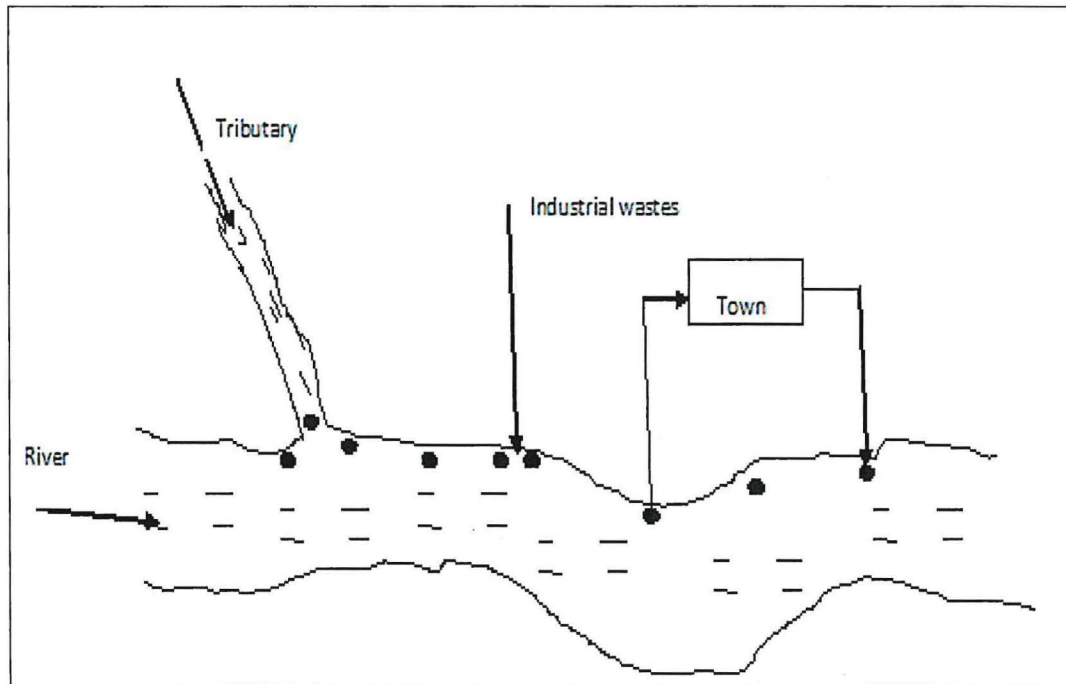


Figure 3.1 schematized map showing selection of sampling stations (spots) along a river

Source; Goel, (2002)

Goel continues to say that, some additional samples can also be drawn below the outfall representing the zone of recent pollution, saprobic zone, recovery zone and clean water zone as shown on figures 3.1 and 3.2

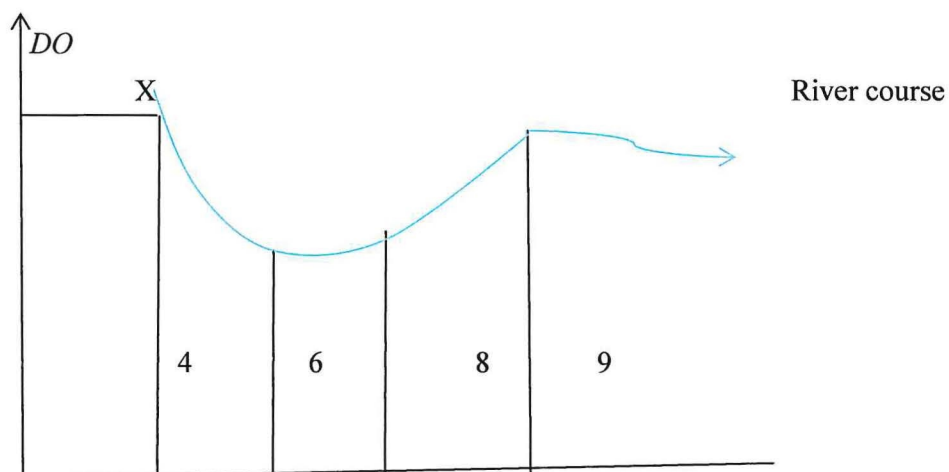


Figure 3.2 showing various zones in a river after addition of an organic waste

Source; Goel, (2002)

According to figure 3.2;

4 -is zone of recent pollution which represents inflow

6- is septic zone which represents hot spots (urban center with many economic activities or land use practices)

8 -is recovery zone

9- is clean water. Both 8 and 9 zones which represent outflow

X -is representing entry of organic waste from a land use into a river

The study employed a relatively similar method of Goel, (2000), by picking samples of water from zone 4 (inflow) and zones 8 and 9 (outflow) in order to make comparisons of the quality of water before it entered the urban center and after the river leaves the urban center.

3.5 Method used for Data Collection

The methods used in collecting data were sampling and observation. Direct and critical observations were used to identify some of the land use activities in the urban area and especially along River Mpanga. And at certain time the researcher traced the trend of waste disposal from a particular land use practices such as; solid and liquid wastes from commercial activities, residential, abattoir, industrial area and car washing bays.

Observation was used during laboratory analysis to ascertain the physical, chemical and biological characteristics of sampled water of a particular land use spot basing on parameters chosen as seen below.

3.6 Methods used during laboratory analysis of sample of water

The laboratory methods used in analyzing samples collected for determination of physical, chemical and biological characteristics included; Electrometric Method and EC meter for EC, TDS and pH, Photometric method and spectrophotometer for TSS, Azinde Modification of Wrinkler Method for BOD, Closed Reflux Calorimetric Method and Spectrophotometer for COD, Persulphate Method for TP, Cadmium Reduction and Spectrophotometric Methods for NO₃ and Membrane Filtration Method (MFM) for FC.

3.6.1 Physical parameter

The physical parameters that were analyzed in the study included total dissolved solids (TDS), electrical conductivity (EC) and total suspended solids (TSS).

3.6.1.1 Electrometric method for total dissolved solids by use of EC meter

According to Trivedi, (1997), an approximate idea of total dissolved solids (TDS) in natural waters is obtained by multiplying the Electrical conductivity at 25°C by a factor of 0.55 to 0.75 with an average of 0.65. Alternatively, the researcher measured TDS using Electrometric Method by direct reading using E.C meter as shown on photograph on plate 3.1 in the laboratory. This was done by selecting the TDS parameter while pressing the mode function and then a probe was dipped into 500-1000ml bottle of each water sampled, the 'read button' was pressed and the result was displayed on the screen in mg/l as shown on plate 3.1, (NWSC, 2009).

3.6.1.2 Determining electrical conductivity by use of electrometric method and EC meter

Electrical Conductivity (E.C) is the ability of water (waste water) to conduct an electric current, which is purporting to have amount of dissolved salts (or cat-ions and anions) in the water. In measuring the E.C of the water, an electrical conductivity meter was used which register the value in a micro Siemens per centimeter ($\mu\text{s}/\text{cm}$), Deborah, (1996). In addition, the researcher measured EC using Electrometric Method by direct reading using E.C meter as shown on photograph on plate 3.1. This was done by selecting the EC parameter while pressing the mode function and then a probe was dipped into 500-1000ml bottle of each water sampled, the 'read button' was pressed and the result was displayed on the screen in micro Siemens as shown on plate 3.1, (NWSC, 2009).

3.6.1.3 Determining Total Suspended Solids (Matter) by use of Photometric method and spectrophotometer

According to Deborah, (1996), the Transparency of the water is determined by lowering a circular disc, called a secchi disc which is 20-30cm in diameter and colored white or with black and white sectors on a calibrated cable into the water until it just disappear and reappear. The reading is recorded as the depth of transparency. While in NWSC, (2009), suspended solids which refers to solid matter suspended (floating) in water and waste water was determined by the researcher by using Photometric Method which is a simple direct measurement where samples of water were collected in clean plastic bottles and stored at 4°C or 39° F. 10ml of sample of water from each land use was measured using a measuring cylinder or put direct in the sample cell with a standard measurement without adding any reagent. A blank sample of distilled water was also prepared. Later on, sample cell containing sample water with a standard measure was put in the spectrophotometer and direct reading was taken.

3.7.1 Chemical parameters

Chemical parameters considered in this study included; pH, COD, BOD, TP and Nitrate (NO₃).

3.7.1.1 Determining of pH water by use of Electrometric Method

Samples of water were transported to the laboratory in completely full tightly Stoppard bottles with no preservatives added. To determine accurately the pH of the sampled water from the river, the researcher employed electrometric method by using a pH meter probe. The pH probe was immersed into the sampled water in a bottle of 500-1000ml and stirred for a short time, after the water stabilized, the button or mode function was pressed and direct reading was taken as shown on the plate 3.1 below. The pH meter probe was rinsed on taking the reading from each sampled bottle. This was to avoid transfer of contamination from one bottle to another, (NWSC, 2009).



TDS & EC Meter Cable and pH Meter Cable

Plate 3.1 Photograph showing analysis of pH using the pH meter

3.7.1.2 Determining BOD by use of Azide Modification of Winkler Method

The BOD test was performed using Azide Modification of Winkler Method. Samples of water from rivers were taken in duplicate in each bottle from each land use sampling spot. Each sample from a land use was put in BOD bottle at 20ml, four liters of aerated distilled water was prepared for a minimum of 2 hours, nutrients was added for bacteria to feed on or as seeding materials since the DO present in the water may not get completely exhausted during incubation period were: ferric chloride (iron III chloride), potassium dehydrogenate sulphate, calcium chloride and magnesium sulphate were added in distilled aerated water each 1ml in all 4ml for all the nutrients. Aerated water containing nutrients was topped up in the sampled water in BOD bottles without leaving any space for air, it was later on put on a DO magnetic stir using a probe being placed in the bottle, and direct initial DO reading was taken there and then using a DO meter as shown on plate 3.2, (NWSC, 2009).



DO meter

The probe

Plate 3.3 Photograph showing the analysis of BOD after 5 days using Azinde Modification of Wrinkler method by use of Dissolved Oxygen Meter

3.7.1.3 Determining C.O.D by use of closed reflux calorimetric method and spectrophotometer

COD test was done by putting potassium dichromate and sulphuric acid in a beaker. These are reagents already contain oxidizing agents which is a mixture of the above having a low range (LR) of 0-150mg/l in a COD bottle. 2ml of each sample of water from a land use was added in to the reagents in COD bottles without diluting with the exception of sample from city abattoir taken on 30th/November/2012 which was concentrated and so 1ml of sample was diluted in 10ml of diluted water making the bottle hot. The samples were put on COD reactor and the reactor was warmed to attain a temperature of 152° C. This was done in order to raise the temperature or change the environment of the samples of water and then refluxed for two hours. After cooling the COD sample bottles, the reading was done using spectrophotometer as shown on plate 3.4. The value got was multiplied by dilution factor to get the COD, (NWSC, 2009).



Spectrophotometer

Plate 3.4 photographs showing the laboratory analysis of COD

3.7.1.4 Determining Total phosphate by use of Persulphate Method

The researcher took 25ml of water from each sample; one milliliter of sulphuric acid and 5 milliliter of potassium persulphate were added into each sample in a bottle including the blank sample. All were put in a sauce pan and put in an auto clave connected to electricity and heated for 30 minutes at 120^oc and cool at room temperature. 1ml of ascorbic acid was added to each sample and the sample was allowed to stay for 20 minutes for blue color development as shown on plate 3.5. The concentration was measured in mg/l at 880 nm using spectrophotometer wave length and the reading was taken, (NWSC, 2009).



Autoclave

Spectrophotometer

Plate 3.5 photographs showing the analysis of TP by use of persulphate method.

3.7.1.5 Nitrate determination by cadmium reduction and spectrophotometric method

25ml sample of water was measured and put in a cylinder; one pillow of nitraver⁶ was added and shaken very well to allow the powder to dissolve. One pillow of nitraver³ was added and precaution not to inhale while shaking was taken. It was left for 15 minutes and a pink color developed for samples which had nitrate. The blank sample was treated in the same way. Later each sample was put in sample cell and then put in a spectrophotometer and the reading was obtained and recorded, (NWSC, 2009).

3.8.1 Biological parameter

3.8.1.1 Determining Fecal Coli form by use of Membrane Filtration Method (MFM)

Pathogens according to Wright, (2008), and NWSC, (2009), are excrement from humans and other animal organisms or their eggs. These were determined by use of a Membrane Filtration Method (MFM) where Membrane Lauryl Sulphate Broth (MLSB) was dissolved in 100ml of distilled water. Each Millipore filter paper was placed in the filter apparatus and each sample of the water being tested was drawn through the filter. This is called sub-culturing. Any bacteria present were entrapped on the membrane. The filter was placed in a Petri dish having an absorbent paper pad that carried the broth on a special medium that supported the growth of bacteria and imparted a particular color to any organism in the water, this was then incubated at 44° c for 24 hours during which time any bacteria present grew and formed a colony visible to the naked eye and later on colonies count were done as shown on plates 3.6 and 3.7.



Plate 3.6 Photographs showing Laboratory preparation, analysis of Fecal Coli form

Source; Laboratory analysis



Plate 3.7 Photographs showing the counting and recording of colonies after incubation

3.9 Methods of Data Analysis

Gregory, (1978), states that for easy comparison of different set of data, it is therefore necessary to be able to summarize these varying values within the one set of data by one value alone. This one value is chosen so as to give at the same time as reasonable an approximation as possible to what is 'normal' or the 'mean'. For instance in a situation where the independent variables which are the land uses take effect on dependent variables which is water quality that is; physically, chemically and biologically, the best measure to be used is standard deviation. This is because samples of water were taken four times from each land use on different days hence their mean has to be got as shown in the below formula.

$$S.D = \sqrt{\frac{\sum fx^2}{\sum f} - \left(\frac{\sum fx}{\sum f}\right)^2}$$

For objective two, tables of the reach were constructed where the average results were put which portrayed changes in the water quality for physical, chemical and biological characteristics.

For objective three, the average values at both inflow and outflow for each parameter were plotted on a mean plot graph to show changes in the water quality such as TDS and EC, TSS, pH, BOD, COD, nitrate and fecal coli form. The focus was made on any changes in the above characteristics and the apparent relationships with the land uses.

CHAPTER FOUR

PRESENTATION AND DISCUSSION OF THERE SEARCH FINDINGS

4.1 Land use practices and their sizes along Mpanga River in Fort-Portal Municipality

Land use according to FAO, (Food Agricultural Organization), (1991), was earlier on defined as the function of the land determined by natural conditions and human intervention. Land use is therefore the way land is being put into use by man such as; land allocated for transportation, residential, markets, agriculture and industrialization. There are other land uses which are natural for example; natural forests, wetlands or swamps, and game parks. FAO, (1989), defines any type of land use as a kind of land use which is described in terms of its products and management hence the combination of a land use type in a specific area is a land use system.

Randolph, (2004), states that the use of land is perhaps the most significant driving force in human impact on natural environment. He also found out that land development for human settlement and resource production poses critical impact on the land itself and also on water, air, materials and energy use. Conversion of natural and productive lands to human use, sprawling patterns and inappropriate location of development, roads and building construction, and land use practices after development, all have broad impact on human environmental health and natural environment which can be exacerbated by land use decisions and can later cause natural hazards and soil erosion, alter hydrological balance, pollute surface and ground water and destroy wild life. The land uses in the study area are as presented in the map of Fort-Portal Municipality showing land uses and their sizes on figure 4.1.

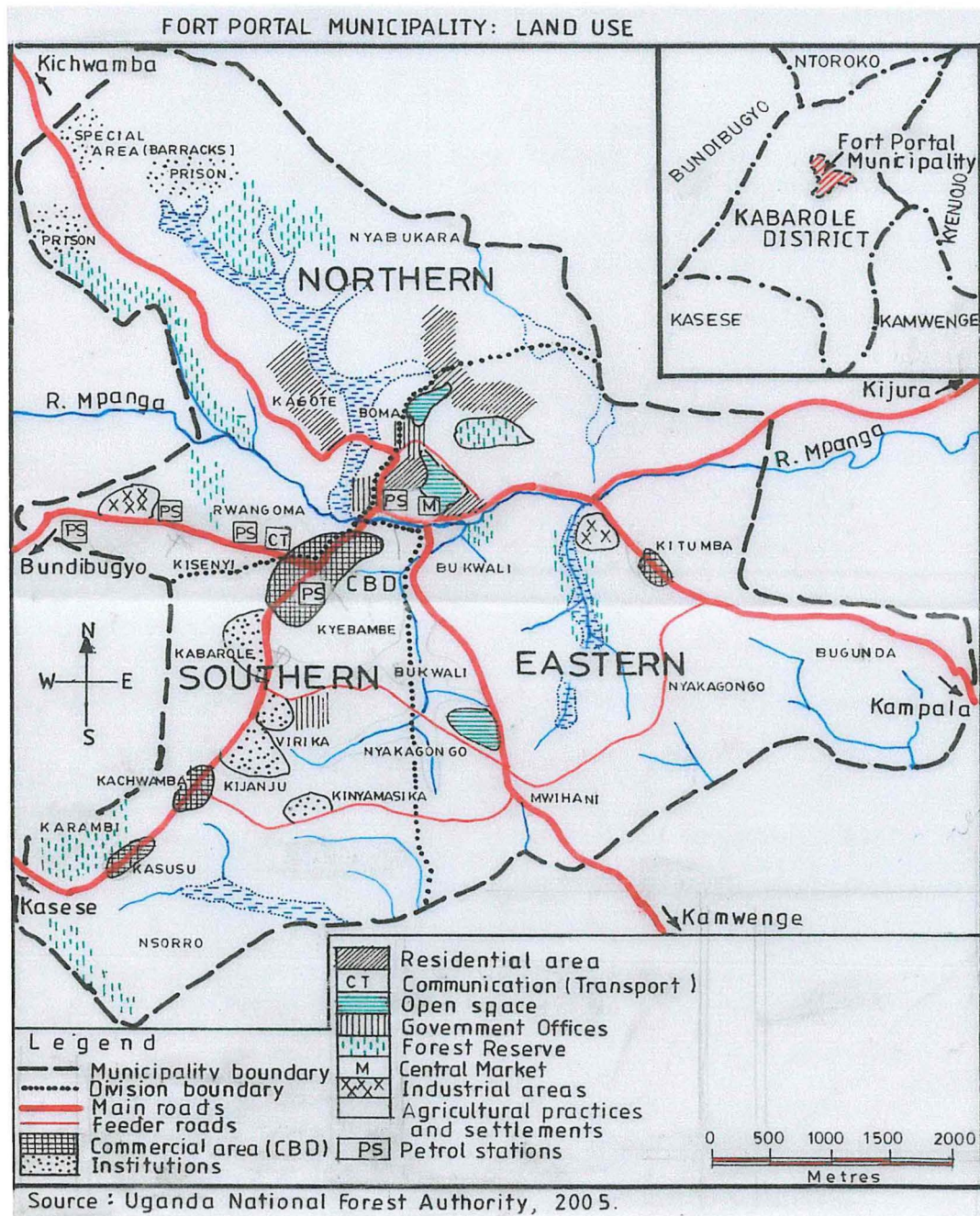


Figure 4.1 showing the map of Fort-Portal Municipality: Land Use

Table 4.1: showing an approximation of Land use practices and their sizes in Fort-Portal Municipality

| Land uses | Land uses in Km² |
|--|------------------------------------|
| Commercial area | 1.20 |
| Agricultural Practices and settlements | 28.00 |
| Institutions area | 3.00 |
| Industrial area | 0.80 |
| Residential area or planned and unplanned settlement | 4.00 |
| Open space area | 1.20 |
| Government offices | 0.30 |
| Wetland area | 2.15 |
| Forest Reserves | 5.00 |
| Total Area | 44.65 |

