MAKERERE UNIVERSITY

URBAN RIVER POLLUTION:

A CASE STUDY OF RIVER MPANGA IN FORTPORTAL CITY, KABAROLE DISTRICT

BY

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AUGUST, 2018

DECLARATION

DECLARATION

I declare that this dissertation is my original work and has not been presented for award of a degree in any other university.

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DATE....21/09/2018.....

Declaration by the supervisor.

NAME: PROF.TWAHA ALI BASAMBA ATEENYI

SIGNATURE.....

DATE....21.9.2018.....

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DEDICATION

I dedicate this research to the family of Mr. and Mrs.Rusoke George William who have supported me throughout my education career.

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First of all I would like to express my sincere gratitude to my Sponsors (my parents and siblings) who provided me with financial support that made it possible to complete this report. In the same way, I would like to thank my supervisor Prof. Twaha Ali Basamba Ateenyi for his academic support and encouragement from the initial stages up to the completion of this report. I appreciate all the laboratory technicians for their guidance and support. Lastly a hand of applause to my friends and relatives whose contributions were paramount towards completion of this report.

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LIST OF ACRONYMS

ANOVA	Analysis of variance
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
EC	Electrical Conductivity
mg/l	Milligram per Liter
mg	Milligram
NEMA	National Environment Management Authority
NWSC	National Water and Sewerage Cooperation
TDS	Total Dissolved Solids
TSS	Total Suspended Salts
TotN	Total Nitrogen
TotP	Total Phosphorous
ppm	Parts per Million
MUARIK	Makerere University Agricultural Research Institute Kabanyolo
Ha	Hectare
GDP	Gross Domestic Product
NH_3	Ammonia
NH_4^+	Ammonium ions
Wc	Water content
K	Potassium
SPSS	Statistical Package for Social Scientists
UN	United Nations

ABSTRACT

Water quality is needed to maintain the integrity of a river system and depends on the preservation of natural (chemical and biological) conditions of the water and the surrounding environment. Unsustainable use and pollution through various human activities can impair the ecological state of a natural ecosystem by altering its chemical composition and the biological communities that naturally occur in it. To identify the human activities carried out on river Mpanga, Assess the effect of these human activities on river Mpanga and finding out the level of awareness of legislations concerning rivers among the community within river Mpanga, a study was conducted where survey data was collected and chemical analyses were carried out. The study employed both quantitative and qualitative methods for data collections, Simple random sampling was used to draw a sample from residents operating and living within Mpanga catchment in Fortportal City. The survey results indicated that various activities carried out within the Mpanga catchment including farming, improper waste and sewage disposal have a large influence on the physical and chemical water quality of the river. These human activities had negative effects on River Mpanga including; siltation, Eutrophication, water hardness, toxicity etc. Laboratory analysis was done on the River water at different points and Using GenStat software, data was analysed at 5% significance level. The results indicated that there was a significant difference in the p^H, P, K, BOD and COD level at different points along the stream ($p<0.05$) . However, there was no significant difference for the levels of N, Ca and Na in the water at different points along the stream ($p>0.05$). It was concluded that human activities have led to increased pollution of this river and was due to lack of information and knowledge about laws concerning rivers. The study recommended that people should be sensitized on the values, uses, guidelines and laws for sustainable use of rivers.

CHAPTER ONE

1.0 Introduction

1.1 Background to the study

Water, like air, is a vital resource without substitute and its supply, allocation, and wastewater disposal present numerous challenges, all of which must be met to support the ever increasing population. The provision of potable water and sanitation in urban areas pose significant challenges for developing countries. Surface water and groundwater resources are increasingly over-exploited. Lack of wastewater treatment and insufficient control over other waste disposals also place water systems at risk of microbiological and chemical contamination. These come up as challenges that must be overcome in order to conserve our freshwater which is a finite resource (Atim, 2012).

Rivers are a major source of water in Uganda; they provide ecological, social and economic statuses which contribute to the GNP (Gross National Product) of the country (Namakambo, 2000; Mafabi *et al*., 1998). They serve both direct and indirect functions, direct functions include provision of fish, fuel wood, wild foods, medicinal plants, water for agriculture, pasture, transport, recreation (green corridors) etc. The indirect or ecosystem functions include; maintenance of water quality (Kansiime *et al*., 1995) and flow, water storage, water recharge, flood control, reproduction area for fish and climate control Other functions include cultural, biodiversity of flora and fauna, aesthetic, heritage bequest values and providing nesting sites for birds.

The Mpanga catchment situated in Western Uganda encompasses rural and urban settlements, valuable nature parks and ecosystems that depend on its waters. The Mpanga River system is the main fresh water resource for the communities that live along its banks who rely on its water for consumption, agriculture and fisheries. Since the river flows into Lake George, the state of Mpanga is also contributing to the quality of the lake and its fish stock. In recent years, the water quality of River Mpanga has been getting affected by human activities. Forestry and river sediment extraction in the catchment area may be providing economic advantages, but affects the water quality, flora and fauna downstream. Complaints about dirty, turbid tap water and concerns about the increased risk of getting water-borne diseases have forced local stakeholders to take action (Van bustle et a1., 2017)

1.2 Problem Statement

Water scarcity has continued to hit several parts of Uganda as some rivers, lakes and wetlands dry up, causing a drastic reduction in the water levels. An example of such rivers is Mpanga in the western part of the country. River Mpanga meanders through three local Governments of Kabarole, Kyenjojo and Kamwenge, serving a population of approximately five million people who directly or indirectly depend on it for survival. However, all is not well with river Mpanga**.** It has been established that the amount of water in the river has reduced significantly in the last ten years; the major cause for this decrease are the many economic human activities in the area. Atim (2012) emphasized that Mpanga River is drying up due to mining of sand and stones on its banks and planting eucalyptus trees which are high water consuming exotic species despite the government's regulation of preserving 100 meters distance from all big river banks for natural vegetation. The main visible wastes in the river are plastics and polythene papers and the major cause for this is improper disposal of waste generated in various trading centers and towns close to it .The river bed is also silted as a result of erosion from gardens and poor soil management practices along the river. Contamination of river Mpanga has negatively affected the health of the surrounding communities and it is in their interest to ensure that the river is protected and water is clean. All this has been said and seen, but there has not been enough research and studies to enlighten people about the dangers their activities are posing on the environment, families, communities, city and country at large..

1.3 OBJECTIVES

1.3.1 General objective

- The general objective of this study was to assess the extent of pollution along river Mpanga in Fortportal city.

1.3.2 Specific objectives

The specific objectives of the study were**;**

i. To identify the major human activities taking place along river Mpanga
ii. To assess how these human activities affect the water quality of the river
iii. To find out the level of awareness on policies and legislations on the river ecosystem conservation among the communities within river Mpanga Catchment.

1.4 Hypothesis

The quality of water at River Mpanga is the same irrespective of the increased human activities on the river catchment

1.5 Scope of the study

The study was carried out in Fort Portal mainly concentrated on Mpanga river catchment area within Fort Portal City. It took in account 20 household in the catchment, it concentrated on people who are more dependent on the River and the key informants like the sub county chiefs, town clerk, Member of Parliament, lecturers and local leaders.

Laboratory analysis was carried out on the water samples from the upstream, midstream and downstream and the results from their analysis together with that obtained from the households were used to generalize on the effect of human activities on River Mpanga.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Human activities carried out along rivers and their effects on the ecological characteristics of the rivers.

According to Atim (2012), the deterioration of the water quality of a river is associated with gold, sand and soil mining in a river and its neighboring sub catchments. In urban sub catchments, rivers are used as waste dumping sites. Domestic waste and sewage are channeled to river which in turn increases the levels of fecal coliforms and E. Coli in the water.

Steve (2007) observed that, many rural household in the tropics have a eucalyptus tree plantations established at river banks. This is very dangerous for the sustainability of rivers because water uptake by this type of trees is so high thus they should not be grown along the river. In the urban sub catchments, tree nurseries are established along rivers. A lot of water is extracted for watering these nurseries. This has resulted into reduced volume of water in the affected rivers. Additionally, soil is eroded from these nursery beds to the river which results into siltation.

