LEVEL OF POLLUTION OF WATER FROM RIVER RWABAKAZI INDICATED BY METAL IONS AND *SUSPENDED* SOLIDS CONCENTRATIONS

BY

HABIMANA MICHAEL

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DEDICATION

I dedicate this research project report to my beloved parents Mr. Ruhiza David and Mrs. Ahobantegeye Oliva, brothers, and sisters. Special thanks go to SESEME CDC Team for the support through finance, encouragement, and morals. May God bless you so much.

DECLARATION

I, **HABIMANA MICHAEL** hereby declare that this research project report is my original work with exceptions from literature review and quotations. I strongly affirm that it has never been submitted to any institution of higher learning for any academic award and is entire I у mine.

Signature .. ∼.

(Student)

3. **Date:23/01/21**

4.

APPROVAL

This is to certify that this research was carried out by **HABIMANA** MICHAEL on the topic .. Level of pollution of water from river Rwabakazi indicated by metal ions and suspended solids concentrations" under my supervision.

cl

Sign .... ⟨signature⟩

Dr. **Mukasa-Tebandeke** 1.Z.

Date:23/01/21

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ACKNOWLEDGEMENT

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LIST OF ACRONOMYS

TSS   Total suspended solids

$Ca^{2}+$ Calcium ions

$Fe^{2"}$ Iron (II) ions

Me   Magnesium ions

WHO   World Health Organization

EDTA   Ethylenediaminetetraacetic acid

$H.O$ Water

$Mn^{2}+$ Manganese (II) ions

$MnO;$ Manganate (VII) ions

ABSTRACT

Pollution resulting from increased anthropogenic activities is affecting river Rwabakazi. Its effects are reflected by high concentrations of calcium, iron (II). iron (111), magnesium and total suspended solids (TSS). In this study. we report the selected physicochemical parameters of waters of Rwabakazi River and how they varied in the selected study area in kabale district. Globally. 2.l billion people lack access to safely managed drinking water services (WHO/UNICEF. 20I7). Uganda is confronted with over IO million people lacking access to safe drinking water (Ojore, 2019), Kabale Municipality inclusive. The study performed in Kabale university involved titration to determine iron (11), lron (Ill), calcium and magnesium ions; and filtration in determining the amount of suspended solids. The results obtained for the samples showed high concentrations of calcium, magnesium, iron (II), and iron (Ill) ions and suspended solids as a result of pollution. The concentrations decreased downstream as follows; iron (II) from 60.04 to 54.40 mg/L; iron (Ill) from 19.50 to 16.50 mg/L; calcium from 99.00 to 68.00 mg/L; magnesium from 7 .20 to 6.00 mg/L and TSS from 15.6 to 10.5 mg/Lall of which exceeded the allowed limits by EPA and WHO guidelines for safe water for human use. The available data can be relied on to assert that river Rwabakazi is polluted as a result of erosion and flush flooding but has capacity to undergo natural self-purification although very slowly. Further studies on nutrient and pesticide pollution of this river should be carried out and trees should be planted on slopes of open surfaces to minimize erosion.

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1.1 Background

Water covers almost 70% of the earth's surface (Frederick. 1995). The quantity and quality ol water are equally important. Water is always referred to as a universal solvent because it can dissolve many types of substances. Humans require water that contains fewer impurities (Garba et al., 2012). The major categories of impurities in water are micro-organism, pyrogens, dissolved inorganic salts, dissolved organic compounds, suspended particles and dissolved gasses. Common impurities in water include metal salts and harmful bacteria. However, in most cases natural waters are not directly drunk by human. It has to go through some treatment to attain safe drinking

standard (Nalatambi, 2009).