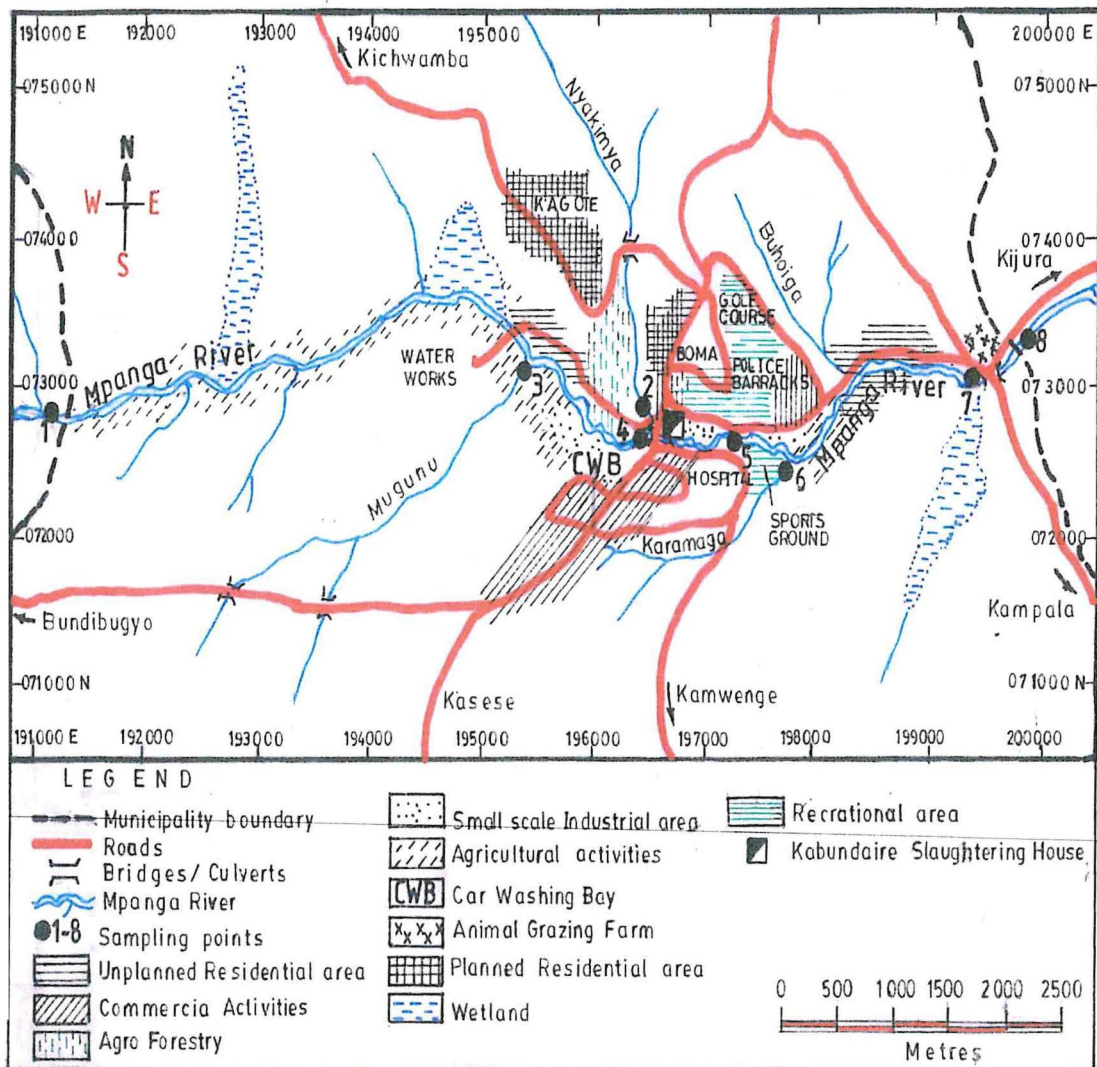
Source: Uganda National Forestry Authority, 2005.

From table 4.1, the largest form of land use in Fort-Portal Municipality is agricultural area and settlement which covers 28.00km² followed by forest reserves which cover 5.00km² and residential areas which cover 4.00km². Other land uses such as; Government offices, industrial area, commercial area and open space area, wetland areas and institutions area. Which range from 0.30 to 3.00km².

4.2 Different land use practices along Mpanga River in Fort-Portal Municipality

The land use practices identified in the study area during survey were; unplanned settlement, car washing bay, planned settlement, municipal abattoir, small scale industries, commercial areas Mpanga market a case in point, tree nursery beds, animal grazing farm, and cultivated farm as shown in the table above. These land uses are being portrayed in the land use map on figure 4.1.

THE LAND USE PRACTICES ALONG MPANGA RIVER IN FORT PORTAL MUNICIPALITY.



Source : Observation from the field by the Researcher.

Figure 4.2 map showing the Land use practice along River Mpanga in Fort-Portal Municipality

According to figure 4.5 and 4.6, sampling point 1 (A) is inflow at Bukuku which is the border of the Municipality (upstream), sampling point 8 (B) is outflow at Kijura which is outside the Municipality (downstream) and sampling point 2 up to 7 are hot spots within Fort-Portal urban center where there are many economic activities taking place as shown on figure 4.2.

4.2.1 Land uses and water quality in River Mpanga

Bowen and Pallister, (2001) and Goel, (2000), continue to point out that in urban areas, the main source of water pollution are sewage, manufacturing industries and power station. It has been confirmed that most sewage in Most Economic Developed Countries is transported via the drainage systems to the treatment works where it is cleaned before re-entering water courses. However, some old treatment works are inefficient and until recently in some places raw sewage was sometimes emptied directly into rivers or the sea or carried by foods after heavy rain for example in United Kingdom, in autumn, 2000 people cleaning up the city were warned to wear mask to prevent contracting wies's disease as a result of being in contact with the raw sewage.

Ojungu, (1992), ascertains that the industrial sector in every country of the East African region is relatively small and it concentrates mainly on processing agricultural and livestock products. For example in the coastal states, the industrial activity include; cashew nut and copra processing, vegetable oil extraction, coffee bean roasting and grinding, sugar and molasses refining, brewing, rice milling, sisal processing, paper and pulp production and soap production. Most of these industries are concentrated in the major coastal cities of Magadishu, Mombasa, Dar-es-salaam, Maputo, Beira, and including Uganda that is Kampala, Jinja, Lugazi and Kinyala. These industries contribute large quantities of aquatic discharges which comprise of suspended solids, chemicals and heavy metals, sludge (mud, slush, and mire) and other dissolved substances. Since these industries are agro-based, large amounts of organic wastes are produced which contribute to total biological demand (BOD) leading to algal growth a sign of features of eutrophication in water bodies.

Ojungu continues to assert that even if Mauritius and Seychelles have substantive sewerage services, 3/3 of the urban population in the region especially from the unplanned settlement near the coast of these cities have improper excreta disposal into the water bodies at the coast leading to bacteriological infections which has resulted to frequent outbreak of cholera in the fishing villages near the coast. Goel, (2000), states that agricultural activities produce wastes which are inform of runoff from the agricultural fields and animal farms. This is because modern agriculture uses a large number of chemicals called agrochemicals in the form of fertilizers, organic manures, pesticides, growth hormones and nutrients solution. All the residual forms of these chemicals along with organic debris from the remains of harvested

crops are trapped by runoff water causing pollution problems in the receiving waters. Since agricultural runoff are considerably rich in nutrients like; nitrogen and phosphorous, organic matter and pesticides, these create the problem of eutrophication and pesticides are responsible for causing toxicities to aquatic life. In addition, pesticides have been reported to get bio-accumulated and bio-magnified through food chains resulting into secondary poisoning to man and predatory birds. NEMA, (2004), reported that land use activities within Fort-Portal municipality such as; car washing bays, Municipal abattoir, and factories and commercial activities have polluted Mpanga River because some of them were set without carrying out Environmental Impact Assessments.

4.4 Land uses and water quality along River Mpanga

Analysis were done on samples of water taken from each land use spot along River Mpanga basing on the parameters on Table in appendix IV in order to establish the relationships between land uses and water quality as discussed below.

4.5.1 Relationships between unplanned settlement land use and water quality

Under this section, the researcher analyzed the physical, chemical and biological characteristics of water.

The unplanned settlement was found to be set up in Kisenyi within Fort-Portal Municipal. According to the survey, it was found to have a number of houses built uphazardly not according to Municipal Structural Plan, (1998-2018). Most houses were 10-30 meters away from the river while in some areas some houses were less than 10 meters away from the river bank. This enabled disposal of wastes to the river very easily. There were also a number of saloons which used chemicals for treating hairs. These chemicals after being applied on the hairs were washed together with soap and other detergents and the wastes were drained direct into the river. Within the unplanned settlement, other activities observed were; timber workshop or carpentry as evidenced on photographs on plate 4.2, grinding mills, small restaurants, and construction of houses. The nature of the houses established were poor houses without flush toilets which instead had pit latrines. Their distance from the river bank was 10-30 meters away while others were 50 meters and above.

There was no place demarcated by the municipal council for disposal of wastes hence the population disposed their wastes anyhow and in most cases just adjacent to river bank or direct into the river as shown in the photographs on plate 4.1.



Plate 4.1 showing photograph of one of the unplanned settlement land use in Kisenyi Fort-Portal Municipality along Mpanga River

Source: Field data taken on 21st/October/ 2013

4.5.1.1 Physical, chemical and biological characteristics of water in unplanned settlement land uses

Physical, chemical, and biological characteristics that were analyzed by the researcher in this section included; TDS, EC, and TSS for the physical characteristics, chemical characteristics included; pH, BOD, COD, TP and NO₃, biological characteristics was FC results areas shown on table 4.3.

Table 4.2: showing physical, chemical and biological characteristics of water within the unplanned settlement land uses

| Physical characteristics | | | chemical characteristics | | | | | Biological characteristics |
|--------------------------|----------------|----------|--------------------------|----------|----------|---------|----------------------|----------------------------|
| TDS mg/l | E C μ S/cm | TSS mg/l | pH | BOD mg/l | COD mg/l | TP mg/l | NO ₃ mg/l | FC fcu/100ml |
| 153.25 | 294.50 | 23.75 | 7.48 | 4.75 | 23.75 | 3.24 | 0.03 | 1920 |

Source: Laboratory analysis

The result of the analysis of samples of water taken from unplanned settlement land use along Mpanga River with mixed activities such as; grinding mills, small restaurants, saloons and construction of houses indicated that FC value was 1920 fcu/100ml. This average value is high compared to FC at the tree nursery bed (agro-forestry) which has an average value of 183fcu/100ml, industrial land use which has an average value of 268fcu/100ml and commercial land use (Mpanga market) which has an average value of 305fcu/10ml. This was because even if the presence of a number of pit latrines just about 6-10 meters away from the river which leached the wastes into the river as evidence on the middle left ground on plate 4.1, the huge volume of water in the river was able to dilute the wastes. This is line with Ghosh, (1992), and NEMA, (2008), who assert that pollution of ponds or rivers are due to human habits because men and cattle take bath hence releasing organic matters and even those who live by the side of the ponds or rivers usually place their latrines on its banks and sometimes bacteria and viruses get into the water because some cities illegally dump raw sewage directly into the water which contaminate water. However the above value for FC is far much lower than the National Standards (Maximum Permissible level) for FC level in water bodies which are 5000fcu/100ml meaning that if the river water was not flowing, unplanned settlement was able to impose serious pollution into the river.

The EC value was 294.50 μ S/cm which was attributed to a smaller amount of disposal of organic wastes like; garbage from households, feces from cows and people, soap from clothes and utensils from households being washed as evidenced in the middle ground on photograph on plate 4.1 showing people washing clothes at the bank of the river and some motorcycles were also being washed from upstream and downstream. Other land uses observed were;

some small restaurants, drug shops, small markets, and saloons where salt from utensils and chemicals washed were drained into the river hence conducting electricity since they had ions and chemicals. However the above value of EC is far much lower than the National Standards (Maximum Permissible level) for EC level in water bodies which are 1500 $\mu\text{S}/\text{cm}$. However, the researcher expected the unplanned settlement land use to impose serious pollution in river water if it was not flowing.

TDS average value was 153.25mg/l. This low value could have been due to less quantity of wastes from land uses mentioned above such as; some small restaurants, drug shops, small markets and saloons where salt from utensils, and chemicals washed were drained into the river. This is in line with what Wright, (2008) and Bowen, (2001), who stated that the main sources of pollution in River Gang in India are from urban wastes which are in form of organic and inorganic wastes, and sewage. But where the wastes deposited in huge volume of water are in less quantity, they are not able to pollute the water body Kannan, (1997) and Debora, (1996). However the above value of TDS is far much lower than the National Standards (Maximum Permissible level) for TDS level in water bodies which are 1200mg/l. This implies that unplanned settlement land use would have caused serious pollution if the river water was stagnant.

Within the unplanned settlement land use, TSS was 12.75mg/l. This average value is low compared to TSS at the municipal abattoir which has an average value of 113.25mg/l, animal grazing farm has 53.25mg/l, and cultivation farm is 48.82mg/l. Even if the activities here were active and capable of producing wastes, these wastes were not enough to increase the TSS in the river probably because the river was flat and calm capable of settling the suspended materials or TSS loads as evidenced on activities like construction, carpentry workshops, and residues of organic wastes from households as shown on photographs on plate 4.2. This is supported by Pierre, (2000), who states that some materials carried in natural stream are deposited in the channels to cause aggradations. This low value which is far much lower than the National Standards (Maximum Permissible level) for TSS in water bodies which are 100mg/l could have been affected by days when samples were collected when it had not rained causing wastes from the surroundings not to be disposed in the river by runoff.

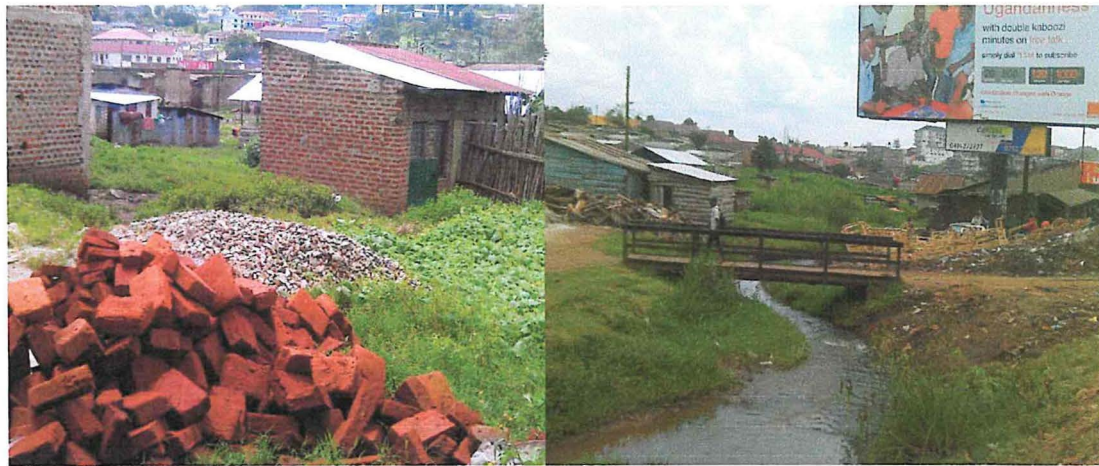


Plate 4.2 showing photographs of some activities within the unplanned settlement land use along Mpanga River in Kisenyi which are able to increase TSS and COD

Source: Field data taken on 21st/October/2013

COD average value was as low as 23.75mg/l according to the National Standards (Maximum Permissible level) for COD in water bodies are 100mg/l. This implied that even though there were extreme wastes from household's activities, restaurants, saloons and markets, wastes like; soap from washing of clothes and motor cycles, detergents, salt, chemicals and other cleaning agents which could increase COD, it is possible that these wastes were eroded into the river by runoff and later diluted by huge volume of water in the river as evidenced on the photographs on plates 4.1 and 4.2. pH of the unplanned settlement was 7.63. This is the ideal level of pH in a water body which is compatible to the National Standards (Maximum Permissible level) for pH in water bodies which is 6.0-8.0. This ideal level of pH meant that unplanned settlement land use did not impose a negative impact on water quality in the river. This means that the wastes within this land use did not contain much carbon dioxide and hydrogen ions because of fewer acids and chemicals. The BOD within the unplanned settlement was as low as 4.75mg/l compared to National Permissible level of BOD in water bodies which is supposed to be 50mg/l. This was because of limited disposal of oxygen-demanding wastes such as: peelings of bananas, human and animal wastes (poultry, cows and goats), pit latrines, vegetables residues disposed in the river from settlement and small markets along the river as it is line with what Kannan, (1997), and Debora, (1996), who stated that when small amounts of sewage or industrial wastes are dumped into a very large water body, it would not be badly polluted and that the normal quality of water can be restored in a reasonable period of time due to dilution and self-purification process.

TP was 3.24mg/l and NO₃ was 0.03mg/l. These values were very low compared to National Permissible level of NO₃ and TP which are both 10.0mg/l in water bodies. The low TP implied that there was very limited use of fertilizers and manures in cultivated fields within the unplanned settlement land use in the municipality, and very low NO₃ could have been because of leaching and percolation of inorganic fertilizers by runoff and very little was disposed into the river as stated by Goel, (2000), that leaching of NO₃ by runoff through percolation causes low level in NO₃ surface water.

This contradicts what Gupta, (1997), and Coble et al, (1981), who said that among chemicals that cause pollution are nitrates and phosphorous from farmlands, sewage and waste water which are released into surface water from households detergents, soaps, and other cleaning agents. However, small amounts of these chemicals are not capable of polluting water bodies. There was a possibility that these values were affected by the samples which were taken on days when there was no rain as evidenced by TSS from the raw data for 9th/October/2012, 21th/October/2012 and 30th/November/2012 where samples of water were taken when there was rain which ranged from 0.32-4.30mg/l compared to sample taken on 8th/November/2012 when there was rain which has 9.30mg/l. This means that wastes from unplanned settlement were not eroded to the river or they leached due percolation process by runoff which was not able to increase nitrates and TP levels in water.