Brick making around the river because of the good clay soil has been intensively practiced. This activity requires a lot of water hence lowering the water volume of the river and as the grounds for brick making are being prepared, land is left bare causing erosion and siltation of the river. The accumulation of domestic waste in the river has led to loss of aquatic life for example mud fish. This type of fish has been in this river since the 1950's but is no more of late (Fierstein *et al*., 2017).

According to Butsel *et al*., (2017), tea production is an important economic activity in Fort Portal as it accounts for 40% of the municipality's employment. Like most croplands, tea plantations are rain-fed, putting them at risk from droughts. While irrigation infrastructure is to be developed in the future, tea factories at present use groundwater as well as water from River Mpanga for processing and machine maintenance in times of rainwater scarcity.

Part of the Mpanga wetland has been reclaimed in an attempt to create transport routes in terms of roads. This has resulted into loss of diverse wetland biodiversity in form of flora and fauna (Atim, 2012)

Severe degradation has been observed in most of the sub catchments that were studied. Unsustainable harvesting of wetland vegetation was recorded in many of the rural sub catchments. Most river banks in the rural sub catchments were encroached and used for agriculture. Animal farms were established in some of the places whereas others were used to grow annual crops like vegetables and food crops. Where grazing is practiced on the river banks, heavy degradation of the banks in form of erosion and siltation has occurred. This has in the long run lowered the water quality of the river since the grazing animals defecate and urinate in this water. Art and craft making is another land use practice around river Mpanga. Different crafts both for social and commercial purposes are made by communities living around river Mpanga (Atwongyeire *et al*., 2018)

2.2 Laws and acts attached to river catchments

According to the town and country planning act (1964), it provides for the orderly planning in urban and rural areas and established guidelines for planning schemes, acquisition of land and compensation for acquired lands as well as consideration to safe guard the natural environment.

The public health act; The act consolidates the law in the respect of the public health and places duties on the urban and local authorities in the meters pertaining to public health. it provides for measures to minimize water, air and noise pollution and empowers local authorities to take lawful, necessary and reasonably practicable measures for the prevention of any pollution dangerous to healthy of any supply of water, which the public within its district has a right to use and does use for drinking or domestic purposes

The water act capt.152; Section.5: all rights to investigate, control protect and manage water in Uganda is vested in the government and in section 31: it makes it an offence to pollute or cause risk of water pollution.

And according to the Uganda wildlife act capt200; any person desiring to undertake any project which may have significant effect on any wildlife species or community shall undertake an environmental impact assessment in accordance with the national environment act.

The local government act, (1997) provides for a district based system of local governments. This system provides for elected councils that have both legislative and executive powers thus the district councils play an important role in land administration, land surveying,

physical planning and management of forests ,wetlands, environment and sanitation services that are not the responsibility of the central government, they are therefore charge with the crucial role of acquisition of land for debt construction purposes and in the sensitization and mobilization of the local communities.

The national environment (wetlands, lakeshores and river banks management) regulations (2000) states that any activity carried out near a river should be one hundred meters (100m) away from the river bank.

2.3 A river as a resource

According to Ray *et al*. (1992), a river basin is the area tributary to a given stream and is separated from adjacent basins by a divide, or a ridge, that can be traced on the topographic maps. All surface water originating in the area enclosed by the divide is discharged through the lowest point of the divide through which the main stream of the catchment passes. A river basin water resources system typically consists of several component sub-projects.

Ray *et al*. (1992) further explained that, River basins are important from hydrological, economic and ecological points of view. They absorb and channel the run-off from snow-melt and rainfall which, when wisely managed, can provide fresh drinking water as well as access to food, hydropower, building materials (e.g. Reeds for thatching), medicines and recreational opportunities; they also form a critical link between land and sea, providing transportation routes for people, and making it possible for fish to migrate between marine and freshwater systems. By acting as natural 'filters' and 'sponges', well-managed basins play a vital role in water purification, water retention and regulation of flood peaks. In many parts of the world, seasonal flooding remains the key to maintaining fertility for grazing and agriculture (Fierstein *et al*., 2017).

Lastly yet significantly, these often very large-scale ecosystems combine both terrestrial (e.g. forest and grassland) and aquatic (e.g. river, lake and marsh) components, thereby providing a wide diversity of habitats for plants and animals (Mafaranga, 2011).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location of the area of Study

River Mpanga catchment is located in the south-west of Uganda along the border with the Democratic Republic of the Congo and is part of the Lake George and Lake Albert sub-basin, situated within the Nile basin. It covers a surface of approximately 4700 km², with its waters flowing over a distance of approximately 200 km through the districts of Kabarole, Kyenjojo and Kamwenge, before discharging into Lake George (Figure 1). River Mpanga's headwaters originate from the slopes of the northern part of the Rwenzori Mountain range (around 1700 m a.s.l.) and join at the eastern foothills to form the River Mpanga. The river then flows east, crossing the city of Fort Portal and an area of tea estates before entering Kibaale Forest National Park and turning south-east. In the downstream area of Kamwenge, Rushagwe River joins Mpanga as an important tributary from the east and the river continues west to discharge into Lake George (920 m a.s.l.).

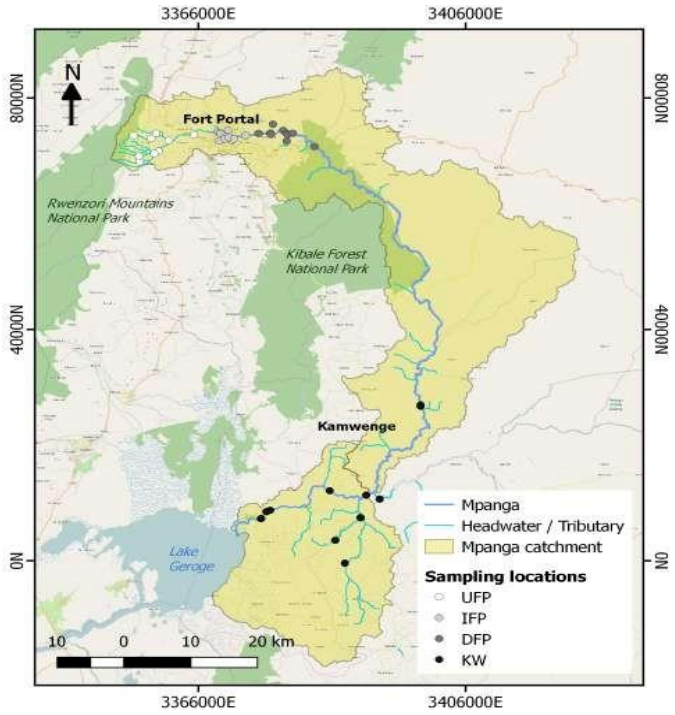

Figure 1: Map of the Mpanga catchment with indication of sampling locations per area (UFP = upstream FortPortal; IFP = in Fort Portal; DFP = downstream Fort Portal; KW = Kamwenge).

3.1.2 Climate

Despite its relatively small size, the catchment comprises a variety of climatologically and ecologically different regions, ranging from a year-round wet climate in the source area of the steep Rwenzori mountains (2000-3000 mm annual rainfall), over a wet climate with two short dry seasons per year (1400 mm annual rainfall) in the mid-range regions of the system, to the drier downstream region (1000 mm annual rainfall) with pronounced dry and wet seasons. Depending on altitude and season, mean temperatures from source to mouth areas may vary from below 10 to over 22 °C. (Bustle et a1., 2017)

3.1.3 Vegetation

Mpanga catchment is covered by wetlands and extensive tea plantations which provide good protection against soil erosion.

3.1.4 Soils

Mpanga catchment has volcanic origin soils and alluvial deposit soils.

3.1.5 Study Population

The study population consisted of approximately 20 (15 local participants and 5 key informants). It included households near the catchment and only those communities within Kabarole district, since the river covers three districts in western Uganda. The study targeted communities living around river Mpanga in only Kabarole district.