World population cannot be sustained without access to safe water (Braunstein, 2007). It is therefore important to conjunetly consider both water quality and quantity in water resources management (Zhang et al.. 2009). Ground water or borehole water becomes unsuitable for domestic use as a resource due to contamination that makes it unfit (Chow et al.. 2007). Standards and guidelines in water quality stem from the need to protect human health (Minh et al.. 20l). Contamination of water has increasingly become an issue of serious environmental concern after years of pollution (Akpoveta et al., 20 l l; Silderberge, 2003). Natural water contains many contaminants such as bacteria, viruses, heavy metals, nitrates and salts; and they have also polluted water supplies due to inadequate treatment and disposal of wastes from humans and livestock, industrial discharges and over use of limited water resources (Singh and Mosley, 2003). The World Health Organization (WHO) recommends the minimum daily per capita water consumption to be 27 liters/person/day. However, many people manage with far less than 27 liters (Fraceys et al., 1991). This results because approximately 70% of the renewable water resources are unavailable for human use or under developed or unevenly distributed (Minh et al., 2011; Gleick, 1993). Drought, desertification and other forms of water scarcity are already estimated to affect as many as one third of the world's population, affecting consumption and migration patterns in many parts

of the world (Talafre and Knabe, 2009).

Currently, it is crucial to understand the components of substances as common as water because they are vital part of life and arc commonly used to drink and cleanse. A common method of evaluating water sample is by testing the water hardness.

Water is said to be hard when there is a substantial concentration of magnesium and calcium ions (Sengupta, 2013). Hardness is one of the common water quality problems throughout the world. Hard water is found at a rate exceeding 85%, as water picks up minerals such as magnesium and

calcium ions from rocks and soil, leading to the hardness. Ground water contains more minerals than surface water, so it is harder than surface water. Knowing the hardness of a water source is important when evaluating its use as a domestic or industrial water supply (Ahn et al.. 2018).

Although hard water is assumed to have no negative health effects. there seems to be a correlation between the hardness of water and various health issues. For example, harder water samples seemed to correlate with the appearance of atomic dermatitis in Danish children (Engebretsen et al.. 2016).

Furthermore, hard water has also been correlated with Alzheimer's disease and cardiovascular disease in certain studies. However, these studies do not claim that the hardness of water affects the healthy directly, but rather the salts dissolved in the water. Similarly, the studies also acknowledged that correlation could not imply causation due to the various uncontrollable variables associated with the subject (Sengupta, 2013). In addition, water hardness impacts ecological and economical concerns. Ecologically, water hardness impacts fish cultures as well as many other species that rely on a steady calcium carbonate concentration. Hard water in the municipal water supply also raises economic issues as a considerable amount of money is spent yearly to ensure that water is softened (minerals arc removed) to avoid its negative impacts such as degrading soaps and precipitate deposition on faucets (Aragaw and Ayalew. 2019).

Iron is the second most abundant metal in the earth's crust (Nordberg et al.. 2014). Elemental iron is rarely found in nature. as the iron ions (Fe- and Fe") readily combine with oxygen and sulfur containing compounds to form oxides, hydroxides. carbonates, and sulfides. Dissolved iron more commonly exists in the form of its oxides. To provide safe drinking water to the public, both government and private organizations measure iron content in drinking water and other tap waters in every sector including schools, hospitals, industries, (EPA, 2017).

Transport of hydrophobic organic pollutants in rivers is mainly coupled to transport of suspended particles. Turbidity measurements and filtration processes are often used to assess the amount of suspended solids in water. In a study of monitoring the total concentration of polycyclic aromatic hydrocarbons (PAHs), the amount of total suspended solids (TSS), and turbidity in Germany revealed linear correlations of turbidity and TSS (Rugner et al..2013). TSS are a major pollutant that affects waterways all over the world. Predicting the values of TSS is of interest to quality control of wastewater processing (Verma et al., 2013). Due to infrequent measurements. time series data for TSSare constructed using influent flow rate and influent carbonaceous bio-chemical ,oxygen demand (CBOD) (Verma et al.. 2013). Over the last 50 years, the effects of suspended solids (SS) on fish and aquatic life have been studied intensively throughout the world. It is now accepted that SS are an extremely important cause of water quality deterioration leading to aesthetic issues, higher costs of water treatment, a decline in the fisheries resource, and serious ecological degradation of aquatic environments. As such, government-led environmental bodies have set recommended water quality guidelines for concentrations of SS in freshwater systems (Bilotta et al., 2008).