4.5.2 Car washing bay land use and water quality

The car washing bay land use sampled was in Kabundaire. The result of the survey presented that the activities being done in this place were more than one. However the dominant one was car washing bay of; motorcycles, vehicles like buses, Lorries, mini buses to mention but a few using soap and other detergents. The approximate numbers of vehicles washed in one washing bay are 100 per day. Most of the vehicles were being used for carrying goods and some were used for carrying salts or goods which contained chemicals. Although car washing bay land use is a dominant activity, there are also other activities on the other side of the river and these include; shops and settlements behind the shops and the goods sold were salt, soap, animal feeds. All the wastes cleaned from these places are all disposed into the river directly or indirectly. All these wastes were directed to river during the course of washing each vehicle as seen from the photograph on plate 4.3.



A person collecting water from the river

Plate 4.3 showing photograph of car washing bay land use along Mpanga River in Nakaseke which are able to increase TSS and COD.

4.5.2.1 Physical, chemical and biological characteristics of water at car washing bay land use

In this section the researcher presents the analyzed data on; physical, chemical and biologic characteristics which included; TDS, EC and TSS for the physical characteristics, chemical characteristics, pH, BOD, COD, TP and NO₃ and biological characteristics is FC as shown on the table 4.4.

Table 4.3: showing physical, chemical, and biological characteristics of water from car washing bay land use along River Mpanga.

| physical characteristics | | | Chemical characteristics | | | biological characteristics | | |
|--------------------------|--------|-------|--------------------------|------|-------|----------------------------|-----------------|---------|
| TDS | EC | TSS | pH | BOD | COD | TP | NO ₃ | FC |
| 159.25 | 298.50 | 11.25 | 7.50 | 5.25 | 26.75 | 4.36 | 0.12 | 1055.00 |

Source: Laboratory analysis.

Within the car washing bay land use, fecal coli form average value was 335cfu /100ml. This indicated that activities like animal grazing and settlement which exist near this land use were able to cause the above value of FC of the water in the river. This value is lower than National Standard for FC level in water body which is 5000fcu /100ml. Implying that the activities in this area is not able to increase the FC in the water beyond the threshold level set by NWSC.

From table 4.4, the EC average value under car washing bay was 298.50 $\mu\text{S}/\text{cm}$. This was because of smaller amount of chemicals from soap used for washing vehicles and motorcycles as well as wastes from shops and settlement behind shops which contained salt and chemicals were all being disposed into the river. This enabled the river water to contain less ions and chemicals which conduct electricity hence leading to low EC average value of 294.50 $\mu\text{S}/\text{cm}$ as shown in table 4.4. This value is low compared to the National Standard for EC level in water body which is 1500 micro Siemens/cm. TDS level in the river water was as low as 159.25mg/l compared to the National Standard for TDS level in water body which is 1200mg/l, this is because of the less quantity of soap used for washing vehicles which returned back in the river with the used up water as shown on plate 4.3. This contradicts the statement made by Ralph, Feather, et al, (1993) and Ramsden, (1997), that pollution of water results from soap and other detergents used in washing. These are able to form a bridge between grease and water because they have the sodium and potassium salts of inorganic acids which are able to conduct electricity and cause the presence of TDS in the water body. This statement points out that there is a relationship between TDS and EC. However Palmer, (2001), refutes the statement of Ramsden, (1997), by stating that in most cases the concentrations in domestic sewage in form of inorganic and organics are small in the receiving river water. This is because their suspended solids may be of little concern unable to cause pollution.

Within the car washing bay, the level of bio-chemical oxygen demand (BOD) on average was 26.75mg/l compared to the National Standard for BOD in water body which is 50mg/l. This was because the inorganic wastes from car washing bay cannot cause a rise in BOD because the inorganic content of wastes in the water is low hence less DO is required to decompose or oxidize these inorganic wastes. Because of a small amount of settlement within this place, they are not enough to produce a huge amount of bio-degradable or organic wastes such as;

peelings from bananas, potatoes and vegetables from; homes, commercial areas and animal farms on top of wastes disposed directly into the river when washing vehicles and motor cycles as shown on the photograph on plate 4.3. Example of wastes included organic wastes such as; vegetables and sewage from homes and markets. However this BOD level has not gone beyond the national permissible discharge of wastes in water body which is supposed to be 50mg/l implying that car washing bay land use was not enough to cause serious pollution on the water in River Mpanga. The low BOD is in line with what Chhatwal et al, (1999), stated that the lower the BOD, the lower the organic content in the water and less DO will be used in the process of their decomposition by bacteria.

The COD was (26.75mg/l) within the car washing bay land use according to table 4.4 a possibility that the amount of inorganic wastes got from wastes containing chemicals such as; salt from shops and homes, detergents and soap being used in washing the motor cycles and vehicles were so little that they got diluted in the river hence not able to rise the COD level as compared to the national standard which is 100mg/l. The TSS within the car washing bay was as low as 11.25mg/l compared to the national standard which is 100mg/l. The low COD is in line with what Chhatwal et al, (1999), stated that the low level of COD could be due to use of less strong oxidants such as; salt from shops and homes detergents from used up water from washing vehicles. This implies that there is less inorganic content in the water and less oxygen will be used in the process of their oxidation.

Despite the fact that the used up water from washing cars goes back to the river of which the researcher expected it to have increased the TSS, but is still low. This was because less eroded soil particles by used up water from washing vehicles and motorcycles flowed with less soil particles back into the river and this soil particles was so little not capable of raising TSS in the river water.

Total phosphate was as low as 4.36mg/l and nitrate was 0.37mg/l as shown on table 4.4. This was because the activities taking place within the car washing bay land use did not have enough effect on the water in the river. pH level was found to be 7.50. This is within the permissible level of pH in water body according to National Standard from NWSC, (2009), revised which range between 6.0 and 8.0. It implies that this activity is environmentally friendly. This is also in line with Dara, (2000), who stated that the pH range of 6.7-8.6 is generally acceptable and a drop or a rise in pH of water bodies beyond or less than this range

would indicate some pollution as a result of effluents from; chemicals and fertilizers or by acidic rain.

4.5.3 Planned settlement land use and water quality

Planned settlement land uses within Fort-Portal Municipality were found in Kagote, Booma, Rwengoma and Nyabukara in western division. The survey on the activities in this area especially Booma which was a case study were found to be well established houses with garbage from households carried to demarcated sites, most of the households here had septic tanks which direct all the wastes to the sewage system. However, within this planned settlement, it is good to note that the survey result presented that there were also some unplanned settlements which had sprung up with poor garbage disposal from small markets and homes within this place, washing of motor cycles along or into the river and pit latrines near the bank of the river. This is also affirmed by Ojungu, (1992), who stated that several unplanned settlements have sprung up in the coastal regions of East Africa because of higher growth rates in population. These have compounded problems within even the planned urban center. The unplanned settlements which have sprung up within the planned settlement are as a result of failure in law enforcement by the Municipal Council and the Physical Planner.



Plate 4.4 showing photographs of planned settlement land use in Booma which is along River Mpanga

Source: Field data of 9/October/2012

4.5.3.1 Physical characteristics of water in the river within planned settlement land use

In this section the researcher presents the analyzed data on; physical, chemical and biological characteristics which included; TDS, EC, and TSS for the physical characteristics, chemical characteristics include; pH, BOD, COD, TP and NO₃ and biological characteristics is FC as shown on the table 4.5.

Table 4.4: showing physical, chemical, and biological characteristics planned settlement land use along River Mpanga

| Physical characteristics | | | chemical characteristics | | | | | Biological characteristics |
|--------------------------|--------|-------|--------------------------|------|-------|------|-----------------|----------------------------|
| TDS | EC | TSS | pH | BOD | COD | TP | NO ₃ | FC |
| 226.25 | 427.00 | 12.75 | 7.63 | 4.75 | 25.25 | 3.20 | 0.03 | 1920.00 |

Source: Laboratory analysis

From all the parameters analyzed from the samples of water taken from the river within Booma planned settlement land use, EC was 427 micro Siemens/cm. This value is less than National Standard for EC level in water bodies which are 1500 micro Siemens/cm. This could have been because of less garbage disposal from inorganic and organic wastes from the unplanned settlement which have sprung up within Booma such as; soap and other detergents used in washing household utensils, motorcycles and clothes, chemicals and salts from saloons which contained less ions. TDS was as low as 226.25mg/l compared to the National Standard which is 1200mg/l. This could have been due to disposal of less inorganic and organic wastes in the river or possibly garbage are always collected and taken to demarcated sites.

Apart from the above factors, the average level of EC which is 427 micro Siemens/cm and TDS which is 226.25mg/l within the planned settlement could have been contributed by limestone rocks especially from Nyakasura which contain calcium carbonate where the tributary of river Mpanga passed called river Nyakimya as seen from the drainage map of Fort-Portal Municipality on figure 4.2. This is because generally Fort-Portal is a karsts region. The season could have also contributed to TDS and EC. For instance from the raw data taken on 9th/October/2012, 21st/October/2012, 8th/November/2012, and 30th/November/2012, the EC values ranged from 90-579 micros Siemens/cm. The TDS ranged from 58.00-279mg/l. The researcher discovered that on days when there was no rain

during the collection of data such as on 9th/October/2012, 21st/October/2012 and on 30th/November/2012, the EC raw data value had slightly risen probably because the dilution of wastes disposed in the river did not take place but on 8th/November/2012 when it rained heavily throughout the time of data collection, the EC went down because of dilution from the runoff from heavy rain which entered the river. This is in line with Trivedi, (1997) and Thorburry, (1969), who stated that since calcium is widely distributed on the earth's crust and especially in the karst regions, it is therefore present nearly in all water bodies hence the water coming from limestone zone may contain greater concentration of calcium hence increasing its TDS and EC. However these values were lower than the National Standards for TDS level which is 1200mg/l and for EC which is 1500 micro Siemens/cm.

The FC level was 355fcu/100ml in the river flowing within the planned settlement land use. But when compared to National Standard for FC level in water bodies which are 5000fcu/100ml, the value of FC within planned settlement is far much lower. This is probably because the human wastes were not discarded into the river. Majority of households use flush toilets which directed human wastes to the municipal sewage treatment plant. This is in line with Bowen, (2001), who stated that in Most Economic Developed Countries where planned settlement exist, most of their sewage is transported through the drainage systems to the treatment works where it is cleaned before re-entering water courses. This is true with Fort-Portal Municipality which has a treatment plant for the above purposes, NEMA, (2004).

The COD was 25.25mg/l compared to National Standard which is 100mg /l possibly because the organic wastes disposed by the unplanned settlement within the planned settlement were not serious to cause pollution in the river within this area. TSS was as low as 7.00mg/l compared to the National Standard which is 100mg/l. TP was 3.20mg/l and NO₃ within planned settlement was 0.01mg/l. This much lower than the National Standard which 10.0mg/l is in water bodies. The extreme decline in TSS was possibly because suspended matters from inorganic and organic wastes were able to settle at the bottom of the river due to its flatness. Low TP and NO₃ were due limited fertilizers used in crop cultivation and dilution from huge volume of water in the river. The pH was 7.63. This average level of pH in river water within planned settlement land use was found normal or acceptable as seen from table 4.5. This implies that planned land use in the urban centers should be given priority for better environmental management. BOD was 8.00mg/l and much lower than the National Standard which is 50mg/l. This is because almost all the bio-degradable and inorganic wastes in this

land use are directed either to the sewage treatment plant or to demarcated sites for wastes disposal. Tripathi, (1993), support this by saying that the low BOD is because the demand for oxygen for decomposition of organic wastes is not proportional to the organic wastes present in water body. In other words it means that the organic wastes present is small and hence consume less oxygen leading to low BOD.

4.5.4 Municipal abattoir land use and water quality

The abattoir was found in Kabundaire in western division. The wastes from the municipal abattoir were observed to be urine, blood, dung with suspended particles, soap and other detergents used in the washing of the abattoir which are all disposed direct into the river through trench. The abattoir is only about 10 meters away from the river as shown on table 4.7.

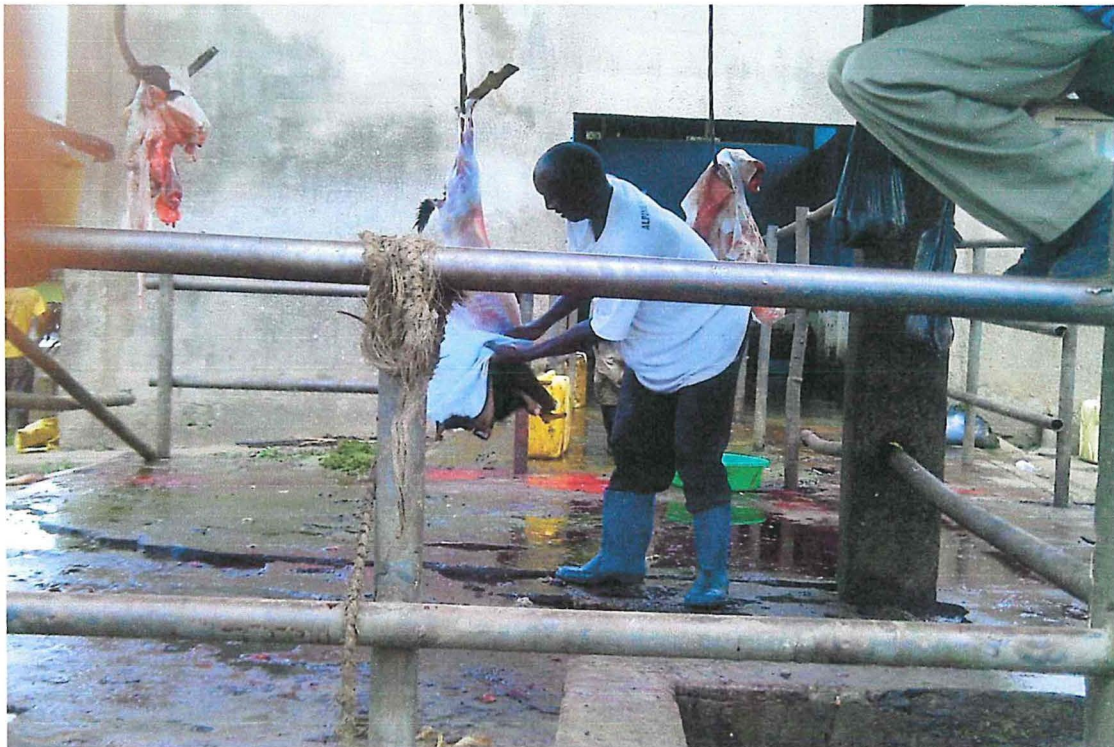


Plate 4.5 showing photograph of municipal abattoir or slaughtering slab land use within Fort-Portal Municipality at Kabundaire along Mpanga River

Source: Field data taken on 9th/October/2012

4.5.4.1 Physical, chemical and biological characteristics of water within municipal abattoir

In this section the researcher presents the analyzed data on; physical, chemical, and biological characteristics. Where parameters for the physical characteristics included; TDS, EC, and TSS, chemical characteristics included; pH, BOD, COD, TP and NO₃ and biological characteristics is FC as shown on the table 4.6.

Table 4.5: showing physical, chemical, and Biological characteristics of water within Municipal abattoir

| Physical characteristics | | | Chemical characteristics | | | Biological characteristics | | |
|--------------------------|--------|--------|--------------------------|-------|--------|----------------------------|-----------------|---------|
| TDS | EC | TSS | pH | BOD | COD | TP | NO ₃ | FC |
| 277.75 | 507.50 | 113.25 | 7.03 | 10.75 | 199.50 | 18.37 | 0.39 | 2067.50 |

Source: Laboratory analysis

The FC water in the river within Municipal abattoir was 2068fcu/100ml compared to National Standard which is 5000fcu/100ml. This seems to be a typical of wastes from the Municipal abattoir because of the bacteria from animal wastes disposed into the river during slaughtering and cleaning the slaughtering house. The FC average value could have also been affected by sample of 8th/November/2012 which was taken during heavy rains and the runoff which eroded a smaller amount of human and animal wastes from the municipal into the river. This is in line with what NEMA, (2004), stated that pollution of rivers especially Mpanga River is as a result of effluents from slaughtering slab in Kabundaire. However this value is low when compared to the National Standard as stated earlier. The EC level within Municipal abattoir was 505.50 micro Siemens /cm lower than the National Standard which is 1500 μ S/cm and TDS was 277.75mg/l while the National Standard is 1200mg/l implying that TDS in this land use is environmentally friendly. This was because of the of dilution of wastes at this sampling spot by the huge volume of river water where animals' wastes from the abattoir such as; dung, urine, blood and soap used for cleaning after slaughtering which were directed into the river through trenches and these wastes had ions and uric acid and chemicals which could have caused serious conductivity of electricity.

At Municipal abattoir (slaughtering slab), TSS was 113.25mg/l higher than the National Standards for TSS level in water bodies which is 100mg/l and COD was 199.50mg/l which is

also higher than the National Standards for COD level in water bodies which is 100mg/l these values exceeded the National Standard for effluents discharge in water bodies. This is in line with what Chhatwal, (1999), said that since the COD is a measure of the amount of oxygen required to chemically oxidize the contaminants to carbon dioxide. Chhatwal continues to say that COD value in most cases is higher than BOD because of the strong chemicals or oxidants used such as soap, calcium and ions from blood, and acid from urine of animals. All these help to deplete the oxygen supply. This could have been affected by the sampling of 8th/November/2012 where raw data for COD was 596mg/l and TSS raw data was 292mg/l. This was because many animals were slaughtered on this date compared to other days and possibly in addition, the runoff from heavy rains eroded both human and animal wastes, soap, and minerals from other land uses within the urban center to the river. At Municipal abattoir the TP was 18.37mg/l. This value exceeded the National Standard which is 10mg/l this could be due to huge amount of animal wastes from Municipal abattoir and from the other land uses within this spot as in line with NEMA, (2004), which states that pollution of water bodies by slaughter slab in Kabundaire has increased contamination in waters bodies in urban areas.

BOD was as low as 10.75mg/l compared to National Standards which is 50mg/l. The low BOD according to Chhatwal, (1999), low BOD is due to less decomposition of organic matter by bacteria which consumes less dissolved oxygen. Nitrate was 0.39mg/l lower than the National standard which is 10mg/l. This could be due to dilution of non-degradable and biodegradable wastes from the heavy rain of 8th/November/2012 where BOD from raw data was 4.00mg/l and nitrate was 0.03mg/l. pH of the river within Municipal abattoir is 7.0. This is acceptable in a sense that it is falling within the National Standards which is ranging from 6.0-8.0.

4.5.5 Industrial land use and water quality

Land uses within industrial area were found to be motor vehicle garages, grinding mills, brick laying industry which used sand and cement as the raw materials for making blocks, metal work shop for welding and painting, aluminum scrap work shop as shown in the photographs on plate 4.6.