3.2 Ethical Consideration

The study required not only expertise and diligence, but also honesty and integrity. According to Cooper and Schindler (2011), ethics are norms or standards of behavior that guide moral choices about individuals' behavior and our relationships with others. Weiman *et al*. (2005) explain that ethical considerations and ethical behavior are as important in research as they are in any other field of human activity. The goal of ethics in research is to ensure that no one is harmed or suffers consequences from research activities. Ethical consideration in research means adhering to good codes of conduct.

3.3 Research Design

The study used the experimental and survey design

The **Experimental design** was used to determine the physical and chemical characteristics of water in river Mpanga, whereas the **Survey design** was used in obtaining data about the economic activities carried out in Mpanga catchment and their impacts on the river

The study employed a cross-sectional research design. It is not repetitive in nature as it is carried out once at a particular point in time. Moreover, it facilitates the study to examine a section of the population at a single-time period (Kothari, 2004).

3.4 Research Approach

3.4.1 Site Description

A one day reconnaissance field trip was conducted along river Mpanga in Fort Portal city to identify study sites. Three study sites were purposively selected; one at the upper stream named point A, then midstream named B which was near Mpanga market where there is a lot of pollution from waste discharge and the third point named point C at the downstream and water samples were collected from the respective points.

3.4.2 Sampling

Approximately 400mls of water were collected from each of the identified sampling points in triplicate (three sub samples) for laboratory analysis of selected water quality parameters. A total of nine (9) water samples were collected into clean 500ml Rwenzori plastic bottles by lowering them into the river and taking water out, after rinsing them four times with the same water to minimize errors. Samples were labeled following a formula of LN where L, represents the point sampled while N is replicate number i.e. (A1, A2, A3, B1, B2, B3, and C1, C2, C3).

3.4.3 Sample Preparation

Water samples collected were taken to the East laboratory at the College of Agriculture and Environmental Sciences for analyses.

3.4.4 Laboratory Analyses

In the laboratory, parameters tested were the physico-chemical parameters of the water samples i.e. p^H, EC, BOD, COD, Total phosphorous and total nitrogen.

3.5 Sampling Technique and procedure

The study employed a simple random sampling method where cross-sectional data was collected. The entire process of sampling was done in a single step with each subject selected independently of the other members of the population.

The required sample size was determined using the Cochran formula below

$$n=\frac{N}{1+Ne2}Deff * \frac{100}{r}$$

Where n= required sample size, N= Total Population of individual using the catchment, *e*= degree of precision , %, Deff is the design effect which is equal to 2 for finite populations, ϒ is the response rate. This method was fully explained by Fierstein *et al*. (2017) and Tejada *et al*. (2012). The advantage of the technique is that it is associated with minimum bias compared to other sampling methods. The technique was used by Michaelsen *et al*. (1994) in the analysis of satellite and terrain data to guide vegetation sampling and surveys.

For laboratory analysis, samples of the water from River Mpanga were collected from upstream, middle and downstream (Figure 1). They were selected at random points to avoid any bias in the results. They were later taken for analysis to avoid any change in concentration of the contents.

3.6 Data collection methods

Primary data was obtained from the field through questionnaires, interviews, observation and laboratory analysis

The questionnaires were printed and distributed to selected households, people in markets and key informants within the catchment area in a systematic method. The study utilized specifically systematic sampling to collect the data which is appropriate in this context of the study because it focused on notable outcomes that typically highlighted, negative or positive (failures or successes), thus the individuals possesses high levels of uncertainty in both selection of respondents and to in obtaining reliable information from them to study the impacts of human activities on the catchment area.

For laboratory analyses, variables that could not be measured in the field, water samples were collected for analysis in the laboratory at Makerere University. This was done for, Total Nitrogen (TotN), Total Phosphorus (TotP), Total Suspended Salts (TSS), Total Dissolved

Salts (TDS) Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), pH and Electric conductivity (EC). N and P was determined calorimetrically (Okalebo *et al*., 2002) and K by flame photometry (Anderson and Ingram 1993). EC and Total dissolved solids were determined using the relationship TDS (mgl^{-1}) = EC(μScm^{-1})*0.67 (NWSC, 2009) in which EC was determined using an EC meter.

3.7 Sample size and sampling procedure:

A sample of 20 respondents was drawn from residents living and operating in and around river Mpanga around Fort Portal City and within the City only.

Simple random sampling method was used to ensure each member of the target population have an equal and independent chance of being included in the sample.

Interviews: Interviews and focus group discussions were conducted.

Questionnaire: Had both open ended and close ended questions.

Observation: This involved at looking at what is actually taking place in the study area (including human activities carried out along River Mpanga and their impacts on the river)

Photography: Photos were taken to show the area of study, human activities taking place and their impacts on the river.

Collecting samples or laboratory analyses: Samples of water from the river was collected from 3 selected sites or points along the river at a distance of 3km along the river upper stream, mid-stream and downstream. The control sample was taken from the less urban influence on the river.

3.8 Data Processing and Analyses

The data from the study was edited and tabulated in form of frequency tables to make -the data more meaningful. Qualitative data was analyzed using descriptive narrations

On establishing that there are various dimensions of the human activities affecting the water quality and quantity in the catchment, advanced to establishing whether the relationship that exists is a cause and effect relationship by computing a multiple regression analysis basing on the linear regression model of;

$$Y=\alpha+\beta_1 Agric+\beta_2 Min+\beta_3 Was + \beta_4 Fac+\beta_5 Dam+\beta_6 Home + \beta_{7i\ BRICK} +\varepsilon_i....$$

Where i= 1, 2…k

Y = Impact of human activities measured using chemical analysis

Agric= Agricultural activities

Min= Mining activities

Was= Waste disposal

Fac= Nearby Factories

Dam= Dam construction

Home= Home use

Brick= Brick making

ε = Random error for unexplained factors

3.9 Statistical Analyses

The obtained results from the Laboratory were entered into Microsoft excel spreadsheet from where the analytical data was exported into Gen Stat statistical software. Statistical analyses were conducted to obtain; the means, variance and standard errors. And while assuming equal variance at P=0.05, a one way analysis of variance (ANOVA) was conducted. The difference in the obtained mean values was considered significant if calculated P values are less than 0.05. Then, Duncan's LSD was used for mean comparison to check for differences in the mean values between sampling points.

Data from the survey study was compiled into Microsoft Excel spreadsheet organised and later analyzed using SPSS software to develop chi squares.

CHAPTER FOUR

4.0 Results and Discussion

4.1 Results

4.1.1 Major Human activities carried out within River Mpanga catchment.

Table 1: Percentage of male and female respondents

	Frequency	Percent	Valid Percent	Cumulative Percent (%)
Male	8	53.3	53.3	53.3
Female	7	46.7	46.7	100.0
Total	15	100.0	100.0	

Results from local participants

Table 2: Academic qualifications

		Frequency	Percent	Valid Percent	Cumulative Percent (%)
Valid	None	1	6.7	6.7	6.7
	Primary	2	13.3	13.3	20.0
	Secondary	9	60.0	60.0	80.0
	University	3	20.0	20.0	100.0
	Total	15	100.0	100.0	

Results from local participants

Table 3: Age brackets of the people who participated in the study

	Frequency	Percent	Valid Percent	Cumulative Percent (%)
Below 20	1	6.7	6.7	6.7
20-25	3	20.0	20.0	26.7
26-30	6	40.0	40.0	66.7
31-35	2	13.3	13.3	80.0
36-40	1	6.7	6.7	86.7
41-45	1	6.7	6.7	93.3
46 and above	1	6.7	6.7	100.0
Total	15	100.0	100.0	

Results from local participants

Table 4: Human activities carried out around the Catchments of River Mpanga

	Frequency	Percent	Valid Percent	Cumulative Percent (%)
Valid crop growing	5	33.3	33.3	33.3
Brick laying	1	6.7	6.7	40.0
Settlement	1	6.7	6.7	46.7
Crop growing, brick laying and settlement	3	20.0	20.0	66.7
Crop growing, animal grazing and disposal of wastes'	5	33.3	33.3	100.0
Total	15	100.0	100.0	

Results from local participants

4.1.2 How the human activities affect the water quality of river Mpanga.

Table 5: Summery ANOVA table with mean squares for different water properties

Source of variation	d.f.	p^H	N	P	K	Ca	Na	BOD	COD
REP stratum	2								
SAMPLE POINT	2	0.292211^{**}	0.793^{ns}	16.0821^{**}	0.0012444^{*}	12.071^{ns}	0.001244^{ns}	1050.78^{**}	713.44^{*}
Residual	4	0.004744	3.223	0.6711	0.000178	8.338	0.004444	45.78	79.11
Total	8								

Results from laboratory analyses

*-Significant **-Highly significand and ns- not significant at $p<0.05$

Statistical analysis of data is shown in (Table 5). The table shows the mean square values of the physicochemical parameters of the water at different points along the river stream. There was a significant difference ($p<0.05$) in the p^H of the water, P, K, BOD and COD level at different points along the stream. However, there was no significant difference ($p>0.05$) for the levels of N, Ca and Na in the in water at different points along the stream.