1.2 Statement of problem

Water from river Rwabakazi 111 Kabale municipality is polluted and used for domestic and agricultural purposes without suspicion.

1.3 Objectives

1.3.1 General objective

To determine level of pollution of water from river Rwabakazi.

1.3.2 Specific objectives

To qualitatively determine the presence of calcium ions, magnesium ions, iron (II), iron **(III)** ions and suspended solids **in** samples of waters from river Rwabakazi from selected sites.

To quantitatively determine the concentration in g/1 or calcium and magnesium ions, iron **(11)** and iron **(III)** ions in samples of water from river Rwabakazi from selected sites.

1.4 Scope of the study

The research was conducted on different selected parts of river Rwabakazi ecological environment Kabale municipality. Kabale district Uganda: where by the water containing the active ingredients was taken to the laboratory for qualitative and quantitative analyses.

The study "Level of pollution of water from river Rwabakazi indicated by metal ions and suspended solids concentrations in Kabale municipality" was carried out from I st January, 2020 to June, 2020. The samples were collected on **11** February, 2020 at 8:30 AM where the samples were taken to the laboratory and kept in refrigerator to maintain their quality; and the experiments were performed on samples from 12" February up to $3^{"}$ march, 2020.

The study was conducted from Kabale District in southwestern Uganda. Kabale District lies between 01 l S'S and 30 OE. Kaba le District has a population of 498,300 people according to the 2012 national census with population density of 296.8 perkm^2. Over 75% of Kaba le district land

is used for agriculture.

1.5 Significance of the study

The study determined calcium. magnesium, Iron **(11)**, and Iron **(III)** ion concentrations and total suspended sol ids revealing the extent of pollution in waters of river R wabakazi.

CHAPTER TWO

LITERATURE REVIEW

In this chapter, information in literature on recent developments in research about water is presented in sub-sections with specific titles. The sub-sections include reviews of the presence of calcium ions, magnesium ions, iron (II) ions, iron **(III)** ions and suspended solids in water.

2.1 The presence and occurrence of calcium ions, magnesium ions, iron (II), iron (III) ions and amount of suspended solids

Dolomite and magnetite arc simple anhydrous calcium and magnesium carbonate minerals occurring mostly at Earth surfaces (Konishi et al.. 2013). Calcium is the fifth most abundant element in Earth's crust and the third most abundant metal, after iron and aluminum. The most common calcium compound on Earth is calcium carbonate. found in limestone (MacAdam& Parsons. 2004). Calcium is present in fossilized remnants of early sea life in forms of gypsum. anhydrite, fluorite, and apatite. Calcium ions enter water sources through weathering of calcium containing rocks. Rocks slowly dissolve by physical and chemical processes, carrying calcium ions into rivers, lakes and oceans. Calcium containing minerals are often more easily weathered than magnesium ion minerals so calcium ion is more enriched in water ways than magnesium ion

Berner, R.A. (2004).

The quality and quantity of chemical elements in surface water can be influenced by land relief, geochemical structure, land use, seasonal variations in weather conditions (precipitationevaporation). plant cover and atmospheric deposition (Grochow ska. Tandyrak,2009). Magnesium (Mg) and calcium (Ca') are found naturally in surface water. Also, their presence in water is often closely correlated with the type of land use in the catchment areas (Wons et al. 2012).

River-lake systems comprise chains of lakes connected by rivers and streams that flow into and out of them. The contact zone between a lake and a river can act as a barrier, where inflowing matter is accumulated and transformed (Potasznik, and Szymczyk.2015). Magnesium and calcium are natural components of surface water. and their concentrations can be shaped by various factors, mostly the geological structure of a catchment area, soil class and type, plant cover, weather conditions (precipitation-evaporation, seasonal variations), land relief, type and intensity of water supply (surface runoffs and groundwater inflows), (Grochowska, Tandyrak, 2009).