↓
River Mpanga

Plate 4.6 showing photographs of some of the small scale industries land use in Fort-Portal Municipality along Mpanga River

Source: Field data taken on 21st/ October /2012

4.5.5.1 Physical, chemical and biological characteristics of water within industrial area

In this section the researcher presents the analyzed data on; physical, chemical and biological characteristics of water within industrial area where for the physical characteristics they included; TDS, EC, and TSS, chemical characteristics included; pH, BOD, COD, TP, and NO₃ and biological characteristics is FC as shown on table 4.7.

Table 4.6: showing physical, chemical, and biological characteristics within the industrial land use along Mpanga River

| Physical characteristics | | | chemical characteristics | | | | | Biological characteristics |
|--------------------------|--------|-------|--------------------------|------|-------|-----|-----------------|----------------------------|
| TDS | EC | TSS | pH | BOD | COD | TP | NO ₃ | FC |
| 159.75 | 301.50 | 21.00 | 7.45 | 4.25 | 17.00 | 3.6 | 0.04 | 267.50 |

Source: Laboratory analysis

The EC in the River within industrial land use was 301.25 micro Siemens/cm. However, this value is far much below the National Standard for EC level in water bodies which is 1500 micro Siemens/cm. TDS was 159.75mg/l lower than the National Standard for TDS level in water bodies which is 1200mg/l. This is in line with what was stated by Gupta, (1997), that the effluents from a fertilizer plant was reported to have caused increase in TDS and EC in River Gang because of high concentration of chlorides, phosphates, sulphates, ammonium, and dissolved solids. However there is low development of small scale industries within Fort-Portal Municipality hence they do not produce serious pollutants like; chemicals, salt, acids and oils. Kyatal, (1989), supports this statement by stating that it is because their waste load is less. These are evidenced from the activities on plates 4.6, 4.7, and 4.8 such as; welding, painting metals, repair in garages, grinding maize, brick making, and cutting aluminum scraps for making saucepans. This implies that these activities are minimal.

FC was 268cfu/100ml although according to the National Standard which is 5000cfu/100 ml, the value is far much below National Permissible level of FC in water bodies. This was because the activities mentioned above in this place had not produced microorganisms which can increase fecal coli form in the river. TDS was 159.75mg/l. But this average value is low when compared to the National Standard which is 1500 micro Siemens/cm, this presents a sign of less presence of pollutants like; chemical and salts from industries.

The TSS was 21.00mg/l compared to the National Standard which is 100mg/l. This means that other land uses such as; the grounded flour particles from the grinding mills and the sand and cement particles from the brick laying industry where not able to cause serious level of TSS in the river. This may be due to the low level of industrial development.



Sand

Used up bag for
cement

River Mpanga behind

Plate 4.7 showing photograph of one of the brick making industries in Kabundaire industrial area which are capable of increasing TSS in the river

Source: Field data taken on 21st/October/2012



Plate 4.8 showing photographs of one of the grinding mills in Kabundaire industrial area which are capable of increasing TSS in the river

Source: Field data on 21st/ October/2012

From the above photographs on plates; 4.7 and 4.8, the researcher observed that rainfall seasonality could have also impacted on the variations of TSS as evidenced from the row data of 8th/November/2012 where the TSS was 27 mg/l compared to 21st/October/2012 where the TSS was 4.00mg/l, and 30th/November/2012 where TSS was 5.00mg/l. This was probably because it did not rain and suspended matters were not eroded to the river. The TSS result for 9th/October/2012 had the highest TSS raw data which was found to be 45mg/l although it did not rain probably the grinding mills and brick laying industry were very busy on this day and there was direct disposal of wastes into the river. Never the less, the average value of TSS is still below the National Standards which is 100mg/l. pH of water in the river within industrial land use was 7.45. This is acceptable value because it falls within the range of National Standards for pH level in water bodies which is 6.0-8.0 meaning that the activities are environmentally friendly.

The bio-chemical oxygen demand (BOD) was 4.25mg/l, COD was 17.00mg/l, total phosphate was 3.64mg/l and nitrate was 0.04mg/l. These values are below the National Standards for BOD level which is 50mg/l and COD level which is 100mg/l in water bodies. These low average values of BOD and COD were due to the activities within the industrial area such as; few settlements behind the shops and Snacks restaurant which disposed limited biodegradable wastes unable to increase the BOD in the river. Low COD, BOD, Total phosphate, and nitrate were due to fewer chemicals produced by the industries. This in line with Katyal and Satake, (1989), who states that factories which discharge BOD and COD wastes with a total load of about three to four times is able to cause serious pollution in water body than the wastes load which is less.

4.5.6 Commercial land use and water quality

Commercial activities were found to be in Kisenyi, Kabundaire markets all in western division, and Mpanga markets in southern division respectively the researcher chose Mpanga market in southern division as a case study as shown on the photograph on plate 4.9.



Plate 4.9 showing photograph of commercial land use case study Mpanga market

Source: Field data taken on 21st/October/ 2012

The result from critical observation on activities within the market included; many saloons, restaurants, shops which dealt in general merchandise and butchers. Other products sold in



Plate 4.11 showing photographs of some of the goods sold within Mpanga market able of increasing TSS in the river

Source: Field data taken on 21st/October/2012

All these wastes were disposed in the river directly or indirectly for instance days in case it rained although they have not posed serious pollution in the water. For example the raw data for TSS of the samples taken four times from Mpanga Commercial land use range from 7-45mg/l that is on 9th/October/2012, 21st/October/2012, 8th/November/2012 and 30th/November/2012 implying that there is no pollution because they do not go beyond the National Standards for TSS level which is 100mg/l. The pH of water within Mpanga market land use was 7.48. This is within the range of the National Standards which ranges from 6.0-8.0 implying that it is acceptable since the activities are environmentally friendly. Chemical oxygen demand (COD) was 26.75mg/l, TP was 7.14mg/l, and BOD was 3.75mg /l, and nitrate was 0.13mg/l. All these values are far below the National Standards as stated earlier probably because of dilution of wastes by huge volume of water in the river or the activities within commercial land use which are not producing serious wastes which pollute water or the wastes are collected by municipal council authority and disposed to demarcated sites as it was evidence by the presence of dust bins and garbage trucks within the market.

Within Mpanga Market, the bio-chemical oxygen demand was (BOD) 3.75mg/l compared to National Standards which is 50mg/l. This value was low compared to the goods or products sold in the market which are capable of increasing the BOD such as; vegetables and fruits

like avocado, bananas, pineapple, tomatoes, cabbages, carrots and yams as shown in the photograph on plate 4.12. The low BOD average could be due to the fact that the biodegradable wastes from the fruits, and vegetables were always collected by the municipal council authority and disposed to the demarcated sites as evidenced garbage trucks and dust bins observed within the municipality leading to less organic wastes disposed into the river. Another alternative could be the huge volume of water in the river which is not stagnant is able to dilute the pollutants leading to low BOD and COD. This in line with what Kannan, (1997), said that when small quantities of organic wastes are dumped into a large water body it would not badly pollute it because of dilution factor which may be high.



Plate 4.12 showing photograph of some of the produce sold in Mpanga market able to contribute to BOD in the river

Source: Field data taken on 21st/October/2012

4.5.7 Agro-forestry land use and water quality

The activity within agro-forestry land use involved digging of soil for making seed beds, and putting the soil particles in the containers where seedlings in beds ready for transplantation were put as shown on the photograph on plate 4.13.

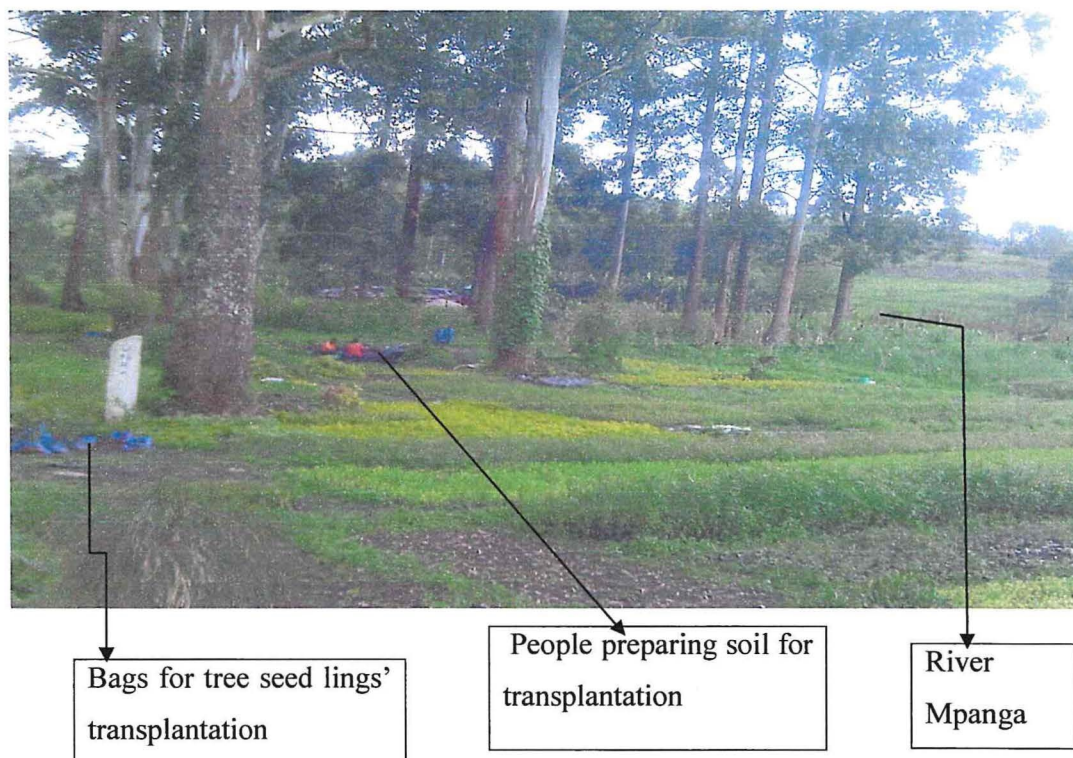


Plate 4.13 showing photograph of people preparing soil for tree nursery bed and containers or bags for transplanting ready seed lings within agro forestry land use

4.5.7.1 Physical, chemical and biological characteristics of water within agro-forestry land use

In this section the researcher presented the analyzed data on; physical, chemical, and biological characteristics which included; TDS, EC, and TSS for the physical characteristics, chemical characteristics pH, BOD, COD, TP and NO₃ and biological characteristics which was FC as shown on table 4.10.

Table 4.8: showing physical, chemical, and biological characteristics of water within agro-forestry land use along Mpanga River

| Physical characteristics | | | chemical characteristics | | | | | Biological characteristics |
|--------------------------|--------|-------|--------------------------|------|-------|------|-----------------|----------------------------|
| TDS | EC | TSS | pH | BOD | COD | TP | NO ₃ | FC |
| 165.00 | 311.00 | 25.75 | 7.48 | 4.00 | 24.25 | 7.11 | 0.06 | 182.50 |

Source: Laboratory analysis

The electrical conductivity (EC) of water in the river within agro forestry land use was 311micro Siemens/cm and Mpanga Market was 310.25 micro Siemens/cm. This could have

been contributed by the short distance between Mpanga Market and agro-forestry land use where the chemicals from products sold within Mpanga Market continued to pollute the river up to this sampling spot coupled with the use of artificial fertilizers in the soil by people preparing seed bed and seedlings' containers or bags as evidenced on plate 4.13. This later on dissolved in the river after disposal by runoff hence raising the electrical conductivity of river water. From the table 4.10, FC was 182.50fcu/100ml while the national standard points out that this value is low meaning that activities here do not produce microorganisms.

TDS value in the river water within agro-forestry was 165mg/l the variations which exist between agro-forestry and commercial land use where TDS average level was 163.50mg/l was due to the short distance between the two land uses according to the observations, agro-forestry was just about a quarter a kilometer from Mpanga market as shown on figure 4.2 meaning that wastes from Mpanga market continued to affect the river within tree nursery bed. Another possibility could be that people planting nursery beds put some artificial fertilizers into the soil which contain chemicals and then runoff from rain deposits the soil particles containing fertilizer into the river which dissolved to increase TDS up to this level. In comparison, TDS within Mpanga market was 163.50mg/l while that of agro-forestry land use was 165mg/l. However, according to the National Standards, the level of TDS in the water bodies is 1200mg/l.

Within agro-forestry land use, TSS was 25.75mg/l. This was because of the activity in this place which involved digging of soil and then putting the soil particles, preparing seed bed and seedlings' transplantation as shown in the photograph on plate 4.13. However, according to National Standard, TSS is 100mg/l meaning that the activities here were not enough to increase TSS. The bio-chemical oxygen demand BOD was 4.00 mg/l, COD was 24.25mg/land TP is 7.11mg/l. These values are far below their National Standards as stated earlier where for BOD is 50mg/l, COD is 100mg/l, for TP is 10mg/l and nitrate is 10mg/l. This was because the activities taking place in this area were not enough to produce wastes which could cause serious pollution in the river. pH value was 7.48 which is within the range of National Standards which is 6.0-8.0.

4.5.8 Animal grazing farm land use and the quality of water

The sampled Animal grazing farm land use was found to be situated in southern division within Fort-Portal Municipality. The distance is approximately from 0-20 meters away from the river bank as shown on plate 4.14.



Plate 4.14 showing photograph of the animal grazing farm along Mpanga River Fort-Portal Municipality

Source: Field data taken on 21st/October/2012

4.5.8.1 Physical, chemical and Biological characteristics of water within animal grazing land use

In this section the researcher presents the analyzed data on; physical, chemical and biological characteristics which included; TDS, EC, and TSS for the physical characteristics, chemical characteristics included; pH, BOD, COD, TP, and NO₃ and biological characteristics was FC as shown on the table 4.1.

Table 4.9: showing the physical, chemical, and biological characteristics of water within animal grazing land use

| Physical characteristics | | | chemical characteristics | | | | | Biological characteristics |
|--------------------------|--------|-------|--------------------------|------|-------|-------|-----------------|----------------------------|
| TDS | EC | TSS | pH | BOD | COD | TP | NO ₃ | FC |
| 149.50 | 306.50 | 53.25 | 7.38 | 5.50 | 22.50 | 12.34 | 0.37 | 1055.00 |

Source: Laboratory analysis

Average value of FC of water in the river within animal grazing land use was 1,055fcu/100ml. This was because of the animal wastes being disposed direct or indirectly into the river as seen from the photograph on plate 4.14. This is in line with Getis, et al, (2006), who asserts that wastes from animal farm such as dung and urine which are disease-

causing pathogens are washed by runoff into the water body hence increasing the FC level. The EC at animal grazing land use was 306.50 micro Siemens /cm; this was low when compared with average values got from other land uses. For example EC at municipal abattoir was 507.50 micro Siemens /cm, at planned settlement EC was 427 micro Siemens/cm and at commercial land use the EC was 310.25 micro Siemens /cm and at tree nursery bed EC was 311 micro Siemens/cm. TDS was 149.50mg/l. This was second lowest compared to the samples got at municipal abattoir which was 277.75 micro Siemens/cm, at planned settlement TDS was 226.25mg/l and at tree nursery bed land use, the TDS was 165.00mg/l as shown on table 4.2. Ideally the EC and TDS at this spot were supposed to be above National Standards just like TP but since the laboratory analysis of EC and TDS did not involve the addition of reagents, and oxidation did not take place, it kept both EC and TDS normal. These average values of TDS and EC were due to animal manure, pesticides used for spraying animals and artificial feeds for feeding the cows which could be deposited into the river by runoff; they dissolved and conducted electricity because of ions present or contribute to TDS in the river. However both values are below the National Standards.

TSS was 53.25mg/l second highest compared to TSS at municipal abattoir which is 113.25 mg/l. This was due to animals trampling on the soil hence loosening it and later eroded into the river by agents of erosion like rain water. This is evidenced by the raw data collected on 8th/November/2012 which was 166mg/l. This value was because the data was collected during the heavy rain. Another reason for high TSS was because at this sampling point the river channel is narrow with high velocity of the water which eroded soils on both sides of the river channel and at the base hence increasing the TSS. Therefore it is natural not because of the land use. This value is low when compared to National Standard for TSS which is 100mg/l. From table 4.11, TP average value was 12.34mg/l however this value exceeds National Standards for TP level in water bodies which is 10mg/l, meaning that the river at this point is highly polluted by animal manure, pesticides used for spraying and probably residues from artificial feeds used within animal grazing farm. However, this could have been triggered by the reagents used during laboratory analysis of TP such as; one milliliter of sulphuric acid, 5 milliliter of potassium persulphate. This is in line with Getis, et al, (2006), who asserts that wastes from animal farm such as feces, dung and urine plus excess nutrients from animal feeds, pesticides used for killing ticks contribute to high concentration of phosphorous in water body after their disposal. NO₃ was as low as 0.37mg/l due to leaching and percolation of wastes into the soil by runoff.

The COD of water in the river within animal grazing land use was 21.38mg/l and BOD was 5.50mg/l. Apart from chemicals from pesticides, and artificial feeds which could have contributed to the occurrence of less values of COD, other activities within this area such as; people bathing in water with soap at this point, and washing of motorcycles using soap also contributed. However the above values are below the National Standards as discussed earlier. Even the decay of hydromorphic vegetation did not produce wastes which could increase the BOD. And this kept the pH which is 7.38 within the range of National Standards which is 6.0-8.0.

4.5.9 Cultivated land use and the quality of water

The cultivation land use sampled was found in southern division which was approximately 200 meters away from the river bank as shown in the photograph on plate 4.15.