Table 6: Means of the water properties along the river stream, P-value, ls d and CV

	POINT ALONG STREAM					
	LOWER	**MIDDLE**	**UPPER**	**p-Value**	**LSD**	**CV (%)**
p^H	7.4	6.833	7.343	<0.001	0.1561	1
N (mg/l)	3.36	2.33	2.8	0.793	4.07	63.4
P (mg/l)	0	4.01	0	0.006	1.857	61.3
K (mg/l)	0.2933	0.3067	0.2667	0.049	0.03023	4.6
Ca (mg/l)	11.47	15.07	11.73	0.337	6.546	22.6
Na (mg/l)	0.547	0.573	0.533	0.769	0.1511	12.1
BOD (mg/l)	37.7	54	16.7	0.006	15.34	18.7
COD(mg/l)	32.7	43	12.7	0.033	20.16	30.2

Results from the laboratory analyses

lsd - least significant difference at 5%

Overall, the middle stream parameters were higher than the upper stream and lower stream parameters. From (Table 6), the p^H of the water was significantly higher at the lower point of the stream (7.4) compared to the middle (6.833) and the upper stream (7.343). Phosphorus was only found significantly available in water in the middle points (4.01) mg/l along the stream while other points of the stream, the level of P was very small.

Table 7: Different agricultural in puts

		Frequency	Percent	Valid Percent	Cumulative Percent (%)
Valid	Fertilizers	6	40.0	40.0	40.0
	Fungicides	2	13.3	13.3	53.3
	Insecticides	2	13.3	13.3	66.7
	None	5	33.3	33.3	100.0
	Total	15	100.0	100.0	

Results from local participants

Table 8: Effects of different human activities on River Mpanga.

		Frequency	Percent	Valid Percent	Cumulative Percent (%)
Valid	Soil erosion	2	13.3	13.3	13.3
	Water contamination	2	13.3	13.3	26.7
	Siltation	3	20.0	20.0	46.7
	Water pollution	4	26.7	26.7	73.3
	None	1	6.7	6.7	80.0
	Water pollution and Siltation	3	20.0	20.0	100.0
	Total	15	100.0	100.0	

Results from local participants

4.1.3 The level of awareness on policies and legislations on the river ecosystem conservation among the communities within River Mpanga catchment.

Table 9: Levels of awareness on laws concerning Natural resource management.

		Frequency	Percent	Valid Percent	Cumulative Percent (%)
Valid	Yes	6	40.0	40.0	40.0
	No	9	60.0	60.0	100.0
	Total	15	100.0	100.0	

Results from local participants

Table 10: Level of awareness in the community on laws governing natural resource management.

		Frequency	Percent	Valid Percent	Cumulative Percent (%)
Valid	Yes	3	60.0	60.0	60.0
	No	2	40.0	40.0	100.0
	Total	5	100.0	100.0	

Results from key informants

Table 11: Major problems that are on River Mpanga.

		Frequency	Percent	Valid Percent	Cumulative Percent (%)
Valid	Water color change	1	20.0	20.0	20.0
	Breeding places for mosquitoes	1	20.0	20.0	40.0
	River meanders are not seen	1	20.0	20.0	60.0
	Water pollution	2	40.0	40.0	100.0
	Total	5	100.0	100.0	

Results from key informants

Table 12: Suggestions and recommendations for stopping the problems.

		Frequency	Percent	Valid Percent	Cumulative Percent (%)
Valid	Public sensitization	1	20.0	20.0	20.0
	Strictness on the community, public sensitization and employ overseers	2	40.0	40.0	60.0
	Employ overseers, strictness on the community and cleanliness around the river	2	40.0	40.0	100.0
	Total	5	100.0	100.0	

Results from key informants

4.2 Discussion

4.2.1 Human activities and their effects on the water quality

4.2.1.1 Crop growing

From the research i found out that thirty three point three percent (33.3%) of the residents carry out crop growing and animal grazing near the river (Table 4), of these almost 66.7% shown in (Table 7) use fertilizers, pesticides and fungicides. According to Atwongyeire *et al*., (2018) constant use of fertilizers and other chemicals can increase the percentage of nutrients including Nitrogen and Phosphorous and this leading to Eutrophication. This can be seen in (Table 6) where the nitrogen levels were high in all the points on the river i.e. almost the same ($p > 0.05$). There are intensive farming systems within the Mpanga catchment; for example, in Kazingo and Kitchwamba communities have cultivated a lot of food crops like Irish, Banana, and Maize etc. on the river banks which results into siltation of the water when carrying out tillage practices. There was a lot of Nursery beds of trees (eucalyptus) established along river Mpanga around the areas of Mpanga Market, and Fortportal - Kamwenge road where by people use water from the river to irrigate their nurseries which results into reduction of water levels. In Fortportal, the major cash crop grown is tea which is seen covering the extensive land area before you enter Fortportal city on Kampala –Fortportal highway. According to Squire,G.R.,& Callander, B.A.(1981), tea production is an important economic activity in East Africa as it accounts for almost 10% of the countries' employment. Like most Croplands, Tea plantations are rain fed, putting them at risk from drought. According to Hirono *et al*. (2009), irrigation infrastructure is to be developed in the future; Tea factories at present use ground water for processing and machine maintenance in times of rain water scarcity. Waste water from the factory is treated in a chain of waste stabilization ponds before it is discharged into the soil. According to a factory director (undisclosed), growing tea no fertilizers or pesticides are used, but herbicides are applied a year round on a three monthly basis. The National Environmental Act.153 stipulates that river banks and lake shores must be surrounded by a natural protection zone in which no human activities are tolerated (unless permission is granted) within a zone of 30m.However, this regulation is not always respected. The absence of a protection zone at the boarder of the tea plantation could thus result into the herbicide affecting the local bank or water quality if it is washed into the rivers, which in a long run result into water pollution.

4.2.1.2 Animal grazing and disposal of wastes.

River Mpanga has a lot of animals especially cows drinking from it. This does not only put the animals at the risk of contracting various diseases from contaminated water but also put the river water at higher risks of being contaminated by animals who defecate in it, silting of the water by animals. Downstream of Mpanga market the river receives additional sewage and wastes from the market and latrines are located directly on the banks of the river and from the extremely polluted side stream Nyakimya. In Fortportal town, car washing bays have been established 20 meters away from the river banks and residual oils from vehicles seep into the river water hence polluting the river water. Nyakimya stream a bigger tributary to river Mpanga has experienced a lot of pollution from the various washing bays which pollute the water through disposing off water containing detergents used for washing cars. Fortportal is among the clean towns in the country; however in some places for example Mugunu stream a tributary to river Mpanga there is a lot of discharge of wastes, and waste water alongside walks which results into pollution of the water especially in rainy seasons when these wastes are washed away into the river by the runoff.

4.2.1.3 Human Settlements

According to (Table 4), 6.7% of the respondents have settlements on the River Banks. The area under study is within Fortportal city, and hence the settlements are both nuclear and linear because the catchment is situated within the city, The more the population in the city goes high, the higher the settlements and increased pressure on the river resource since waste disposal become high from different residential and commercial settlements within the town. This has greatly contributed to the increased pollution of river Mpanga.