It has become more expensive in terms of soap that is needed for washing clothes. This is basically due to the presence of calcium and magnesium ions present; and suspended solids in water through the reaction with soap thus producing the scum. Soap scum or lime soap is the white solid composed of calcium stearate. magnesium stearate. and similar alkali metal derivatives of fatty

acids. These materials result from the addition of soap and other anionic surfactants to hard water. Hard water contains calcium and magnesium ions, which react with the surfactant anion to give

these metallic or lime soaps (Angelo Nora, et al.. 2005).

$$C_{17}H_{35}COO^-Na^+ + Ca^{2+} \rightarrow (C_{17}H_{35}COO)_2Ca + 2\ Na^+$$

Calcium stearate

$$C_{17}H_{35}COO^-Na^+ + Mg^{2+} \rightarrow (C_{17}H_{35}COO)_2Mg + 2\ Na^+$$
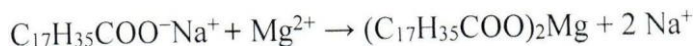
Magnesium stearate

In this reaction, the sodium cation in soap is replaced by calcium and magnesium to form calcium stearate and magnesium stearate.

Clean water and sanitation considerably lessen water-related diseases which kill thousands of children every day (UN, 2006). 1.I billion People lacked access to an enhanced water supply in 2002, and 2.3 billion people got ill from diseases caused by unhygienic water. Each year 1.8 million people die from diarrhea diseases, and 90% of these deaths are of children under five years (WHO, 2004) thus there is missing information about the pollution of water by the stated

parameters hence a need for the study.

Ground water usually has larger levels of hardness, but also some larger surface water supplies also have the same issue. Calcium concentrations up to and exceeding 100 mg/1 are common in natural sources of water, more especially ground water. Magnesium is present in natural ground water usually at lower concentrations (from negligible to about 50mg/l and rarely above I 00 mg/I), so calcium-based hardness usually predominates (National Research Council, 1977). The bio availabilities of calcium and magnesium from milk and water are on the order of 50% (Ong, Grandjean and Heaney, 2009). For the case or calcium and magnesium, the typical contribution from water is 5-20% (WHO. 1973: National Research Council. 1977: Neri and .Johansen. 1978).

Water hardness is determined by measuring the total concentration of magnesium and calcium in a water source. Water hardness is reported as the concentration of carbonates in parts per million (ppm), using calcium carbonate as a generalized concentration that encompasses all divalent cations in the sample. Magnesium and calcium concentrations (the most abundant ions in water) are used to calculate water hardness by the formula: $[CaCOs]oar-2.5[Ca] + 4.1[Mg]$.

The method called a complexometric titration is used to find the total calcium and magnesium content of milk, sea water and various solid materials. It can also be used to determine the total hardness of fresh water provided the solutions used are diluted. The combined concentration of calcium and magnesium ions is considered to be the measure or water hardness. The method uses a very large ion called EDTA' which forms a complex with calcium and magnesium ions. ED TA

is short form for ethylenediaminetetraacetic acid. *A* blue dye called Eriochrome Black T (ErioT) is used as the indicator. This blue dye also forms a complex with the calcium and magnesium ions, changing color from blue to pink in the process. The dye-metal ion complex is less stable than the ED TA metal ion complex. For the titration, the sample solution containing the calcium and magnesium ions is reacted with an excess of EDTA. The indicator is added and remains blue as all the Ca- and Mg? ions present are complexed with the EDTA. A back titration is carried out using a standard solution of magnesium chloride. This forms a complex with the excess EDTA molecules until the end-point, when all the excess EDTA has been complexed. The remaining magnesium ions of the magnesium chloride solution then start to complex with ErioT indicator. immediately changing its color from blue to pink. The main reactions are:

ca" +EDTA'[Ca-EDTA}

Back titration EDTA' + Mg'' ·[Mg-EDTAF
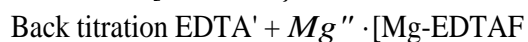
Indicator reaction: note. ErioT is blue and ErioT-Mg is pink. Eriol+ Mg" »Eriol-Mg.