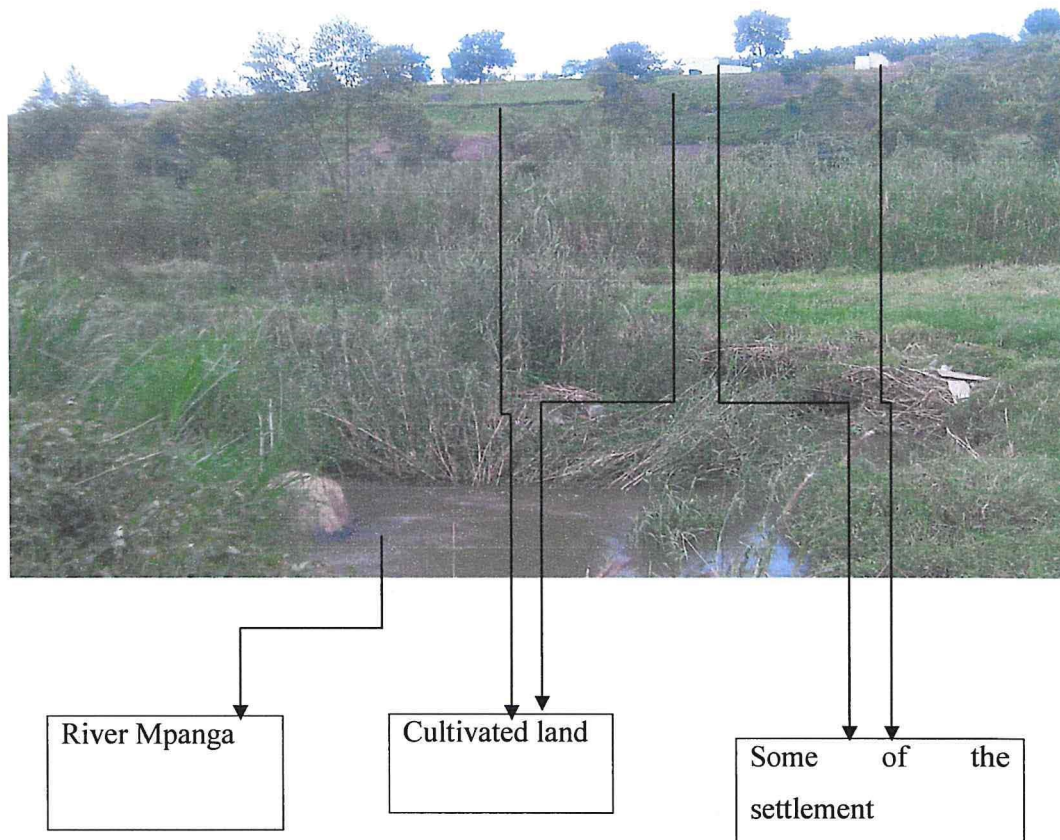


Plate 4.15 showing photograph of the cultivated land use in Fort-Portal Municipality

Source: Field data taken on 21st/October/2012

4.5.9.1 Physical, chemical and biological characteristics of the water within cultivated farm

In this section the researcher presents the analyzed data on; physical, chemical and biological characteristics which included; TDS, EC, and TSS for the physical characteristics, chemical characteristics pH, BOD, COD, TP and NO₃ and biological characteristics was FC as shown on table 4.12 below.

Table 4.10: showing physical, chemical, and biological characteristics of the river within cultivated land use

| Physical characteristics | | | chemical characteristics | | | | | Biological characteristics |
|--------------------------|--------|-------|--------------------------|------|-------|------|-----------------|----------------------------|
| TDS | EC | TSS | pH | BOD | COD | TP | NO ₃ | FC |
| 156.25 | 308.25 | 48.50 | 7.48 | 3.75 | 16.00 | 7.32 | 0.07 | 1170.00 |

Source: Laboratory analysis

From the table 4.12, FC average value was 1170fcu/100ml compared to other land uses such as; animal grazing farm land use which was 1055.00fcu/100ml, commercial land use which was 305.00 fcu/100ml agro-forestry which was 183fcu/100ml, industrial land use which was 268 fcu/100ml, car washing bay and planned settlement which are 335cfu/100ml as shown on table 4.2. This was because of the human wastes from settlement within cultivated land use as evidence in plate 4.15. In addition it is possible that pollution from animal grazing land use also continued to affect the water in the river at this point (cultivated land use) because of the small distance between the two land uses. But the National Standards for FC level in water bodies is 5000fcu/100ml. This implies that the river is not seriously polluted by the animal grazing land use. EC was 308.50 micro Siemens/cm, this is probably because of the application of pesticides, herbicides and artificial fertilizers used in the fields which are later disposed into the river by runoff and when they dissolved, they conducted electricity because of the ions. TDS was 156.25mg/l and TSS as 48.50mg/l. These values are below the National Standards for EC which is 1500micro Siemens /cm, TDS is 1200mg/l and for TSS is 100mg/l. This is because at this sampling point there is huge volume of water in the river which diluted suspended matters from soil and agricultural wastes such as; chemicals from artificial fertilizers, pesticides, herbicides, organic, and inorganic wastes from households. In addition it was observed that the hydromorphic vegetation capture some of the wastes hence leading to acceptable level of EC, TSS and TDS. This is in line with what Pierre, (2000), says

that all the eroded particles where human activities like; settlement, industrialization and agricultural practices which are carried do not reach the watershed outlet because particles detached from bare upland area are trapped in vegetative areas before reaching the river hence causing low suspended solids.

The pH was 7.48 which are within the range of the National Standards which ranges from 6.0-8.0 as shown on appendix III. COD was 16.00mg/l, BOD was 3.75mg/l, TP was 7.32mg/l, and NO₃ was 0.07mg/l. These values are below the National Standards as stated earlier. This was due to limited wastes produced by cultivated land use. It is also possible that the hydromorphic vegetation filtered the wastes before reaching the river as shown on the photograph on plate 4.15. Goel, (2000), supports the low average levels of COD, BOD, TP and NO₃. He attributes it to the higher self-purification capacity of the flowing nature of a river. He says that in this case, the conservative pollutants (non-degradable wastes) tend to concentrate in the river systems however after their entry they get diluted in the flowing water while some are absorbed at the bottom sediments causing low level of pollutants in the water.

4.5.10 comparing the quality of water in the river from Inflow to Municipality at the border of Bukuku and Fort-Portal Municipality and Outflow in Kijura

Inflow can be defined as the sampling point where the water was picked before the river entered the Municipality. It can also be called upstream. And outflow is a point where the water was sampled after the river had left the Municipality which can also be called downstream. Under this section, the researcher made comparisons of river water at the two sampling spots. Sampling spot designed for inflow to the municipality is represented as code 1 and outflow from the municipality at Kijura is represented as code 2 on the mean plot line graphs on figure 4.16. The River flows from mount Ruwenzori and crosses the main road of Bundibugyo and passed through Nyakasura side. The land uses along Mpanga River within inflow were found to be; rural settlement pattern which were very sparse and some were near the river while others were not very near the river. Agricultural practices such as crop growing and animal rearing were minimal with less application of fertilizers and pesticides, brick making, construction of roads and houses were also identified as shown on the photograph on plate 4.16 and map on figure 4.2.



Plate 4.16 showing photograph of the sampling point at inflow from the boarder of Bukuku and Fort-Portal Municipality

Source: Field data taken on 8th/November/2012

At the outflow that is after the river had left the urban center in Kijura road. The land use activities found were agricultural practices such as; crop growing and animal grazing, sparse rural settlement and car washing bay, schools and a forestation were identified as shown in the photograph on plate 4.17 and map on figure 4.2.



Plate 4.17 showing photograph of the outflow sampling spot from Kijura outside Fort-Portal Municipality

Source: Field data taken on 21st/ October/2012

4.5.10.1 Physical, chemical and biological characteristics of water at the outflow and inflow

Physical, chemical and biological characteristics that were analyzed in this section include; TDS, EC, and TSS for the physical characteristics. Chemical characteristics include; pH, BOD, COD, TP, and NO₃ and biological characteristics include FC as shown on the table 4.13.

Total dissolved solids at inflow and outflow

Analysis of the data obtained from the sample at the inflow indicated that the mean TDS at inflow was only 105.75mg/ l while at outflow; the TDS was 163.50mg/l. This outflow value is higher than TDS at inflow. The increase at outflow which is 50% can be attributed to land uses within the municipality such as; the car washing bay at the junction of Kampala-Kijura road at Kyembogo Bridge and Kabundaire where many vehicles and motor cycles were washed using soap and other detergents. Other land uses within the municipality include; municipal abattoir, planned settlement land use, unplanned settlement land use and cultivation farm. Even if the settlement patterns were found to be sparse near Kyembogo Bridge, the few ones observed were just very near the river implying that all their wastes which contained inorganic matter such as; salt and chemicals from households were disposed in the river hence increasing the TDS at inflows as shown on figure 4.8. This aligns with Bowen, (2000), Getis, et al, (2006) and Goel, (2000), who state that agricultural practices, commercial land use and settlement upstream and within urban areas contribute excess chemicals in runoff from application of fertilizers, pesticides and herbicides.

However Randolph, (2004), and Goel, (2000), contradict the above statement by saying that the effects of the pollutants depend on the beneficial uses of the natural water that receive them and their nature such as; fresh water like rivers and streams which are shallow can mix pollutants very well. This can enable dilution of wastes to take place hence leading to a low level of TDS which is within the National Standards. All the residual forms of these chemicals along with organic debris from the remains of the harvested crops are trapped by runoff water from rainfall causing pollution problems in the receiving waters. The low average level at inflow was because land uses such as; animal grazing farm, cultivation farms, settlement, and brick laying within this area were not able to produce wastes that contained minerals of which as soon as it dissolved in water can increase TDS of the river. This is because these activities are practiced at a minimal level. However there is a clear effect of urban land use on the TDS in the river as evidenced by the increase which is noticed to be 55%. But according to National Standards for TDS levels in water bodies which are 1200 micro Siemens/cm means that TDS levels both at inflow and outflow are acceptable because both are below National Standards.

Electrical conductivity at inflow and outflow

From figure 4.9, EC at inflow was 195.75 micro Siemens/cm while at outflow EC was 335.75

Table 4.11: showing the physical, chemical and biological characteristics of water at the outflow and inflow

| | Physical characteristics | | | Chemical characteristics | | | | | Biological characteristics |
|---------|--------------------------|--------|-------|--------------------------|------|-------|------|-----------------|----------------------------|
| | TDS | EC | TSS | pH | BOD | COD | TP | NO ₃ | FC |
| Inflow | 105.75 | 195.75 | 8.50 | 7.50 | 4.5 | 25.25 | 2.58 | 0.04 | 157.50 |
| Outflow | 163.50 | 335.75 | 29.75 | 7.48 | 4.25 | 27.75 | 3.45 | 0.08 | 232.50 |

Source: Laboratory analysis

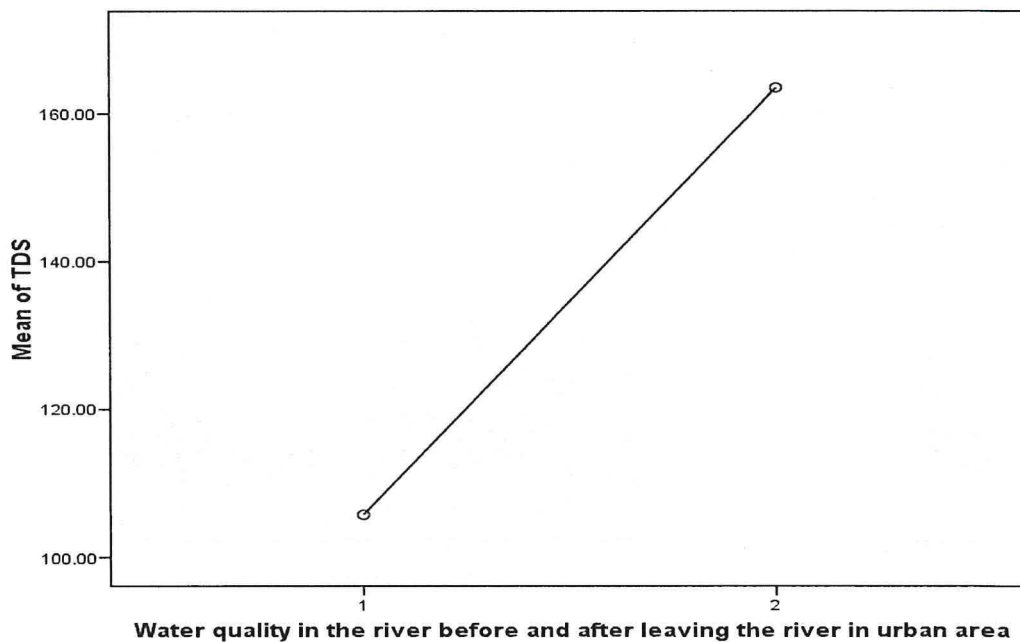


Figure 4.3 showing the mean plot for TDS at inflow and out flow

Source: Field Data analysis

Key for the codes on the mean plot line graphs;

Code1. The mean TDS values for water or before the river entered the Municipality (inflow).

Code 2.The mean TDS values for water after the river had left the Municipality (outflow).

4.5.10.1. Physical characteristics of water at inflow and out flow

micro Siemens/cm. The increase at outflow which is 72% can be attributed to land uses within the municipality such as; municipal abattoir, planned settlement land use, industrial land use, un planned settlement land use and cultivation farm, the car washing bay at Kyembogo Bridge and Kabundaire where people used water from the river for washing vehicles and motor cycles then the used up water flowed back into the river which contained soap with some sodium ions capable of increasing electrical conductivity. Although EC at outflow is higher than EC at inflow, both values at inflow and at out flow are below the National Standards for EC level in water bodies which are 1500micro Siemens/cm. These imply that the land uses in both sampling spots are environmentally friendly. However there is a notice effect of urban land use at the end. This is in line with what Chhatwal and Satake, (1999), who stated that it has been established that at downstream of the source of pollution, the river flows and after a while, pollution matters gradually disappears and water regains its original state through the process of self-purification.

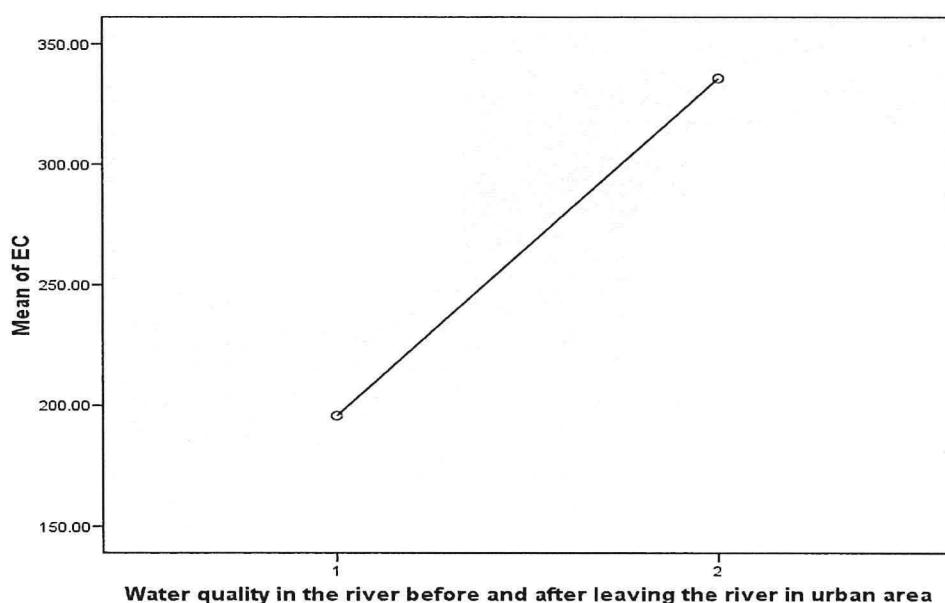


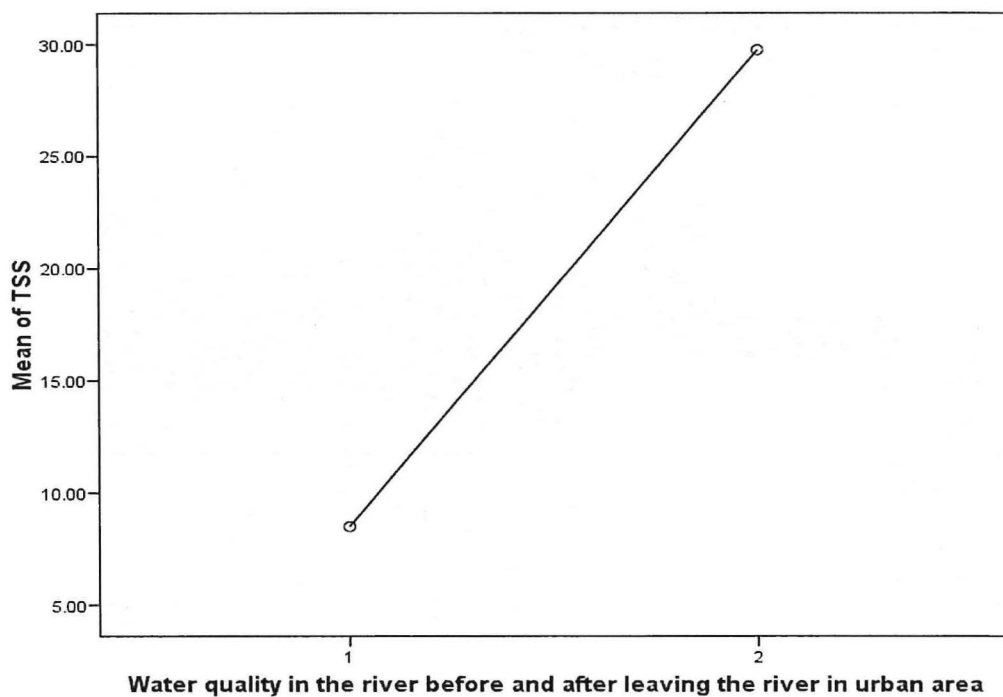
Figure 4.4 showing the mean plot for EC at inflow and out flow

1: mean EC values at the inflow 2: mean EC values at the outflow

Total suspended solids at inflow and outflow

At inflow or before water in the river entered the municipality, the TSS was 8.50mg/l, while at outflow or after water in the river has left the municipality; the TSS was 29.75mg/l. The

increase at outflow which is 130% can be attributed to land uses within the municipality such as; municipal abattoir, animal grazing farms, cultivation farms, industrial land use and commercial land use which are capable of causing pollution. The reason for low TSS at inflow could be because the river at this point was flat and calm, and so the TSS was able to settle at the bottom of the river hence low TSS as observed on the above photograph on plate 4.16. This is in line with what Pierre, (2000), said that all the eroded particles where human activities like; settlement, industrialization, agricultural, and commercial activities are carried out and reach downstream hence causing suspended solids and some materials carried in natural streams are deposited in the channels to cause aggradations. Even though TSS at outflow is slightly high as evidenced on figure 4.10, both values that is; at inflow and, outflow are below the National Standards for TSS levels in water bodies which is 100mg/l.