There are various institutions situated in Fortportal city which greatly contribute to river Mpanga pollution; they include schools, hospitals, army barracks, factories, markets etc.

All kinds of wastes collected from these institutions inform of polythene, plastics, sewage, water from laundry are deposited into river Mpanga which has greatly contributed to its pollution. This was observed along Mugunu stream which is near Fortportal Senior Secondary School with a lot of wastes in form of plastics and polythene observed on the water surface.

4.2.2 Effect of the activities on nutrient composition and water quality of the river

Majority of the respondents indicated by four participants (26.7 %) said that these human activities carried out around river Mpanga cause water pollution and the least number of respondents indicated one participant (6.7 %) are un aware of effects that are caused by human activities on river Mpanga. A lot of pollution on river Mpanga is caused by people throwing garbage in the river, plastics, people bathing from the river and many others. (Table 8)

4.2.2.1 Nitrogen

Nitrogen majorly comes from agricultural activities carried out near river banks because of increased use of nitrogenous fertilizers like Urea (table 7). From this study, (Table 6) shows that there is no significant difference between Nitrogen levels across the river ($p > 0.05$). This shows that most of the agricultural activities are carried along the river banks. These results are in line with Songa *et al.* (2015) who concluded that the high nitrogen levels in rivers are the major cause of Eutrophication and therefore the major cause of increased biological oxygen demand.

Levels of nitrogen were mainly high in the middle point of the river with 0.3067mg, followed by lower (0.2933mg) and upper (0.2667mg) (Table 2). This can be explained by Ntale (2012) who emphasized that nutrients are washed from upstream to downstream and effects of pollution are mainly field by individuals on the downstream of most rivers and streams.

According to Brian (2009) high nitrogen levels may lead to water pollution, siltation and death of aquatic organisms (Table 8). He further explains that the primary hazard from drinking water with nitrate-nitrogen occurs when nitrate is transformed into nitrite in the digestive system. The nitrite oxidizes the iron in the hemoglobin of the red blood cells to form methemoglobin, which lacks the oxygen –carrying ability of hemoglobin. This creates the condition known as methemoglobinemia (sometimes referred to as ‘blue baby syndrome’) in which blood lacks the ability to carry sufficient oxygen to the individual body cells causing the veins and skin to appear blue.

4.2.2.2 Phosphates, Potassium, Calcium and Sodium

According to (Table 6) the Phosphate concentration (mg/l) in the different points of the river is significantly different ($p<0.05$) i.e. the middle point has a lot of phosphate content compared to the other points with no phosphate content. The same applies to the levels of Potassium, calcium and sodium. This is supported by the high levels of BOD and COD in the area compared to other areas on the river.

According to Golterman (1973), phosphates far formed from natural processes like decaying of dead plants and animals, partially treated and untreated sewage, runoff from agricultural sites and application of some lawn fertilizers. (Table 6) shows more phosphates in the middle point being the most industrial area. He further added that high levels phosphates can stimulate the growth of plankton and aquatic plants which provide food for large organisms; this may lead to over production of the lake which would latter lead to fluctuation in water quality, siltation (Table 8) and trophic status and in some cases period blooms of cyanobacteria.

According to Schneider (2011), high calcium levels in the river of over 15mg/l could be due to erosion of lime into the water bodies, it is also present in cement and concrete all which could have come from the constructions near the rivers. He further stresses that high calcium levels increase hardness in water and may influence aquatic organisms concerning metal toxicity. In soft water compared to hard water membrane permeability in gills is increased. Hardness also makes water inefficient for domestic use e.g. washing cloth (it wastes soap).

Potassium is mainly applied in glass production, fluid soap production and medicine and applied in photography or tanning. In most cases Potassium is not an active ingredient but rather the adjacent anion. potassium mainly does not play a vital role in pollution but high levels can lead accumulation of Potassium Cyanide with may be toxic to plant (Golterman, 1973). From (Table 6) the level of potassium is below the toxic level (10-12.0mg).

According to (Table 6) sodium levels at different points on the rivers is not significantly different ($p>0.05$). Sodium is attributed water hazard class 2; in other words, it is a risk when present in water. Sodium chloride however is not a risk and is attributed water hazard class 1 as it is not a risk. But high levels of sodium may be a danger to farmers using the water for irrigation as it may cause salination and may be so costly to restore these soils (Morrison *et al.*, 2001).

4.2.2.3 p^H

From (Table 6), the p^H of the water was significantly higher at the lower point of the stream (7.4) compared to the middle (6.833) and the upper stream (7.343). These are in line with Morrison *et al.* (2001) results who suggested that low p^H in rivers is as a result of high industrialization and excessive use of agricultural chemicals. He further stressed that low p^H could be very dangerous to aquatic organisms as p^H can affect the solubility of chemicals and heavy metals in water. The majority of aquatic creatures prefer a p^H range of 6.5-9.0, while sensitive ones such as salmon prefer between7.0-8.0, However as p^H moves away from this range it can stress animal systems and reduce hatching and survival rates (Morrison *et al.*, 2001). This shows that as p^H continues to decrease in any area, a lot of animal species, including fish can be lost.

4.2.2.4 Biological Oxygen Demand (BOD)

Biological Oxygen Demand is the amount of dissolved oxygen used by micro-organisms in the biological process of metabolizing organic matter in water. The more organic matter there is (e.g. in sewage and polluted bodies of water), the greater the BOD; and the greater the BOD, the lower the amount of dissolved oxygen available for higher animals such as fishes (Kim *et al.* 2003). The BOD is therefore a reliable gauge of organic pollution of a body of water. According to (Table 6), there is a significant difference in the BOD present at different point on the river ($p < 0.05$). According to Zhanga (2004), a BOD level of 1-2ppm is considered normal, as there will not be much organic waste present in the water supply. A water supply with a BOD of 3-5 ppm is considered moderately clean while water with a BOD level of 6-9ppm, the water is considered somewhat polluted because there is usually organic matter present and bacteria are decomposing this waste. At a BOD levels of 100ppm or greater, the water supply is considered very polluted with organic waste.

Therefore, from (Table 6) all the points on the river have relatively high BOD with the highest being the middle point with (54mg/l which is the same as 54ppm). This shows that the water is very polluted. The lower point had 37.7 mg/l and the upper 16.7; this signifies that all water tested was polluted with organic water. This could have been caused by poor sewage disposal, constant fertilizer use, brickmaking etc. (Table 8).

Generally, when BOD levels are high, there is a decline in dissolved oxygen levels. This is because the demand for oxygen by bacteria is high and they are taking that oxygen dissolved in water. If there is no organic waste present in the water, there won't be as many bacteria

present to decompose it and thus the BOD will tend to lower and the dissolved oxygen will tend to be higher (Atwebembeire *et al.,* 2018*).*

According to Jouanneau *et al.* (2014), at high BOD levels organisms that are more tolerant of lower dissolved oxygen (i.e. leeches and sludge worms) may appear and become numerous. Organisms that need higher oxygen levels (i.e. caddisfly larvae and mayfly nymphs) will not survive.

4.2.2.5 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand is the measure of the capacity of water to consume oxygen during the decomposition of organic matter and oxidation of inorganic chemicals such as ammonia and nitrites (Hur *et al*., 2010). He further states that high COD levels mean a greater amount of oxidizable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in Dissolved Oxygen (DO) can lead to anaerobic conditions, which is deleterious to higher aquatic life forms.

In (Table 6) it is shown that there is a significant difference in the levels of COD in the different points on the river with the middle point (43mg/l), lower end (32.7mg/l and the upper end (12.7). According to the standards of Central Pollution Control Board, permissible value of COD depends on water the water is being used for but generally it should be less than 60mg/l but Abdallah, K.Z, & Hamman (2014). Emphasises that there should be zero COD levels, as all the oxygen present in water it is very important for aquatic life. The high results of COD in the middle area could have been as a result of the washing bays and tea factories present near the river which enrich the waters with a lot of chemicals.