2.2 Occurrence of iron

In nature, iron occurs as Fe and Fe" ions which readily combine with oxygen and sulphur containing compounds to form oxides, hydroxides, carbonates, sulphides, and dissolved iron ores (Nordberg et al., 2014). Iron enters water as a result of collosion of iron containing materials. Any water, regardless of its composition, after a certain period of contact with a clean iron surface wi 11 cause corrosion of the metal (Langelier, 1936). The clumping of domestic and industrial wastes in the water bodies is responsible for elevated levels of iron in the water (Khatri et al.. 2017).

Iron is an objectionable constituent of potable water. Presence of iron in water imparts a bitter and metallic characteristic taste and oxidized precipitate. Water containing significant qualities of iron may appear clear when drawn and change quickly upon exposure to air. This process is called oxidation and it involves the conversion of ferrous ion to ferric ion. Iron stains everything with which it comes in contact; Concentrations of 0.3 ppm of iron is often recommended and is based on preventing taste and staining problems for humans (Damron and Eldred, 2002).

Iron in the drinking water may be safe to drink, except that iron forms sediments, which together with other trace impurities may support bacteria that are harmful, and these bacteria are mostly found in wells where the water has not been chlorinated. Iron also promotes undesirable bacteria growth within a water works and distribution system because of large deposition of iron minerals on piping (EPA, 2017). So, quantification of concentration of ions of iron in water masses is
essential in finding out the level of pollution.

In the drinking water supply, iron (II) salts are unstable and are precipitated as insoluble iron (Ill) hydroxide which forms as a rust colored sediment. When water is directly pumped from the well. the water may contain iron (II) ions at concentrations or up to several milligrams per liter without

any color or turbidity. When the iron levels are more than 0.05-0.1 mg/L, turbidity and color develops in the pipe system. If the concentration is more than 0.3 mg/L, staining of laundry and water systems may be damaged (Annex, 2017). The iron concentration in rivers has been reported as 0.7 mg/L, and in groundwater which is anaerobic, iron is in the form of iron (11), with the concentration being usually 0.5-10 mg/L; and sometimes, the concentration is found as high as 50 mg/L. The concentration of iron in water should be less than 0.3 ppm (0.3 mg/L). However. it may be higher in countries where various iron salts are used as coagulating agents in water treatment plants and where cast iron. steel, and galvanized iron pipes are used for water distribution (WHO. 2003). The limit for iron is less than 0.3 ppm (0.3 mg/I.) in municipal drinking water. Although iron is only toxic at very high concentrations. it acts as a useful surrogate for other heavy metals (Annem.. 2017). Determination of iron content in water is possible. An experiment that mainly focuses on measuring iron content in tap water and determines whether the water meets the standards can be done, and may also suggest the presence of other contaminants. Solutions containing iron are colorless at low concentration. so the iron solutions are tested by adding a complexing agent that absorbs at a specific wavelength and is analyzed using a spectrophotometer.

Various iron salts are used as coagulants in water treatment.

In an experiment, a standard solution of potassium permanganate is used to determine the concentration of Fe" in a water sample. Permanganate ion reduces to a manganese **(I)** ion in the acidic solution. This reaction requires five electrons and eight hydrogen ions.

$$MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O$$
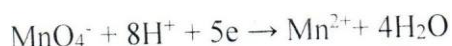
Therefore. one mole of manganate ions reacts with live moles of iron (II) ions to form five moles of iron **(II) and** one mole ofMn'

Net ionic equation

MnO, **+** 5Fe? **+** 8H+Mn' + 5Fe? + 4H.O
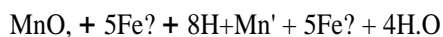
2.3 Amount of suspended solids

The total dissolved solids concentration in coproduced water can vary between 1,000 mg/L and over 400,000 mg/L; however, some basins tend to have much lower median values of TDS. Sodium chloride was found to be most dominant salt found in coproduced water across all basins studied. Oil and grease, ethyl benzene, benzene, phenols, and toluene are the most common organic contaminants found in coproduced water. The total oil content in coproduced water can range from 40 mg/L to 2.000 mg/I. Understanding the composition and quantity of coproduced water is essential for assessing the viability of beneficial reuse and selecting appropriate treatment

processes for the water (Benko ct al.. 2008).