1: mean TSS values at the inflow

2: mean TSS values at the outflow

Figure 4.5 showing the mean plot for TSS at inflow and out flow

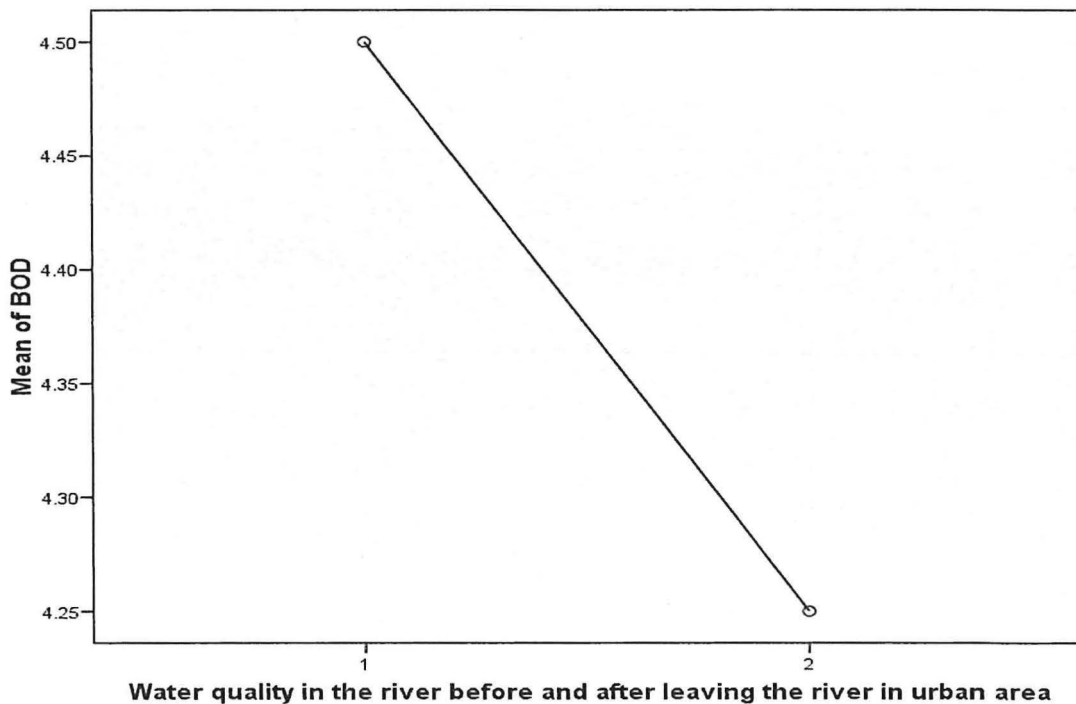
4.5.10.2 Chemical characteristics of water at inflow and out flow

pH at inflow and outflow

Figure 4.11, and table 4.13, shows pH at inflow which was 7.5 while the pH at out flow is 7.48. The increase at inflow which is 1.4% means that there is serious change in the pH of river water by the urban land uses. This is because the pH of land uses within the municipality ranges from 7.03-7.63 and the highest being from planned and unplanned settlement land uses which have a pH of 7.63, second highest from car washing bay which has a pH of 7.50, then cultivated farm and tree nursery bed land uses have a pH of 7.48 and abattoir has the least pH of 7.03. Nevertheless both values of pH at inflow and out flow are within the range of National Standards for pH levels in water bodies which is 6.0-8.0. These imply that the values of pH at both sampling spots are acceptable because wastes which contain acid and chemicals are carried from upstream by relatively shallow river water and it is able to purify itself by the time it reaches at outflow.

This means that activities taking place in these areas are environmentally friendly hence could not alter the pH of the river beyond the National Standards. This is in line with what Goel, (2000), said that shallow river water are often well mixed this is because they provide a better mixing ground for pollutants in contrast to deeper waters which only a part of the waters column is mixed completely. This contradicts what Munyaradzi, (1996), who said while giving example of pollution of rivers from mining centers in Africa. He stated that stretches of acid which polluted Olifants River in the Eastern Transvaal have been attributed to the coal mines upstream. This is because mining centers in Africa use water as a medium for mineral extraction processes and this water contains toxic chemical compounds such as high level of sulphur and nitric acids. This toxic compound enters into rivers directly by runoff or through seepage. This polluted water with low pH value is more acidic and corrosive and at the same time a high pH value indicates increase alkalinity. But according to National Standard for effluents discharge in water bodies, the acceptable pH level is 6.0 to 8.0 meaning that pH level of both inflow and outflow are environmentally acceptable.

joined the main river with some wastes. But according to observation, the volume of the river water was big even before the stream had joined the main river at this spot. This is in line with Tripathi, (1993), who asserted that when wastes containing organic matters are discharged into streams, they create heavy pollution load at some critical points, the DO of the river starts decreasing up to a minimum value. This means that dilution would have been caused by the huge volume of the river water hence causing low BOD as shown on the figure 4.12. At the same time dilution by the adjoining stream may not be absolutely true because generally, BOD within the Municipality is low in all the land uses along Mpanga River. However, Cunningham, et al, (2004), also has another statement which almost support what Tripathi asserted by saying that within upstream from the pollution source, the organic and inorganic matter are low, leading to low oxygen level hence low BOD. This could be the reason why BOD is lower than the National Standards for BOD level in water bodies, which is 50mg/l which presents that there is no pollution in the water by the land uses around.



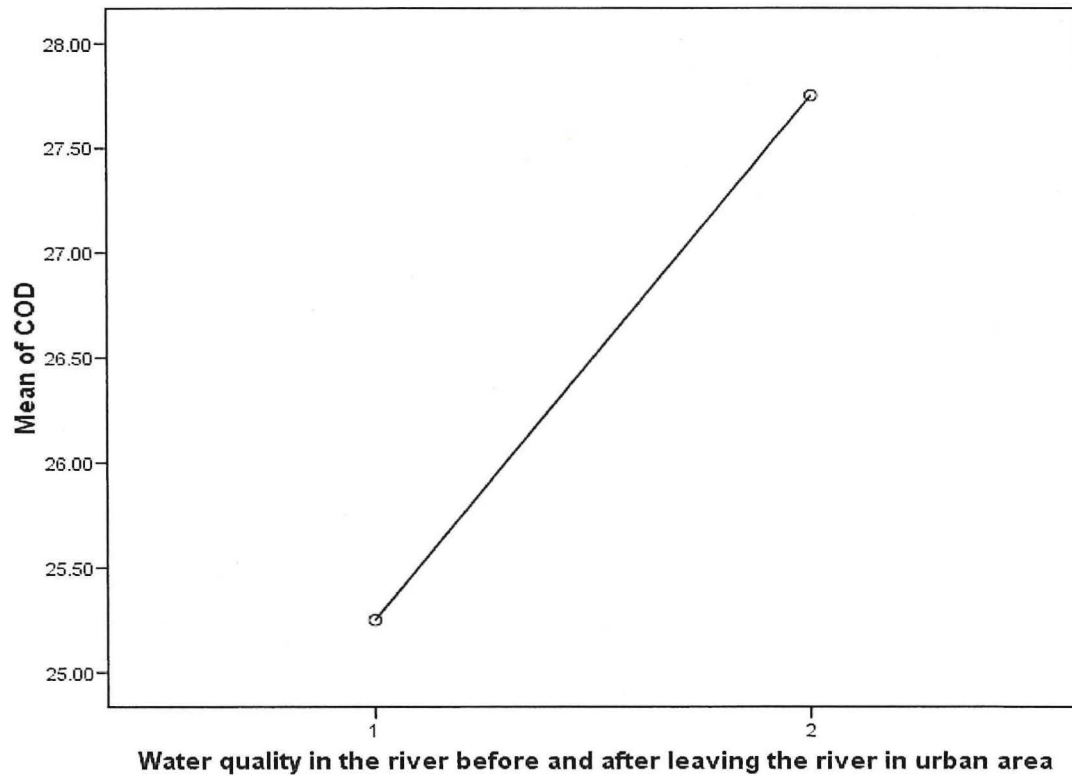
1: mean BOD values at the inflow

2: mean BOD values at the outflow

Figure 4.7 showing the mean plot for BOD at inflow and out flow

Chemical oxygen demand (COD) at inflow and outflow

From figure 4.13 and table 4.13, COD at inflow to municipality or before the river enters the urban center is 25.25mg/l while at outflow or after the water in the river has left the municipality COD was 27.75mg/l. The increase at outflow which is 6% can be attributed to land uses within municipality such as; municipal abattoir, which has COD value of 199.50 mg/l and it is above the national standards, commercial land use, planned and unplanned settlement land uses and cars washing bays especially at Kyembogo Bridge and Kabundaire. These land uses produce wastes in form of soap, salt, chemicals and other detergents. The differences which exist between the COD levels at inflow and outflow are both below the National Standard for COD level in water bodies, which is 100mg/l. This contradicts with what Bowen, (2001), Getis, et al, (2006) and Goel, (2000), stated that settlement and agricultural practices upstream of urban areas contribute excess chemicals in runoff from application of fertilizers, pesticides, and herbicides and chemicals causing pollution problems in the receiving waters hence increasing total dissolved solids and COD of the water body. Instead Palmer, (2001), attributes the low COD and BOD at outflow to self-purification process of river water by saying that streams and rivers are linked tightly to their surroundings and serve in many cases to eliminate the metabolic products of terrestrial ecosystem. In reality BOD at inflow and outflow are below the National Standards for COD level in water bodies as stated earlier.



1: mean COD values at the inflow

2: mean COD values at the outflow

Figure 4.8 showing the mean plot for COD at inflow and out flow

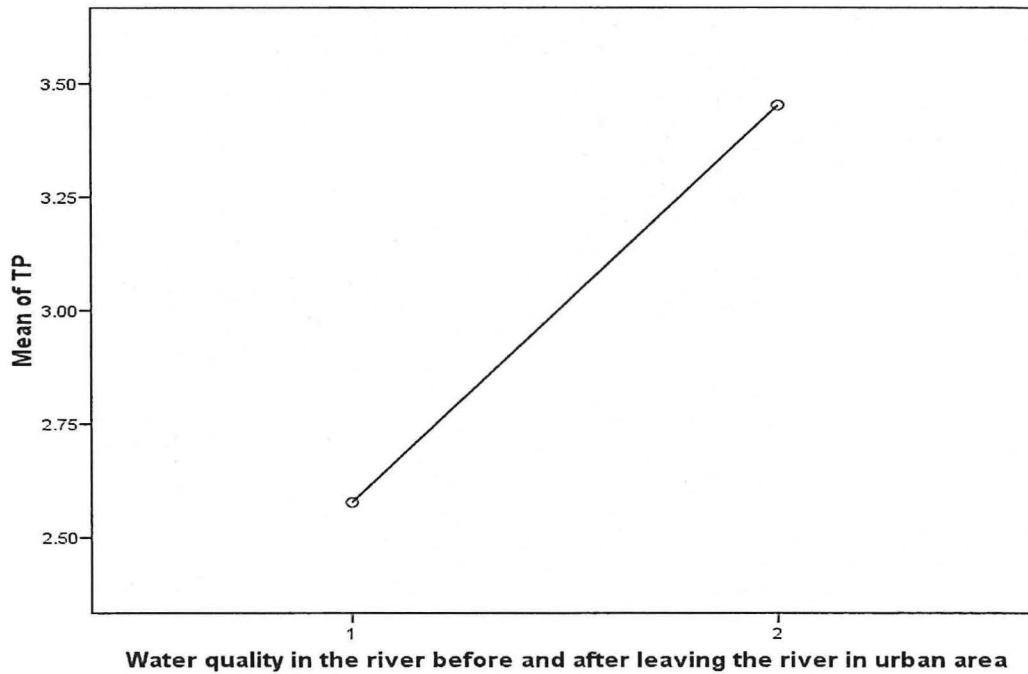
Total phosphate at inflow and outflow

At inflow to municipality or before the river enters the urban center TP was 2.58 mg/l while at outflow or after the river has left the municipality, the TP was 3.45mg/l as shown in the figure 4.14 and table 4.13. The increase at outflow which is 34% can be attributed to land uses within municipality such as; municipal abattoir, which has TP value of 18.37mg/l and it is above the national standards, commercial land use, animal grazing farm, cultivated farm land use, tree nursery bed land use and cars washing bays especially at Kyembogo Bridge and Kabundaire as shown on table 2.6. These land uses produce wastes inform of soap, salt, chemicals and other detergents. These low values could be due to the following contributing factors; there was a stream joining the main river and might have caused dilution at outflow however this stream is believed to have passed in areas where land use practices are done

which the researcher does not expect it to dilute the wastes in the river water because it will have carried wastes from where it has passed.

However the distance between the adjoining streams and the main river was observed as being more than 2km which would have not caused serious dilution at sampling spot a head. The distance from the inflow up to the outflow which was approximately 17km could have also buffered down the pollutants which is called self-purification process. At the same time when looked at critically on table in appendix III, most of the land uses have low TP with the exception of Municipal abattoir land use and animal grazing farm which is a typical of TP level in those land uses. This contradicts what Bowen, (2001), Getis, et al, (2006), and Goel, (2000), stated that regardless of the usefulness of agricultural, commercial, cultivated farm land use, tree nursery bed land use and cars washing bays runoff from upstream of urban areas as being rich in nutrients like; phosphorous, organic matter and pesticides, these nutrients create the problem of eutrophication in the receiving waters hence increasing TP of the water. But Getis, et al, (2006), asserts that wastes from animal farm such as dung and urine plus excess nutrients from animal feeds, pesticides used for killing ticks contribute to high concentration of phosphorous in water body after their disposal. NO_3 was as low as 0.37mg/l due to leaching and percolation of wastes into the soil by runoff.

This is not the case because the TP at inflow and outflow are both very low compared to the National Standards for TP level in water bodies which is 10mg/l.



1: mean TP values at the inflow

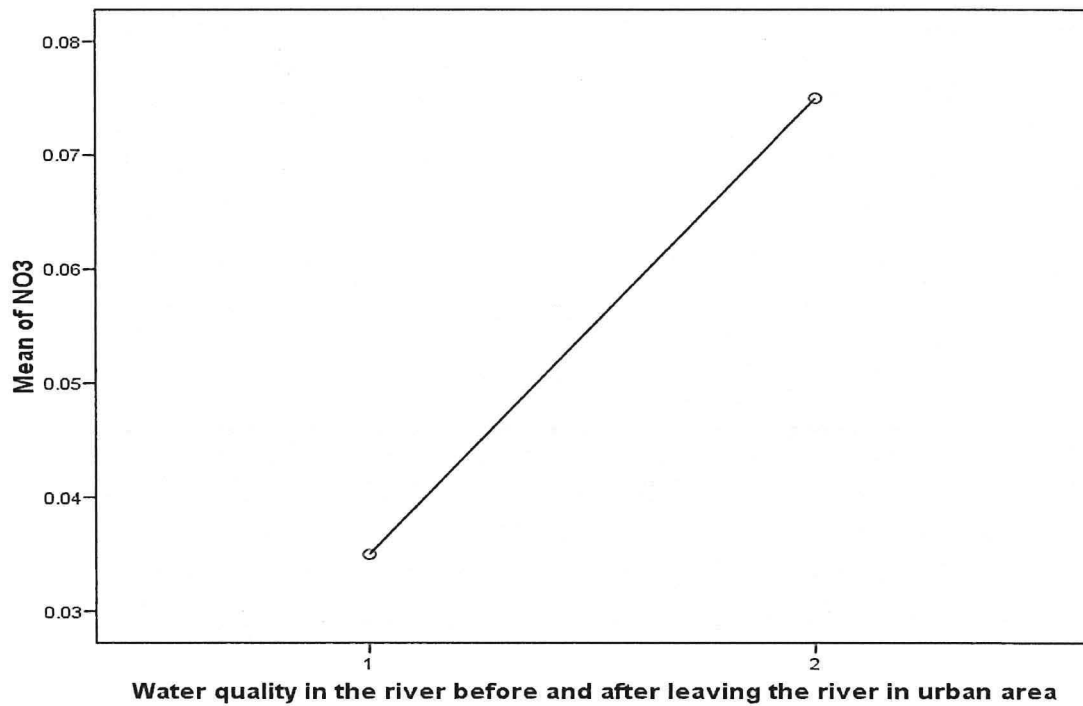
2: mean TP values at the outflow

Figure 4.9 showing the mean plot for TP at inflow and out flow

Nitrate (NO₃) at inflow and outflow

At inflow, the Nitrate was 0.04mg/l while at outflow was 0.08mg/l as shown on figure 4.15 and table 4.13. The increase at outflow which is 100% can be attributed to land uses within municipality such as; municipal abattoir, commercial land use, animal grazing farm, cultivated farm land use, tree nursery bed land use and cars washing bays. This means that urban land uses have contributed to pollution and self-purification process was not able to buffer down the NO₃ level in river water at outflow. However all the above land uses have low NO₃ when compared to the National Standards for NO₃ level in water bodies which is 10.00mg/l. In addition to that, even if the chemicals like; herbicides, pesticides and artificial fertilizers were applied or disposed in water, they were not able to increase the level of nitrate in the river beyond the National Standards because of low level of socio-economic development such as; agriculture, commercial land use and settlements which lead to less amount of wastes leached by runoff from rainfall. Gupta, (1997), and Kyatal, (1989), point out that rain water and increase use of inorganic fertilizers to the soil in order to increase crop yield make nitrates leach, infiltrates and percolates into the soil through runoff and where they are extensively used, they appear in surface water like; wells, rivers, and streams. Hence

the ideal low level of nitrate at inflow and outflow could have been due to the leaching, and percolation.



1: mean NO₃ values at the inflow

2: mean NO₃ values at the outflow

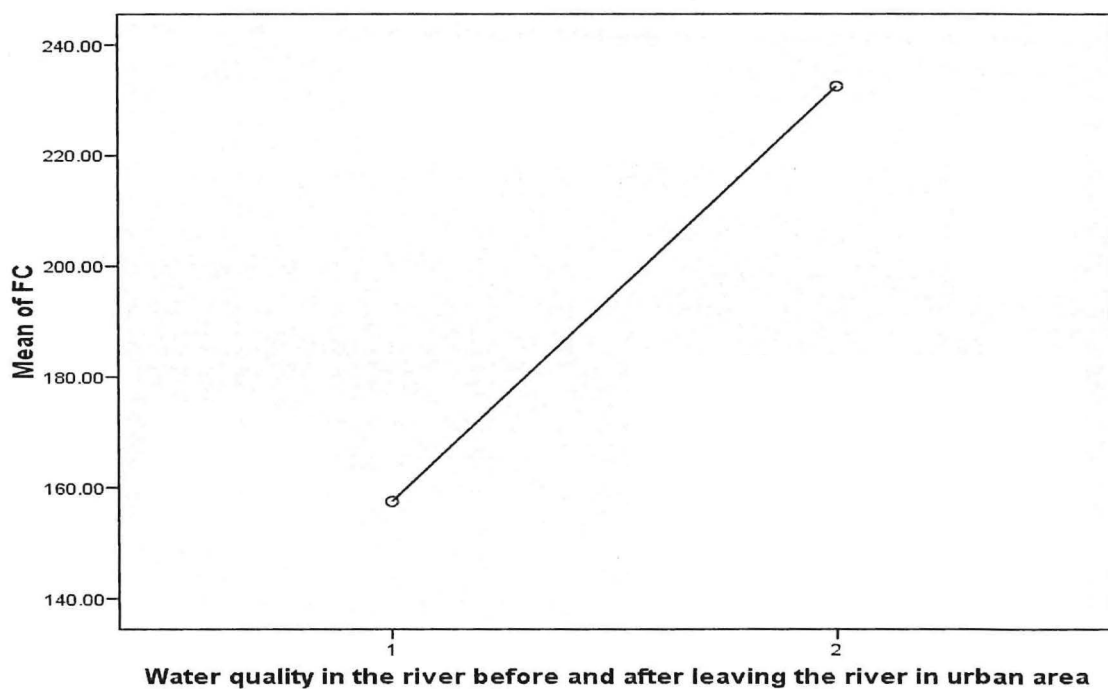
Figure 4.10 showing the mean plot for NO₃ at inflow and out flow

4.5.10.3 Biological characteristics of water at inflow and out flow

Fecal coli form (FC) at inflow and outflow

FC was 158.50fcu/100ml at inflow while at out flow FC was 232.50fcu/100ml as shown on figure 4.16. The increase at outflow which is 47% can be attributed to land uses within municipality such as; municipal abattoir which had an FC of 2067.50cfu/100ml, unplanned settlement had an FC of 1920.50cfu/100ml, cultivated farm land use had an FC of 1170.00fcu/100ml, animal grazing farm had an FC of 1055.00fcu/100ml and the least being tree nursery bed land use and industrial land use with FC of 182.50fcu/100ml and 267.50fcu/100ml respectively. When inflow and outflow results are compared to the cumulative effect of land uses within urban center, the average results of urban land uses show that there is a serious pollution of river water within municipality which continues to reduce up to outflow due self-purification process. In addition, the land uses at inflow were

found to be; agricultural practices like cultivation of farms, settlement, animal grazing, and forestation. These were able to cause less value in FC since they are practiced at a limited basis. This contradicts to what Bowen, (2001), and Goel, (2000), who pointed out that those human wastes from settlement, cattle slurry, and silage from animal feed lots may also leak into the rivers and streams or are disposed directly. These may cause pollution in the downstream rendering the water unfit for aquatic life and human consumption because they introduce microorganisms in water. But Kannan, (1997), rejects the above statement by saying that when small amounts of sewage or wastes from residential are dumped into a large water body, it would not badly be polluted and that the normal quality of water can be restored. However the average level of FC at inflow and outflow are below the National Standards for FC levels in water bodies which is 5000fcu/100ml.