4.2.3 Levels of awareness on policies and legislations

According to (Tables 9 and 10), 60% and 40% respectively of respondents are not aware of any policies and legislations concerning natural resource management this has increased the higher rate of river pollution since people have little or no knowledge at all on how to conserve these natural resources and they end up dumping wastes, pouring waste water in the river, and other activities which may pollute the river in the due course

In (Table 2) 6.7% of respondents are not educated at all, 13.3% primary level, 60% secondary and only 20% in University. This shows that most people in the area are educated though there are some who need more sensitization on how to use the river.

Table 5 shows that the majority (40%) of people in the area who involve themselves in activities around the catchment area, are between the ages of 26-30. This is the age were people are very active and wanting to provide for their family so they end up occupying the river banks which have many opportunities. High population growth will later pollute the river. This is enhanced by the majority of occupants being men (Table 3) who have the working power to engage in any activity as long as the get income not concerned on the outcomes.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The analysed data from water samples and social economic factors reveal that,

1. The major human activities carried out along river Mpanga are crop growing, animal grazing, waste disposal, settlement, brick laying, infrastructure development etc. all these have directly and indirectly caused the increased water pollution of water in river Mpanga due to the increased pressure these activities put on the river ecosystem.

2. In the study area, different factors contribute to the Chemical, Biological and Physical quality of water in river Mpanga in Fortportal city. The main issue is increased waste disposal from market, schools, hospitals into the river and increased agricultural practices like crop growing, animal rearing, and tree nursery beds and other economics activities like brick making, road construction, settlements that have increased the rate of pollution on river Mpanga. If these practices are not managed in a sustainable way, they are likely to lead to further deterioration not only of the chemical and physical but also the biological integrity of the river.

3. From the study it was observed that the highest percentage of individuals who live and work within the catchment of river Mpanga are unaware of policies and legislations concerning the conservation of natural resources like rivers. This has greatly contributed to the increased pollution of river Mpanga since people just use the river anyhow without conserving for the future.

5.2 RECOMMENDATIONS:

- ✓ The government should work hand in hand with Authorities responsible for natural resource management for example NEMA to sensitize the public about the issues concerning natural resource management and conservation, values, uses and guidelines of rivers. This will help to create awareness about policies and legislations among the communities within river catchments.

- ✓ The key informants and other individuals who have enough knowledge about the dangers or impacts of different activities along the river should make it their

responsibility to teach other people who are not aware about these effects .This will help in reducing on increased water quality pollution for the betterment of the environment, Fortportal city and the country at large.

- ✓ In the city the major source of pollution including the discharge of sewage and other waste waters must be addressed to prevent the resilience and recovery capacity of Mpanga's ecosystem to get impaired downstream

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APPENDICES

Appendix 1 (Questionnaire for local participants)

MAKERERE UNIVERSITY SCHOOL OF AGRICULTURAL SCIENCES,

DEPARTMENT OF AGRICULTURAL PRODUCTION

Good morning/Afternoon/Evening sir,

Mr. /Mrs./ Fr/Dr……..

TOPIC; INVESTIGATING THE MAJOR ACTIVITIES CARRIED OUT ALONG RIVER MPANGA AND THEIR EFFECTS ON THE RIVER. BY AMANYIRE STELLA 14/U/4959/PS

Dear respondent,

I am Amanyire Stella, a student of Makerere University pursuing a Bachelor's of science in Agricultural Land use and Management. With regards to the above mentioned subject, I humbly request you to participate in this study. The questionnaire has been designed to assess the economic activities carried out within the Mpanga catchment and the effects of these activities to the river. All information collected from you will be kept confidential and will only be used for academic purposes. Your participation in this study is highly appreciated as it will enable me to complete the partial fulfilment for the award of Bachelors of Science in Agricultural Land Use and Management.

PLEASE PROVIDE THE INFORMATION BELOW

1. What is your sex?

a. Male b. Female

2. What is your age group in terms of years?

a) Below 20 b) 20-25 c) 25-30 d) 30-35

e) 35-40 f) 40-45 g) 45 and above

3. Highlight on your marital status.

a) Single b) Married c) Widowed d) divorced

4. How many members make up your family (household?)

a) Less than 3 b) 3-5 c) 5-10 d) 10-15 e) More than 15

5. What are your highest academic qualifications?

a) None b) Primary level c) Secondary level d) University level

6. Which land tenure system is applied on your land?

a) Tenant (rent) b) Kibanja c) Mailo land d) Freehold e) Lease f) Customary

g) Others (specify)…….

7. What is the approximate size of the land described above?

a) Less than ¼ an acre b) Between ¼ to ½ an acre c) Between ½ to 1 acre.

d) Between 1- 2 acres e) Between 2-5 acres f) More than 5 acres.

8. What are the major activities carried out around River Mpanga?

a) Crop growing

b) Brick laying

c) Animal grazing

d) Settlement

e) Sand mining

f) Disposal of wastes from washing bays, wastes from market.

g) Others (specify),……

9. Why do you think people carry out these activities on this river?

……
……
……
……..

10. You as an individual do you carry out any activity around river Mpanga?

a) Yes b) No

11. If yes, which ones do you carry out?

a. Brick lying

b. Crop growing

c. Animal grazing

d. Settlement

e. Waste disposal

f. Other, (specify)…….

12. If crop growing which crops do you grow,

…….

…….

13. Are there any soil and water management practices you apply on your tenure system?

If yes which ones

……
……..

14. Which of the following agricultural inputs do you use,

a) Fertilizers

b) Herbicides

c) Fungicides

d) Insecticides

e) Other, (specify)…….

15. How do you think these activities affect the river?

……
……

16. Are there conservation measures you practice on your land to conserve the river?

……
……
……

17. What is the approximate distance from the river bank to your garden?

a) 0-5meters b) Between 5-10meters c) Between 10-15 d) More than 15meters

18. Do you use water from the river in your crop growing practices?

a) For irrigation

b) Spraying inputs

c) Construction of farm crop stores

19. which animals do you have

a) Goats b) Cattle c) Sheep d) Chicken e) Others (specify)…….

20. How many per category

a) Goats ……. b) Cattle……. c) Sheep….. d) Chicken……. e) Others ……

21. Using your experience what are the major threats imposed on the river by individuals who carry out economic activities on the river?

……
……
……
……
……..

22. Are you aware of any laws (land use and water management policies)concerning natural resource management?

a) Yes b) No

If yes from where,

……
……

23. The laws where about what/?

a) Digging near the river

b) All activities carried out near the water body should be 100meters away

c) Others (specify)….

24. Do you think individuals follow or put in practice of these laws while using these natural resources?

a) Yes b) No

25. What are two major problems you encounter regarding the rivers existence?

……
……

26. How does the surrounding community contribute to the quality and pollution of River Mpanga?

……
……
……

27. Is NEMA doing a good work towards natural resource management?

a) YES b) NO

Please give a reason to your answer

……
……..

28. What are the roles played by the local leaders regarding river conservation in the area.

a) Sensitizing the community about the safe use of natural resources like rivers

b) Punishing law breakers

c) Putting extra laws that govern the use of water bodies..

d) Others (specify)……

29. Any recommendations you would like to give concerning Mpanga river management?

……
……
……
……

30. Please rank your opinion in the question below (A. Strongly agree B. Agree C. Disagree

D. strongly disagree)

a) The bylaws on natural resource management are not well known by the community……

b) The few people who know and understand these laws don't follow and respect them……

c) Most cultural practices have less effect on river pollution……

Questionnaire for key informants

MAKERERE UNIVERSITY SCHOOL OF AGRICULTURAL SCIENCES,

DEPARTMENT OF AGRICULTURAL PRODUCTION

Good morning/Afternoon/Evening sir,

Mr. /Mrs./ Fr/Dr……..