The turbidity of water is one of the important physical parameters for water quality, defining the presence of suspended solids in water and causes the muddy or turbid appearance of water body (Tiwari et al., 2015).

As turbidity increases, it reduces the clarity of water to transmitted light by causing light to be scattered and adsorbed. Turbidity itself does not always represent a direct risk to public health: however, it can indicate the presence of pathogenic microorganisms and can be effective indicator of hazardous events through the water supply systems from catchment to point of use (Alpha,
2012).

High turbidity in source waters indicates pollution and can harbor micro bio pathogens; and consumption of high turbid water may cause a health risk, as excessive turbidity can protect pathogenic microorganisms from effects of disinfectants (Tiwari and Singh, 2014, Singh et al..
2013)

Water pollution is usually defined as any physical, chemical or biological change in water quality which adversely impacts on living organisms in the environment or which makes a water resource unsuitable for one or more of its beneficial uses (Chapman, 1996).

Most times, pollution may be derived from natural processes such as weathering or/ and soil erosion. Majority of the cases, impairment of water quality is either directly or indirectly as a result of human activities (Akpan et al.. 2008).

Pollution of the water is evident by the coloration of water which in most of the rivers and streams in the mining area varies from brownish to reddish orange. Low pll (between 2-3). high electrical conductivity, high concentration of ions of sulphate. iron and toxic heavy metals, low dissolved oxygen (DO) and high biological oxygen demand (BODO are some of the physiochemical and biological parameters which characterize the degradation of water quality (Swer & Singh, O. P,
2004).

METHODOLOGY

3.1 Research design

An exploratory qualitative and quantitative research study was used as most appropriate research. Titration methods were used to determine the concentration of calcium and magnesium ions that cause hardness of water, iron (II) and iron (III) ions; and suspended solids concentration was **determined by filtration procedures.**

3.2 Sampling size

The Researcher used different parts of river **Rwabakazi** considering about 20 kilometers where **water was collected to be analyzed**

3.3 Sample collection

The areas where water was collected were first identified. Using the three labeled plastic bottles A, B, and C, the water samples were collected from those identified points; and then taken to the **laboratory for the qualitative and quantitative analyses.**

3.4 Sampling

Three samples of water were collected by filling lL plastic bottles with water from selected sites at junction where river crosses the bridges as follows: A for Kabale-Kirigime road, B for KabaleKatuna highway and C for Mbarara Kabale Highway, as in the map below;

:EKUU.

%

Kikungiri
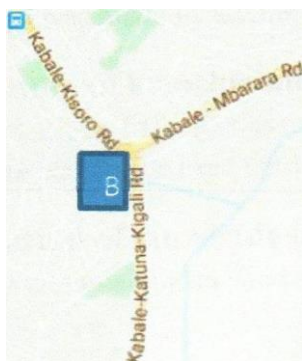
3.5 Experimental

3.5.1 Qualitative analysis for ions in Rwabakazi water

Samples of water (ImL) were put in test tubes separately. Different ion testing reagents (0.5ml) were added to each portion. the changes which occurred were recorded as observations and inference made thereof recorded as deduction.

3.6.1 Preparation of EDTA
Sodium hydroxide pellets (0.183g) were added to EDTA (0.73g) powder in a conical flask and the mixture was stirred until dissolution of EDTA was complete. The solution was transferred into a 250 ml Stoppard volumetric flask and distilled water was added up to the mark.

3.6.2 Preparation of potassium permanganate solution
0.00 IM potassium permanganate solution was prepared by dissolving crystals (0.032g) in distilled water (200ml) in a 250 mL volumetric flask and Stoppard.

3.6.3 Preparation of buffer solution
Ammonium chloride (5.4g) was dissolved in water (20mL). 10\\11 ammonia solution (35ml.) was added to it and then diluted with water to 100ml

3.6.4 Preparation of sodium hydroxide solution
Sodium hydroxide pellets (8 g) were dissolved in distilled water (100 mL) in a stoppered volumetric flask.