1: mean FC values at the inflow

2: mean FC values at the outflow

Figure 4.11 showing the mean plot for FC at inflow and out flow

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1.0 Conclusion

Basing on the results from this research about an assessment of the impact of land use practices within the municipality or urban center on water quality in Mpanga River, the following conclusions can be made:

5.1.1. Land Use practices along Mpanga River in Fort-Portal Municipality

The study was concluded that the most dominant land use in Fort-Portal Municipality were found out to be; agricultural land use and settlement which covers 28.00km² followed by forest reserves which cover 5.00km² and residential area which covers 4.00km². Other land uses within Fort-Portal Municipality include; Government offices, industrial area, commercial area and open space area, wetland area and institutions area. Which range from 0.30 to 3.00km² as shown on map on page 58.

5.1.2 The Relationships between the different land use practices and their physical, chemical and biological characteristics of the water in River Mpanga, Fort-Portal

Basing on the results of the study, it was also revealed that unplanned settlement land use had the second average value of FC which is 1920fcu/100ml. This was associated with the presence of a number of pit latrines just about 6-10 meters away from the river bank which leached the wastes into the river or at times these wastes were put by children near river which were later washed in to the river by runoff. Wastes which contribute to TDS, EC, pH, and COD within unplanned settlement land use were due to soap from washing dishes, clothes, chemicals from saloons and other detergents. Gupta, (1992), supports this statement by saying that those who live by the side of water resources wash their clothing and utensils hence polluting the water. BOD is attributed to domestic wastes like; peelings of bananas, potatoes, fruits, and sewage. Otto et al, (1981), asserted that true detergent containing large amounts of phosphates, and nitrates pollute water resources. TSS is attributed to wastes from carpentry and timber workshops, construction and grinding mills as shown on photograph on plate 4.2

TDS, EC, COD, pH, TP and NO₃ within Car washing bay as shown on appendix IV are attributed to liquid wastes from soap and other detergents used for washing vehicles and motor cycles, wastes from animal feeds and fertilizer from shops around this sampling point. BOD which is 5.25mg/l is due garbage from settlement behind the shops. FC is as a result of pit latrines near the river and wastes of some animals which graze around this sampling point. TSS of 11.25mg/l is attributed to wastes water from washing vehicles which flows back to the river together with soil particles as shown on photograph on plate 4.3.

Planned settlement also has EC of 427mg/l and TDS of 226.25mg/l next to abattoir .These have been as a result of the unplanned settlement which have sprung up within the planned settlement in Booma which comprise of activities such as: washing of motorcycles with soap direct in to the river, saloons have been established which use a lot of chemicals on hairs and later its wastes are directed into the river .Wastes from households like soap and other detergents used for washing the utensils are disposed into the river. It could also be due to the fact that river Nyakimya which passes in Nyakasura where there are limestone rocks containing calcium carbonate increased the EC and TDS up to that level. However the above values are far much lower than national standards for TDS and EC as shown in appendix III in water bodies. The rest of the land uses have low average levels in all parameters meaning that land uses are environmentally friendly. For instance the low level of FC was attributed to the use of flash toilets in planned settlement land use which direct all the human wastes in to the treatment plant.

Low TDS, COD, pH, TP, NO₃ due to less inorganic and organic wastes such as chemicals like salt from shops and homes, detergents and soap being used are to limited amounts of wastes produced. Low BOD is because most of the garbage are collected by the Municipal Council and deposited far away from the urban center. FC within planned settlement is 1920 mg/l which is attributed to unplanned settlement which have sprung with latrines near the river.

It was concluded that Land use practices along Mpanga River which have contributed to FC were the city abattoir with the highest average value of 2067.50fcu/100ml and the highest TSS of 113.25mg/l. These were mostly attributed to the residues from animal wastes and soil particles deposited into the river by runoff hence increasing the TSS which has caused a change on the aesthetic property of the water and providing avenue for bacteria and sometimes that particles causing turbidity or TSS is food to bacteria. NWSC, (2009), supports

this statement by saying that Samples with high turbidity or high total suspended solids have to be diluted preferably 1:100 ratio to reduce particulate matter interference on colony growth. This means that TSS and Turbidity in water body provide avenue for the growth of bacteria and sometimes that particles causing turbidity is food to bacteria. Therefore TSS and turbidity is directly proportional to the levels of bacterial pollution.

According to the national permissible limits of TSS in water bodies which are 100mg/l, this implies that TSS at Municipal abattoir which is 113.25mg/l is higher than the national acceptable level which is 100mg/l. This type of Land use was responsible for pollutants such as; animal feces and feces put by other people anyhow which might have incorporated human wastes from residential within the Municipality which were directed into the river by runoff especially the heavy down pours of 8th/November/2012.

The city abattoir was found to be having the highest average value of TDS which was 277.75 mg/l and EC was 507micro Siemens/cm. These two parameters have a relationship because of the huge amounts of animals' wastes from the abattoir such as dung, urine, blood and soap used for cleaning the abattoir after slaughtering animals which were directed to the river through trenches and these wastes had ions which conducted electricity. However the levels of these wastes are lower than the national permissible limits of TDS and EC in water bodies which are 1200mg/l and 1500mg/l respectively. Values of TDS, EC and COD as shown on appendix IV were due to wastes from slaughtered animals like urine, feces from intestines, blood, and soap used for washing the abattoir. TP was 18.37mg/l, and BOD was 10.75mg/l within animal abattoir. The COD and TP exceed the national standards in water bodies. National permissible level of COD is supposed to 100mg/l, TP is 10.0 mg/l, except BOD is low as shown in appendix IV. These were possibly because the runoff from heavy rains eroded both human and animal wastes, soap, and minerals from other land uses within the urban center to the river. TP is 18.3mg/l higher the national standard. pH is acceptable because of limited wastes disposed in to the water body.

The activities within small scale industrial land use are evidenced on plates 4.6, 4.7, and 4.8 such as; welding, painting metals, repair in garages, grinding mills, brick making, and cutting aluminum scraps for making saucepans. TDS and EC are due to dissolved solids from broken metals, paints, chemicals from oil and grease from garage. Low FC of 267 fcu/ 100ml is as a result of the activities which are not able produced microorganisms in the river because they are minimal. The TSS is produced by grounded flour particles from the grinding mills and the

sand and cement particles from the brick making industry. Average values of COD, TP, NO₃, pH as shown on appendix IV, are due to wastes from fertilizers and animal feeds sold from shops within this sampling point which are disposed in to the river directly or indirectly. BOD is due to bio-degradable wastes from restaurants, and settlement within this area.

Within commercial land use (Mpanga market), EC average value was 310.25micro Siemens/cm and TDS average value was 163.50mg/l. These wastes were generated from many saloons, butchers and restaurants which disposed wastes like; salt, chemicals, and soap in to the river through trenches as shown in the photographs on plate 4.10 and when they dissolved they conduct electricity because of the presence of ions. FC average value was 305 fcu/100ml which is due to human and animal wastes from this sampling spot which when they are eroded into the river by runoff or any agent of erosion, they are able to pollute the river water. TSS within this sampling point is attributed to sales of maize and millet flour, animal feeds, and wastes from butchers. Chemical oxygen demand (COD) was 26.75mg/l due to wastes like; salt, chemicals from fertilizers, saloons and soap which are disposed in to the river directly or indirectly.

Bio-chemical oxygen demand (BOD) was 3.7mg/l due to bio-degradable wastes such as; vegetables and fruits like avocado, bananas, pineapple, tomatoes, cabbages, carrots and yams as shown in the photograph on plate 4.12. Nitrate was 0.13 mg/l and TP was 7.14mg/l were due wastes which contain nitrates and phosphates from agricultural fertilizers and animal feeds from shops within the market. This statement is supported by Ann Bowen et al, (2000), who stated that water pollution increased in UK as a result of new agricultural practices where the main source of pollution is from nitrates and phosphates from agricultural fertilizers.

The electrical conductivity (EC) and TDS of water in the river within agro-forestry land use was coupled with the use of artificial fertilizers in the soil by people preparing seed bed and seedlings' containers or bags as evidenced on photograph on plate 4.13. This later on dissolved in the river after disposal by runoff hence raising the electrical conductivity and total dissolved solids of river water. From table 4.10, FC value of 182.50fcu/100ml is due to animals grazed within this sampling spot which dispose their droppings in to the river.

Within agro-forestry land use, TSS was 25.75mg/l. This was because of the activity in this place which involved digging of soil and then putting the soil particles in seedlings' bags, preparing seed bed and seedlings' transplantation as shown in the photograph on plate 4.13. Runoff from rain deposits these soil particles in to the river. The bio-chemical oxygen demand (BOD) is attributed to animals' droppings or wastes, decomposed leaves of trees and grass. COD, TP, pH and nitrates (NO₃) are due to artificial fertilizers used during seed bed preparation and transplantation which contain chemicals and then runoff from rain deposits the soil particles containing fertilizer in to the river. All these affect the physical, chemical and biological characteristics of the water in River Mpanga.

Animal grazing farm have average values of TDS, EC, pH, and COD as shown on appendix IV which were attributed to wastes like urine, artificial fertilizers used for feeding animals, pesticides, and animal feeds which contain chemicals. TSS was attributed to animals trampling on the soil hence loosening it and later eroded into the river by agents of erosion like rain water. FC was due to animal droppings plus human wastes from within the urban center and settlement around. The decayed hydromorphic vegetation and animal droppings is thought to have produced wastes which could increase the BOD in the water. TP and nitrates (NO₃) within animal grazing farm was were due to pesticides used for spraying and artificial feeds for feeding the cows which were deposited in to the river by run-off in addition to animal wastes.

EC, pH, COD and TDS were probably because of the application of pesticides, herbicides and artificial fertilizers used in the fields which are later disposed into the river by runoff and when they dissolved, they conducted electricity because of the ions. TSS is attributed to soil and agricultural wastes such as; particles from chemicals like artificial fertilizers, pesticides, herbicides, organic, and inorganic wastes from households. BOD was due to decomposed hydromorphic vegetation. Wastes like artificial fertilizers, pesticides, herbicides were able to impose TP of 7.32mg/l, and NO₃ of 0.07mg/l in River Mpanga hence altering the physical, chemical and biological characteristics of water in River Mpanga.

TSS though it is a physical parameter, has a very big relationship with FC which is a biological parameter. It has been found out that distance of a land use practice from the river also has a big impact on water quality. For instance from the photographs on plate 4.5 pit latrines were near the river and caused infiltration of human wastes into the river leading to

increased FC. In most cases where the TSS was high, the FC was also high this is because TSS gave a good ground for bacteria to grow and also provide food to the bacteria for instance in Kabundaire where there is a city abattoir (slaughtering slab) the TSS was 113.25mg/l and FC was 2067.50fcu/100ml and at animal grazing farm just next to the river has relatively high TSS of 53.25mg/l and FC was 1055fcu/100ml. The high FC was due to the huge amounts of animal wastes disposed in to the river implying that suspended materials in the river leads to growth of fecal coli forms in water.

It is also noted that the land uses under study in relation to parameters like; TDS, EC, BOD, pH, and FC did not pollute the water in the river. This is because their average values are below the National Standard for wastewater discharge as evidenced on table in appendix III.

According to the observation made throughout the study, the land use practices along River Mpanga would have caused serious pollution to the water in the river. But since the water in the river is continuously flowing, the river water is able to purify the pollutants through self-purification process. This is evidence by values of TP, COD and TSS for City abattoir land use as shown on appendix IV which were above the national standards for wastes water discharge as shown on appendix III. The TP for animal grazing farm land use is also above the national standards for waste water discharge. Since the small scale industrial land uses are next to the City abattoir, the high TP, COD and TSS from the City abattoir did not cause pollution at small scale industrial land uses. This is because of self-purification process within a river channel. The same applies to cultivate farm land uses which are next to animal grazing farm land use where its high TP did not continue to pollute the water in the river at cultivate farm land uses.

5.1.3 Comparisons of water quality in the river before and after leaving the urban area

Land uses within the urban center or Municipality have contributed slightly to pollution than at inflow and out flow. For example, the outflow from the municipality has low EC of 335.75 micro Siemens and Source: Laboratory analysis inflow has 195.75 micro Siemens, and land uses within the municipality such as; municipal abattoir has EC of 507.50 l micro Siemens, planned settlement has EC value of 427.00 micro Siemens, animal has 306.50 micro Siemens. TDS at inflow is 105.75mg/l while at outflow the TDS is 163.50mg/l. And yet land uses within the municipality such as; municipal abattoir has TDS of 277.75mg/l, planned

settlement has TDS value of 226.25mg/l, animal has TDS of 149.50mg/l. At the outflow from the municipality the TP is 3.45mg/l and at inflow the TP is 2.58mg/l and land uses within the municipality such as; municipal abattoir has TP of 18.37mg/l, planned settlement has TP of 3.20mg/l, animal has TP of 12.34mg/l and tree nursery bed has TP of 7.11mg/l. The few examples above show that land uses within urban center have polluted river water than at inflow and outflow. This is because their average values are far much below the national standards.

Runoff from sparsely populated or rural areas within inflow and outflow can pick up substances from soil, including nutrients and inorganic debris. These are not able to pollute the water resources because the land use practices are limited in these places.

5.2 RECOMMENDATIONS

Basing on the above findings on the extent of the changes, the effects, causes and impact of the existing socio-economic development resulting from different land use practices within Fort-Portal Municipality, the researcher put forward the following recommendations to the various stakeholders.

There is need for the Government through the Ministry of Lands and Water to come up with well-coordinated and comprehensive regulations and socio-economic development policies on the pollution of the river basin so as to check on the mismanagement of fresh water resources.

Basing on the findings of the spatial patterns of the land uses such as; expanding timber workshops at the banks of the river, unplanned settlement, saloons, restaurants, markets, grinding mills, brick making industry, slaughtering house (abattoir), car washing bays, animal grazing farm, cultivated farm land use, and aluminum can work shop along Mpanga River and its tributaries which have contributed to increased industrial, commercial, and residential wastes and cosmetic discharge into the river. It is therefore recommended that The Municipal and District policy makers and implementers can design policies which guide the layout of these spatial patterns so as to make the distribution of land uses more efficient and more equitable. For instance the concentration of the small scale industries along River Mpanga in Kabundaire would have been very dangerous to the environment if the water was stagnant. Alternatively re allocation of other industries to some places in order to reduce the wastes

load in the river would help improve the situation in case if some of the land uses in future will tend to impose serious pollution in to the river.

The Local government together with NEMA should conduct Environmental Impact Assessments (EIA'S) for activities that are likely to have adverse impact upon the water body or river should be carried out as a pre-requisite to development while in some cases there may be sound economic and social arguments for the use of land along the river. Such development should be subjected to detailed EIA'S studies which should include Environmental audit of major on-going projects or land use activities within the municipality and mostly basing on the frequency with which phenomena (spatial pattern) has occurred for instance in Kabundaire , there are quite a number of grinding mills along the river. Preferably the number could be reduced or reallocate some of them far away from the bank of the river to avoid pollution by suspended matter.

The district local government and the political arm of the district (Policy makers) need to put the limits of animals to be slaughtered per day and should put measures on which detergents to use for cleaning the abattoir after the slaughtering is done so as not to pollute the river with strong detergents since the TP, and COD within city abattoir exceeded the national standards for effluents discharge in water bodies. Monitoring of wastes at this sampling by NWSC Fort-Portal branch is required continuously. Alternatively, if this land will cause serious pollution to the river in future, it should be re allocated some where else.

Although the use of agro-chemicals in the catchment area of the water bodies are to be restricted to estate crops like tea, there is an indication that as the population within the constituency and municipality in question is increasing, the farmers are concentrating on growing crops which are of high demand such as fruits and vegetables like tomatoes, pineapples, green paper, cauliflower, and cabbages. This implies that the demand of these crops within the municipality therefore increased the usage of fertilizers and some of these farms are along the river. For instance the TP in the river within cultivated farm or agricultural area was 7.32mg/l. This could be because of pesticides, herbicides and fertilizers used in controlling pests, weeds and adding manure in the soil for crops yields. This level of TP is controlled naturally by continuous flow of the river of which without that pollution would have been worse at this sampling spot.

The study also put forward the recommendation by FAO, (1989), that in order to choose the best use for a particular area of land, one needs to know what kinds of land use is suited for and what is not suited for which means finding out the suitability of each land unit in the planning area. This implies that the land must also be able to support the land use on a sustained basis. This means that the use must not progressively degrade the land. This is true because many changes of land use cause initial loss of land resources for example when forest is cleared for tea plantations or for arable farming, there is always a loss of forest habitat ,wildlife , soil and accumulated plant nutrients in the water body. Hence use of land must be on a sustained basis.

The policy makers need to enforce sustainable development policies which allow establishment of a land use which is friendly to a particular environment for example the car washing bays were not well established in compliance to the Fort-Portal Municipal Structural Plan for (1998-2018) and National Environmental Act Cap 153. NEMA, (2004), which indicates that most of the areas where car washing bays exist are supposed to be meant for open spaces. Restrictions concerning the types of houses or settlement along the river are to be put in place. Such settlement or residential to be allowed are those with well-established houses with flush toilets unlike the ones in Kisenyi along the river with pit latrines just very close to the river. This can enhance disposal of human wastes through infiltration or direct in to the river.