TOPIC; INVESTIGATING THE MAJOR ACTIVITIES CARRIED OUT ALONG RIVER MPANGA AND THEIR EFFECTS ON THE RIVER. BY AMANYIRE STELLA 14/U/4959/PS

Dear respondent,

I am Amanyire Stella, a student of Makerere University pursuing a Bachelor's of science in Agricultural Land use and Management. With regards to the above mentioned subject, I humbly request you to participate in this study. The questionnaire has been designed to assess the economic activities carried out within the Mpanga catchment and the effects of these activities to the river. All information collected from you will be kept confidential and will only be used for academic purposes. Your participation in this study is highly appreciated as it will enable me to complete the partial fulfilment for the award of Bachelors of Science in Agricultural Land Use and Management.

Title……..

1. What are the major activities carried out by the community within the Mpanga catchment?

……
……
……

2. How do you think these activities affect the water quality of the river?

……
……
……..

3. Is the community within the Mpanga Catchment aware of any Laws, policies and legislations concerning the river ecosystem on how to conserve and manage it?

a) Yes b) No

4. Do you think there is a problem on river Mpanga?

If yes which one,

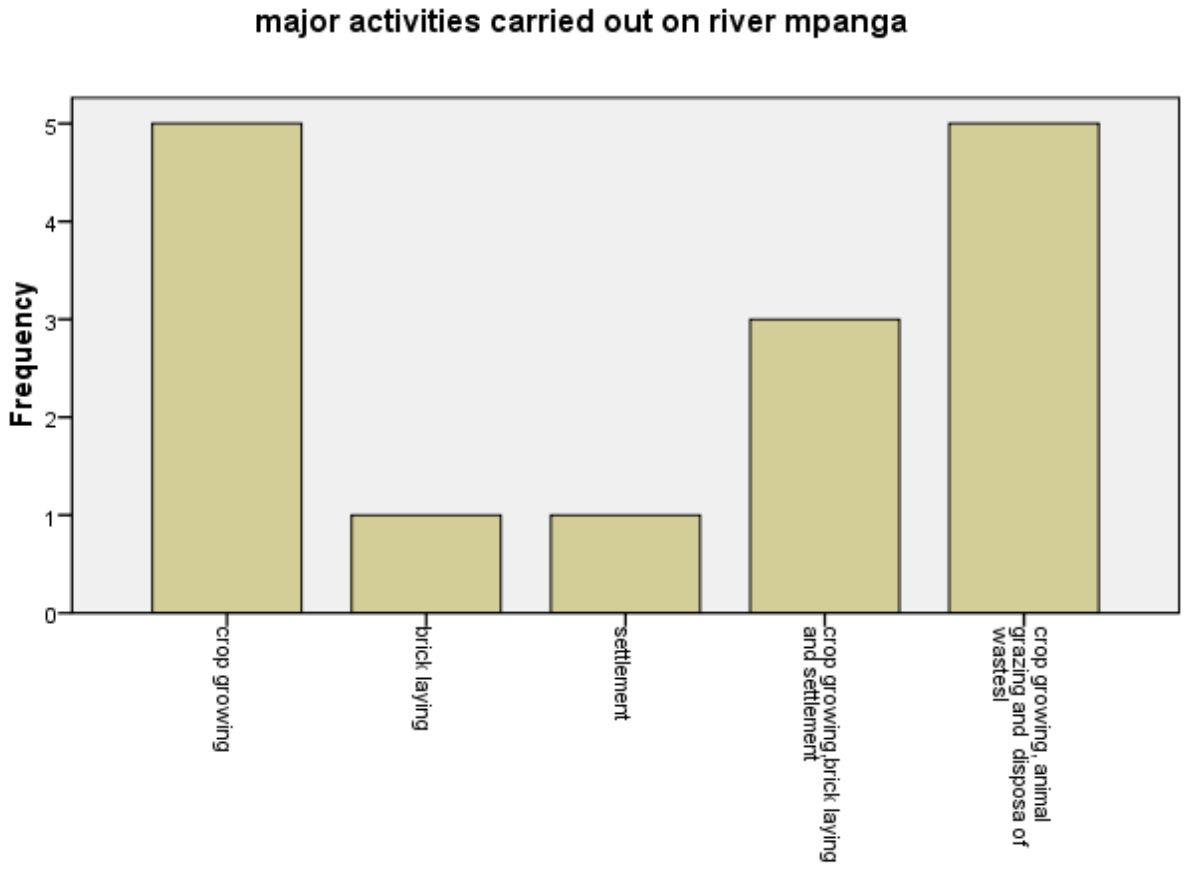
……
……
……..

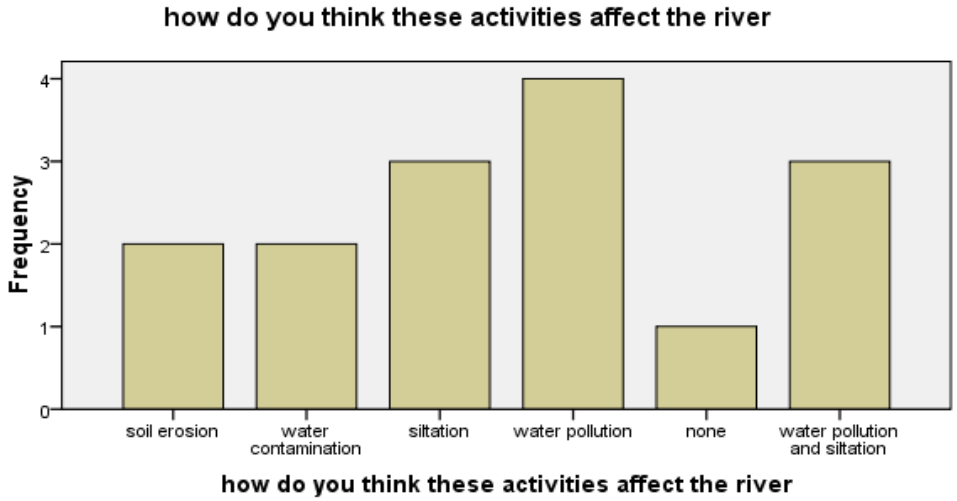
5.Give any suggestions and recommendations for stopping these problems.

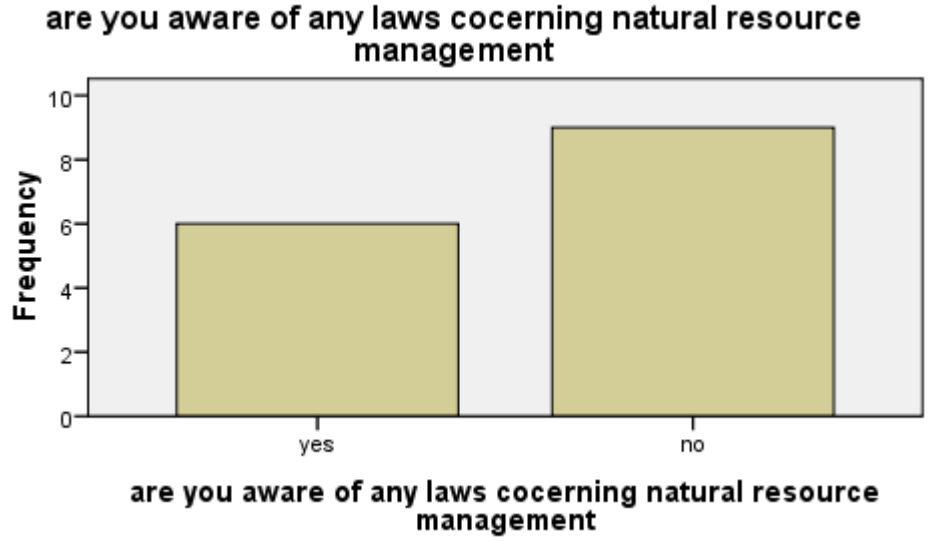
……
……
……
…….