3.6.5 Preparation of sulphuric acid
IM sulphuric acid was made by adding concentrated acid($\backslash$ 3.6 cm) to distilled water ($250cm^3$).

3.6.6 Preparation of Eriochrome Black T indicator
Solid Eriochrome Black T (0.5g) was transferred to a small beaker and ethanol (50 mL) was added to it. The mixture was then stirred until when Eriochrome Black Thad fully dissolved.

3.6.7 Preparation of murexide indicator
Murexide (0.2g) was mixed with solid sodium chloride (100g) and the mixture was ground to form a powder.

3.7 Titration procedure for determination of ions in water samples

3.7.1 Determination of iron (II) ions in water sample
0.001M potassium permanganate solution was put in the burette. Water sample (20ml) was pipetted into a clean dry conical flask and IM sulphuric acid (20ml.) was added to the sample. The solution sample was titrated with potassium permanganate from the burette until when the color

changed to pink as the end point. The initial and final volume reached on the burette was recorded. The procedure for other two experiments was repeated to get other consistent values. The experiment was repeated for other samples and also the initial and final volumes were recorded. The results were tabulated for each of the three samples.

3.8 Determination of concentration of iron (III) ions in water samples by titration

Water sample (20.0 mL) was pipetted into a clean dry conical flask. Zinc powder (0.1 g) was added to the mixture and stirred. 1 M sulphuric acid (20ml) was added to the sample mixture. The mixture was then titrated with the 0.00 IM potassium permanganate solution from the burette until a purplish pink color appeared. The final volume reached was obtained by reading it on the burette calibration and it was recorded. The procedures were repeated two times to get consistent values. The experiment was repeated wholly for other water samples. The results were recorded in table
form.

3.9 Determination of the concentration of calcium ions by titration

Water sample (20.0 ml) was placed in a volumetric flask. 2M Sodium hydroxide solution ($>.$) ml) was added to the water sample. Murexide indicator (1 spatula endful) was added to the mixture. The mixture was titrated with standard EDTA solution to violet end point. The volume of EDTA used was read on the burette calibration and recorded as final volume. The experiment was repeated using the same procedures to get other results The experimental procedures above were repeated for other samples and the results were recorded in a suitable table.

3.10 Determination of total concentration of magnesium and calcium ions in water samples

Water sample (20.0 mL) was pipetted and poured into a clean conical flask. Ammonia buffer solution (2.0 ml) was added and the mixture shaken. Eriochrome Black T solution (4 drops) was added to the sample mixture. The sample solution mixture was titrated with EDTA solution from the burette until a permanent pink color appeared. The final burette reading was recorded as final volume reached. The procedure was repeated twice to get other titre values. The titration experimental procedure was repeated for other samples to get concordant results.

3.11 Determination of concentration in g/1 of magnesium ions

The average volume of EDTA that reacted with magnesium ions only was obtained by subtracting the volume of EDTA that reacted with Calcium ions alone from the volume of EDTA that reacted with both calcium and magnesium ions. The difference got was then used to obtain the concentration of magnesium ions in the water samples.

CHAPTER FOUR

3.12 Determination of suspended solids in water

RESULTS, TREATMENT OF RESULTS AND DISCUSSION 4.1

Preliminary qualitative tests on Rwabakazi water

Test tube reactions carried out to determine ions present in Rwabakazi water yielded results shown in Table I below.

Table 4.1: Qualitative analysis results on Rwabakazi water

Test procedure	Observation	Deduction
Sodium hydroxide solution was added drop wise to the water sample (1 cm^3) ti 11 excess.	White precipitate insoluble	Ca? and Mg? present
Ammonia solution (3 drops) were added to the water sample (I cm^3)	White precipitate was formed	Mα present
Dilute sulphuric acid (3 drops) were added to the water sample (I cm^3)	White precipitate formed	Ca?' present
Bariu nitrate solution (2 drops) were added to the water sample (1 cm?) followed by dilute nitric acid (2 drops)	White precipitate formed	SO? Present
Silver nitrate solution (3 drops) were added to the water sample (1 cm^3) followed by dilute nitric acid (3 drops)	Colorless solution was formed	Cl absent
Dilute nitric aci (4 drops) was added to the water sample \ (I em')and the gas was passed over lime water.	Lime water turned milky	HICO present
Ammonia solution was added to the water sample (1 cm') drop wise till excess.	Dirty green precipitate insoluble 117 excess solution was formed	Fe present
Ammonium thiocyanat (3 _cm^3) were added to the water sample (I cm^3)	A blood re solution was formed	Fe? present