Even if laws and ordinances concerning abuses on environment exist in Fort-Portal municipality, a stricter and implemented one would be applied by the municipal authority to solve the problems of abuses on environment. For instance technical and financial support should be extended to local government both at the districts and Municipality to design and implement by-laws on the establishment of land uses along the water resources.

NEMA and the District Physical Planning land office should also consider sensitization of the community, encourage and support research on this issue as a measure to solve the problems caused by land use activities on water quality. In this way the community will be made to know the value of using their environment sustainably for instance through proper disposal of households garbage away from the river banks, and not disposing chemicals from saloons in to the river.

The Municipal Council need to device strict means to see that households' wastes, raw sewage within the planned and unplanned settlements are not dumped into the river or adjacent to the river bank. These wastes should be dumped several miles away from the river banks and municipality at large so as to ensure good quality of water in the river. More emphasis should be put on collecting garbage within unplanned settlement land use.

The local government and Municipal Council need to encourage the communities to put much emphasis on environmentally sustainable economic development which involve using political and economic systems to discourage the environmentally harmful and unsustainable forms of economic growth that degrade natural capital and encourage environmentally beneficial and sustainable forms of economic development that help to sustain natural capital.

Among the positive recommendations given by the researcher towards the appropriate establishment of land use practices by the developers along River Mpanga are below;

Grinding mills are one of the recommendations given by the researcher to be set along River Mpanga. Regardless of the increase in TSS in the water brought about the grinding mills, since the water in the river is flowing continuously, this is able to dilute and purify the suspended matters. The District Physical Planner and Engineers on the other hand should think of establishing a micro or mini or Picho Hydroelectric power which is equivalent to the amount of water found in the river throughout the year. This could be used to generate hydroelectric power since there is the availability of water throughout the year. This will increase the rate of developing such grinding mills, timber workshops and factories along the river at a sustainable and minimal cost.

Tree nursery beds or agro forestry is a recommended land use by the researcher. This is because in spite of its increase in TSS in the water, its establishment near or along the river is appropriate for the support of this project. This is because the river water is clean water without acid and with a good pH value rather than watering the seed lings with rain water which is acidic. The National Forest Authority should device means of encouraging and maintaining this sustainable project along the river.

The researcher also recommended the setup of brick making industry along the river. This is because in spite of its increase in TSS in the water, its location is suitable because it is near the water source which is one of the raw materials for that industry. The District Planner

should encourage this developmental project so as to make the best use of the water resource for the good of the people.

Another recommendation given by the researcher is that animal grazing farm should not be so near the river bank. This is because their wastes and chemicals used in sustaining them which are inform of; manure, pesticides and artificial feeds has increased the level of total phosphates in the river up to 12.34 mg/l as evidenced in figure 4.14 where some cows even cross up to the river to look for pasture. This has made the level of TP at this point to exceed the National Permissible level of TP effluents in water body which is 10.00mg/l.

The researcher also recommends that both houses meant for residential and commercial purposes within planned and unplanned settlement land uses should not be so near the river bank even if the EIA's had approved them as not being detrimental to the water in the river. This is because aesthetically, it is not appealing as evidenced on plate 4.2 showing photographs of some activities within the unplanned settlement land use along Mpanga River in Kisenyi

Fish ponds can also be established along River Mpanga especially at inflow and outflow since the BOD and COD are generally low. This is because BOD and COD measure the amount of organic and inorganic materials (pollutants) in the water in terms of how much oxygen will be required to break down both pollutants biologically and chemically to carbondioxide. This is because less oxygen will be required during decomposition of organic or bio-degradable wastes and less oxygen will be required during oxidation of inorganic materials. If much organic and inorganic pollutants were released into the water course or River Mpanga for that matter, during decomposition process, the DO of the receiving water would be used at a greater rate than it can be replenished, causing oxygen depletion which has severe consequences for stream biota. This would be reflected in high values of COD and BOD which will be above the national standards for waste water discharge. But since there is low BOD and COD, this means that DO is enough for fish growth.

Inflow and outflow spots are suggested for establishment of fish ponds because within the CBD or Central Business District in Fort-Portal Municipality, there are very many land use activities put in place and especially along Mpanga River. These land uses are releasing both organic and inorganic pollutants which at any one time, any or some land uses may tend to

release wastes which can increase the BOD and COD above the national permissible level of waste water discharge in water body. This is evidenced with COD and BOD within City abattoir and TP within animal grazing farm which are above national standards. This will mean death of fish at any time.

REFERENCES

- Arber, N., Lomas, S., Garrett Nagle, G., Thompson, L. & Thomas, P. (2001). *Geography 1 Matters Foundation*. United Kingdom : Heinemann Edition Publishers.
- Alber, Adams and Gould, (1972). *Spatial Organizations: The Geographers View of the World*. London: Prentice hall International.
- Amander, B., Fern, D., R., & Skinner, M. (2006). *AQA (A) Advanced Geography*. UK: Phillip Allan Updates, and Oxford.
- Ang'ienda, E., Kabajogya, A., Kahunde, A., Atwooki, J., A., & Akinyi, M. (2011). *Fort Portal Municipal Council Fact Book*. Kampala.
- Banga, T., R., & S.C. Sharma, (1995). Delh: *Hydraulic Mechanics*. Khann Publishers, Delhi.
- Bowen, A., & Pallister, J. (2001). *A2 Geography*. London: Heinemann Educational Publishers.
- Chhatwal ,G., R., Mehra, M., C., Satake, M. & Nagahiro, T. (1999). *Environmental Water Pollution and its Control*. New Delhi: J.L. Kumar for Anmol Publications PVT Limited.
- Cutter, S.L., Lambert, H.R & William, H. ,(1998). *Exploitation, Conservation, Reservation: A Geography Perspective on Natural Resource Use* (2nded.). N.Y. Singapor: John Willey M.C & Sons.
- Cunningham, W.,P., & Cunningham, A. (2004). *Principles of Environmental Sciences: Inquiry and Application* (2nd, ed.), McGraw-Hill Companies, inc., New York.
- Coble, C., G., Murray, E., G., & Dale, R., Rice, (1981). *Annotated teacher's, Earth Science*. London: Prentice-Hall International, Inc.
- Conte, Thompson, & Moses, (1997). *Earth Science, An Integrated Perspective*. US, Washing: Time High Education Group Inc.
- Dara, S., S. (2002). *A text book of Environmental Chemistry and Pollution Control*. New York: S.Chand and Company Ltd, Ramgar.

- Deborah, C., (1996). *Water quality Assessments: Guide to the use of Biota, Sediments and Water in Environmental Monitoring* (2nd ed.).UK: E and FN Spon.
- De Zaune, J., P.E. (1990). *Drinking Water Quality, Standards and Control*. London, England: Van Nostrand Reinhold International Company Limited.
- Departments of Land and Surveys, (1962). *Atlas of Uganda, first Edition*, Kampala.
- Enger, D., Eldon and Smith, Bradley, F. (2004). *Environmental Sciences: A study of Interrelationship*. (9thedi.).U.S: McGraw-Hill Companies, Inc.
- FAO, (1989). *Guide Lines for Land Evaluation for Extensive Grazing, Management and Conservation Services*. United Nations, Rome.
- FAO, (1991). *Land and Water Development Division*, Rome Italy.
- Getis, A., Getis, J., and Fellmann ,J. D. (2006). *Introduction to Geography*. (10thedn.). New York: McGraw-Hill, St.Francisco.
- Getis .A, Getis .J, Fellmann,D. (1999). *Element of Human Geography*. USA: McGraw-HILL.
- Goel, P.K. (2000). *Water Pollution, Causes, Effects and Control*. New Delhi: New Age International Limited.
- Gregory, S. (1978). *Geography for advanced Studies: Statistical Methods and the Geographer*. England: (4thedn.). Longman Group Limited.
- Gupta, S., & Gupta, M. (1997). *Water and Basic Environment Technology*. New Delhi: J.L. Kumar for Anmol Publications, PVT, Limited.
- Ghosh, G. (1992). *Environmental Pollution: A Scientific Dimension*. New Delhi: S.B. Nangia Aishish.
- Huggget, R., Lindley, S., Gavin, H., Kate, R. (2004). *Physical Geography: A human Perspective*. Great Britain: Arnold, Hodder Headline Ground.
- Haggett, P. (2001). *S Geography: A Global Synthesis*. England: Pearson Edition Limited.
- Hickman, G. (1990). *Lands and Peoples of East Africa*. China: Longman Group, Limited.
- Kabarole Local Government, (2008-2018). *Fort-Portal Municipal Structural Plan*. Kabarole.

- Kaggwa, R.(1998). *Assessment on the effects of Water Treatment Sludge from industries on a papyrus lake in Kampala.*
- Kannan, K. (1997). *Fundamentals of Environmental Pollution.* Ram Nagger, New Delhi: S.Chand and Company Limited.
- Kasozi, J. (2007· April). A leachate lake at Masese (Jinja) wetland formed as a result of fish processing in the area. *New Vision, Thursday, 19th.*
- Katyal, T., & Satake, M. (1989). *Environmental Pollution,* New Delhi: Anmol Publications PVT. Limited.
- Kumar, S. G. (1979). *Water Resources and Hydrology.* (3rdedn.). New Delhi: Khanna Publishers.
- Lwasa, S., L., & Mwaanje, E.E. (1997). *A Cost-effectiveness evaluation of water hyacinth Control Methods: The case of Lakes Kyoga and Victoria Ecosystems.* Kampala, Uganda.
- Mahajan, S.P. (1985). *Pollution Control in Processing Industries.* India: TATA McGraw-Hill.
- Mugisha, M. (2013 April). A fountain of sewage gushing into the middle of Nakivubo Road opposite the bus terminal recently. *New Vision Wednesday, 10th.*
- Munyaaradzi, C. (1996). *Water in South Africa.* Harare, Zimbabwe: Print Holdings.
- Mason C.F. (1991). *Biology of fresh water Pollution.* (2nded.).UK England: Longman Group Ltd.
- National Water and Sewage Corporations, Central Laboratory, Revised in, (2000). *National Standards for Waste Water Discharge:* NEMA Standards. Bugolobi, Kampala.
- National Curriculum Development Centre and Ministry of Education, (1993). *Intergraded Geography, Environment, Population and Development: Student's Book One.* Pilkington Road, Kampala: Macmillan Uganda Limited.
- NEMA, (1995). *State of Environment Report for Uganda.* Kampala, Uganda.
- NEMA, (1996). *State of Environment Report for Uganda.* Kampala, Uganda.

- NEMA, (1998). *State of Environment Report for Uganda*. Kampala, Uganda.
- NEMA, (2004). *Districts State of Environment Report for Kabarole District*. Kampala, Uganda.
- NEMA, (2008). *State of Environment Report for Uganda*. Kampala, Uganda.
- Ntabadde, C. (2005 June). Makula inspects drainage in Katanga, where there is a cholera outbreak. *New Vision, Wednesday, 22nd*.
- NWSC, (2009). *Quality Department, Laboratory Procedure Manual*, Bugolobi, Kampala.
- Omara Ojunga, P. H. (1992). *Resource Management in developing Countries*. London U.K: Longman Group.
- Otim, J. (2008). *Assessment of the Domestic Water Quality in Peri Urban Settlement of Lira Municipality*.
- Otto, J.H, Towle, A., and Badley, J.V. (1981). *Modern Biology*. NewYork : Holt, Rhinehart & Winston Publishers.
- Pacione, M.R. (2005). *Urban Geography: A global Perspective*. (2nded.). New York. McGraw Companies, Inc., Avenue of Americas.
- Palmer, M.D. (2001). *Water Quality Modeling*. USA, Washington.
- PierraJulien, (2000). *River Mechanisms*, Cambridge University Press, United Kingdom.
- Prakash, R., & Choubey, S.M. (1990). *Environmental Pollution and Health Hazards*. New Karol, Bagh Delhi: Tagmander Book Agency.
- Presscot, L.M, Harley, J., P., & Klein, D.A. (2000). *Microbiology*, (5th ed.). North America New York: McGraw-Hill Companies, Inc.
- Ralph, Feather,M. Jr, Snyder, S., L., Dalence, & Hesser, (1993). *Teacher Wrap Around Edition*. USA: Glencoe Division of Macmillan / McGraw-Hill 936 East wind Drive Westerville.

- Ramsden, E. (1997). *Key Science for GCSE Chemistry*. Wellington Street, London: Stanley Thorns Publishers Limited, Ellenborough House.
- Randolph, J. (2004). *Environmental Land Use Planning and Managements*. N.Y, Washington: Island Press.
- Ssengendo, H., & Nkunda, G. (2004). *Macmillan Uganda Secondary School Atlas*. Kampala: Macmillan (Uganda Publishers).
- Ssengendo, H., and Nkunda, G. (2013). *Moran Uganda Secondary School Atlas*. Moran Publishers Uganda Limited, Kampala.
- Selmes, I., Walker, R., Grocott, K., and Fielding, A.M. (1995). *The Geography Collection World Wide: A Core text for A- level*. London: Hodder and Stough Educational.
- Tenywa, G. (2013 April). The waste being dumped in Masese oozes brown liquid, draining towards the lake. *New Vision Saturday, 17th*.
- Thornbury, W.D. (1969). *Principles of Geomorphology*. United States: Second Edition, John Wiley and Sons.
- Tripathi, A.K. (1993). *Advances in Environmental Sciences*. Punjabi Bagh, New Delhi: Ashish publishing House.
- Trivedi, P.R., and Guardeepraj, (1997). *Encyclopedia of Environmental Science Series, Water Pollution*. New Delhi: Akashideep Publishing.
- Wright, R.T. (2008). *Pearson International Edition, Environmental Science*. (10thedi.).U.S: Pearson Edition Inc.

APPENDICES

APPENDIX I:

LISTS OF ACRONYMS AND ABBREVIATIONS

| | |
|-----------------------|---|
| BOD | Biological Oxygen Demand |
| CO₂ | Carbon dioxide |
| COD | Chemical Oxygen Demand |
| DDT | Dichlorodiphenyl Trichloroethane |
| DO | Dissolved Oxygen |
| EPA | Environmental Protection Agencies |
| FAO | Food and Agricultural Organization |
| FC | Fecal Coli form |
| HO₂ | Water |
| LEDs | List Economic Developed Countries |
| MEDs | Most Economic Developed Countries |
| NEMA | National Environmental Management Authority |
| NFA | National Forest Authority |
| NGO | Non-Governmental Organization |
| NPK | Nitrogen Phosphorus Potassium |
| NPS | Non Point Sources |
| PS | Point Sources |
| TDS | Total Dissolved Solids |
| TSS | Total Suspended Solids |
| U.S | United States |
| UK | United Kingdom |
| MLSB | Membrane Lauryl Sulphate Broth |
| MFM | Membrane Filter Method |
| NO₃ | Nitrate |

| | |
|----------------|--|
| CBD | Central Business District |
| EIA'S | Environment Impacts Assessments |
| FCU | Fecal coli form Units |
| NWSC | National Water and Sewage Corporations |
| GPS | Ground Positioning System |
| ICT | Information and Communication Technology |
| Inflow | Before the river enters Fort-Portal Municipality |
| Outflow | After the river leaves Fort-Portal Municipality |

APPENDIX II:
AN OBSERVATION GUIDES

In collecting the data, the researcher collected the data through the observation method by use of observation guides which involved areas where observations could be best used in data collection such as;

- Spatial patterns of land uses along Mpanga River.
- The sizes of land allocated for a particular land use.
- The types of wastes generated by a particular land use.
- Some places where the wastes for a particular land use were being disposed.
- The nature of the river at a particular land use for instance whether the river is calm, the width of the water channel and vegetation around or near or within the river.
- The types of soils for e.g. clay soil from limestone rocks which contain calcium carbonate where the river passes.
- The nature of the land use for e.g. types of settlement i.e. planned or unplanned settlements and their facilities like toilets or latrines.
- Finally the observations done on samples during laboratory analysis.

APPENDIX III:

NATIONAL STANDARDS FOR WASTE WATER DISCHARGE, NEMA STANDARDS, (2009 REVISED).

| Parameters | Units | National standards for effluents discharge (Maximum permissible level) in water bodies |
|-------------------------|-----------|--|
| Electrical conductivity | μS/cm | 1500 |
| pH | | 6.0-8.0 |
| Total dissolved solids | Mg/l | 1200 |
| Total suspended solids | Mg/l | 1500 |
| Total phosphates | Mg/l | 10.0 |
| Nitrate | Mg/l | 10.0 |
| BOD | Mg/l | 50 |
| COD | Mg/l | 100 |
| FC | Fcu/100ml | 5000 |

Table showing National standards for wastewater discharge

Source: NEMA Standards, 2009 revised.

APPENDIX IV:

GENERAL TABLE SHOWING THE AVERAGE VALUES ON PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF WATER IN RIVER MPANGA FOR EACH LAND USE UNDER STUDY.

| Land use practices | Physical Characteristics | | | Chemical Characteristics | | | | | Biological characteristics |
|-------------------------|--------------------------|--------|--------|--------------------------|--------|-------|-------|-----------------|----------------------------|
| | TDS | EC | TSS | pH | COD | BOD | TP | NO ₃ | FC |
| Unplanned settlement | 153.25 | 294.50 | 12.75 | 7.63 | 23.75 | 4.75 | 3.24 | 0.03 | 1920.00 |
| Car washing bay | 159.25 | 298.50 | 11.25 | 7.50 | 26.75 | 5.25 | 4.36 | 0.12 | 1055.00 |
| Planned settlement | 226.25 | 427.00 | 12.75 | 7.63 | 23.75 | 4.75 | 3.24 | 0.03 | 1920.00 |
| Abattoir | 277.75 | 507.50 | 113.25 | 7.03 | 199.50 | 10.75 | 18.37 | 0.39 | 2067.50 |
| Small scale industries | 159.75 | 301.50 | 21.00 | 7.45 | 17.00 | 4.25 | 3.64 | 0.04 | 267.50 |
| Commercial land use | 163.50 | 310.25 | 30.25 | 7.38 | 26.75 | 3.75 | 7.14 | 0.13 | 305 |
| Tree nursery bed | 165 | 311 | 25.75 | 7.48 | 24.25 | 4.00 | 7.11 | 0.06 | 182.50 |
| Animal grazing land use | 149.50 | 306.50 | 53.25 | 7.38 | 22.50 | 5.50 | 12.34 | 0.37 | 1055.00 |
| Cultivated land | 156.25 | 308.25 | 48.50 | 7.48 | 16.00 | 3.75 | 7.32 | 0.07 | 1170.00 |
| Inflow | 105.75 | 195.75 | 8.50 | 7.50 | 25.25 | 4.50 | 2.58 | 0.04 | 157.50 |
| Outflow | 163.50 | 335.75 | 29.75 | 7.48 | 27.27 | 4.25 | 3.45 | 0.08 | 232.50 |

Source: Laboratory analysis