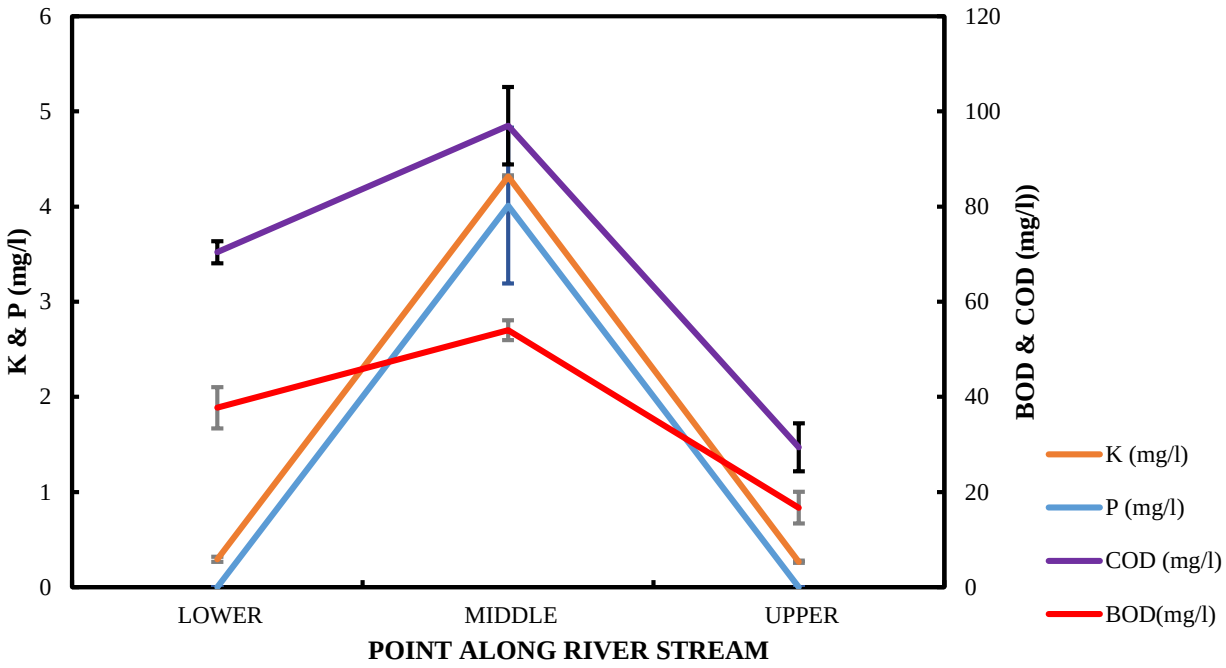
THANKYOU

APPENDIX 2: (graphs and figures)




how do you think these activities affect the river
Frequency
4
3
2
1
0
soil erosion
water contamination
siltation
water pollution
none
water pollution and siltation
how do you think these activities affect the river


are you aware of any laws cocerning natural resource management
Frequency
10
8
6
4
2
0
yes
no
are you aware of any laws cocerning natural resource management



	POINT ALONG STREAM					
	LOWER	**MIDDLE**	**UPPER**	**P-Value**	**LSD**	**CV**
p^H	7.4	6.833	7.343	<0.001	0.1561	1
N (mg/l)	3.36	2.33	2.8	0.793	4.07	63.4
P (mg/l)	0	4.01	0	0.006	1.857	61.3
K (mg/l)	0.2933	0.3067	0.2667	0.049	0.03023	4.6
Ca (mg/l)	11.47	15.07	11.73	0.337	6.546	22.6
Na (mg/l)	0.547	0.573	0.533	0.769	0.1511	12.1
BOD (mg/l)	37.7	54	16.7	0.006	15.34	18.7
COD(mg/l)	32.7	43	12.7	0.033	20.16	30.2

Analysis of variance

Variate: Na_mg_l

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.004622	0.002311	0.52	
REP.*Units* stratum					
SAMPLE_POINT	2	0.002489	0.001244	0.28	0.769
Residual	4	0.017778	0.004444		
Total	8	0.024889			

Tables of means

Variate: Na_mg_l

Grand mean 0.551

SAMPLE_POINT	LOWER	MIDDLE	UPPER
	0.547	0.573	0.533

Analysis of variance

Variate: Ca_mg_l

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	9.209	4.604	0.55	
REP.*Units* stratum					
SAMPLE_POINT	2	24.142	12.071	1.45	0.337
Residual	4	33.351	8.338		
Total	8	66.702			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Ca_mg_l

Grand mean 12.76

SAMPLE_POINT	LOWER	MIDDLE	UPPER
	11.47	15.07	11.73

Analysis of variance

Variate: K_mg_l

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.005689	0.002844	16	
REP.*Units* stratum					
SAMPLE_POINT	2	0.002489	0.001244	7	0.049
Residual	4	0.000711	0.000178		
Total	8	0.008889			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: K_mg_l

Grand mean 0.2889

SAMPLE_POINT	LOWER	MIDDLE	UPPER
	0.2933	0.3067	0.2667

Analysis of variance

Variate: P_mg_l

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1.3422	0.6711	1	
REP.*Units* stratum					
SAMPLE_POINT	2	32.1641	16.0821	23.96	0.006
Residual	4	2.6845	0.6711		
Total	8	36.1909			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: P_mg_l

Grand mean 1.34

SAMPLE_POINT	LOWER	MIDDLE	UPPER
	0	4.01	0

Analysis of variance

Variate: N2_mg_l

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	3.153	1.577	0.49	
REP.*Units* stratum					
SAMPLE_POINT	2	1.585	0.793	0.25	0.793
Residual	4	12.892	3.223		
Total	8	17.631			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: N2_mg_l

Grand mean 2.83

SAMPLE_POINT	LOWER	MIDDLE	UPPER
	3.36	2.33	2.8

Stratum standard errors and coefficients of variation

Variate: pH

Stratum	d.f.	s.e.	cv%
REP	2	0.025	0.3
REP.*Units*	4	0.0689	1

75 SET [IN=*]

SAMPLE POINT	REP	pH	EC (us/cm)	K (mg/l)	Na (mg/l)	Ca (mg/l)	P (mg/l)	N2 (mg/l)	BOD (mg/l)	COD (mg/l)
UPPER	1	7.35	428	0.24	0.56	12	0	5.32	20	3
UPPER	2	7.36	426	0.28	0.52	8	0	0.84	10	15
UPPER	3	7.32	383	0.28	0.52	15.2	0	2.24	20	20
MIDDLE	1	6.8	446	0.28	0.56	18	5.57629	3.36	55	30
MIDDLE	2	6.8	442	0.32	0.56	14	2.810099	2.8	50	58
MIDDLE	3	6.9	441	0.32	0.6	13.2	3.644347	0.84	57	41
LOWER	1	7.5	447	0.24	0.44	10	0	2.24	30	35
LOWER	2	7.34	444	0.32	0.64	12	0	4.2	45	35
LOWER	3	7.36	443	0.32	0.56	12.4	0	3.64	38	28

APPENDIX 3(*FIELD PHOTOS)*

Crop growing within Mpanga catchment

Waste disposal along the River banks

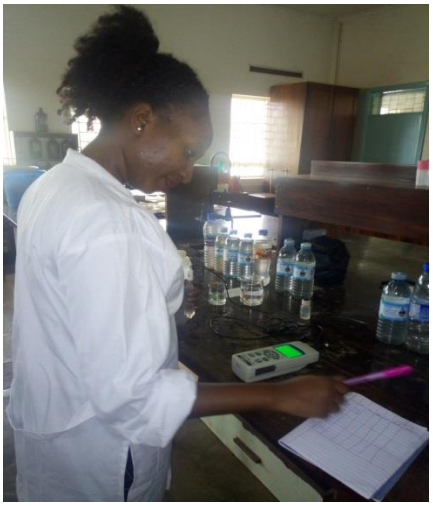
Narrow buffer zone between a tea plantation and river Mpanga

Settlements in form of buildings along Mpanga river

Individuals wash their vehicles and bathe from the river

Water sample collection from one of the selected points along the river

Water samples collected from the river



Determination of p^H and EC using p^H and EC meter

Testing phosphorous using Spectrophometer model 6405uv/VI's

Testing for Nitrogen using kjedahl Distillation Method

Water samples assembled for Nitrogen testing

One of the key informants (lecturer at MMU) filling the questionnaire