As observed in Table 4.1 above. calcium, Iron (11). Iron (Ill), magnesium, hydrogen carbonate. and sulphates ions are present in the water flow in Rwabakazi River. Presence of these ions in permissible quantities would have no harm if the water is used for domestic, industrial or farm purposes. However, if the concentrations of these ions exceed the permissible limits it would indicate that the water is polluted. It was therefore necessary to perform quantitative determinations of some of these ions to find out whether river Rwabakazi waters are pol luted or not.

The data obtained in the quantitative determinations have been recorded on Tables 4.2 to 4.16,

4.2 DETERMINATION OF Fe?"
The data obtained on quantity of iron (II) ions present in water is shown in Table 2 below.

SAMPLE A; KIRIGIME BRIDGE

Volume of pipette used 20.0 ml Table

4.2: Iron (II) in sample A

Experiment number	1	2	", .)
Final burette reading (cm)	4.40	12.20	14.30
Initial burette reading (cm^3)	0.00	8.00	10.00
Volume of KMnO; used (cm')	4.40	4.20	4.30

Table 4.2: shows the results for obtaining the concentration of Fe^2+ in sample A

Titre values   4.40, 4.30, 4.20

Average volume of KMnO, <u>4.20+4.30+4.40</u>   <u>12.90</u>

$$4.30 \ crn^3$$

Standard deviation of Fe^2+ in the water samples

Variance= <u>(4.20-4.30)^2 + (4.30-4.30)^2 + (4.40-4.30)^2</u>

                3-1

<u>=(-0.1)±(0.OP ± (0.L 2</u>

                      O.OI

        = <u>0.02</u>

         2

Standard deviation for Iron (II) ions= (Variance)"

$$=(0.01)\%\,^\circ$$

$$= 0.1$$

Calculating for iron (Il) ions concentration in sample from Kirigime bridge 1000

cm^3 of KMnO4 Contains 0.001 Moles

4.30±0.1 cm^3 of KMnO4 Contains <u>Q.00 l</u> x (4.3±0.1) Moles 1000

Moles of KMnO,   4.310"± Ix10

From the equation,

MnO+ 5Fe? + 8H'»Mn? + 5Fe? + 4H.O
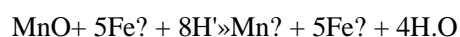
1 Mole of MnO4- reacts with 5 moles of Fe$^{2}_{+}$

4.3 x 1 0-^{6} ±1 x 107 moles of MnO; react with 5 (4.3 x 10-^{6} ± Ix 1 0-^{7}) moles of Fe$^2_+$

Moles ofFe"= 2.15x 10°+ 5x107

20 Ml of Fe$^2_+$ solution contains 2.15 x 10°± 5xl 0-^{7} moles

I 000 Ml of Fe$^2_+$ contains <u>2.1510°±5x 10-^{7}</u>

20x l0'   20 x l0'

Molarity of Fe?'= (1.075x I 0^{-3} ± 2.Sx 10)M Concentration of Fe

in grams per liter= Molarity x RFM = (l .075x l 0-^{3} ± 2.SxJ0-^{5})

x55.85

= 0.06004 ± 1.396x10 grams.

=60.04± 1.396 mg

The mean volumes potassium permanganate used on acidified water samples from river Rwabakazi are shown in Table 4.3 below.

Table 4.3: Mean volumes of MnO.- used

Volume of MnO;/em3	Place
4.30	A Kirigime bridge
4.17	B Katuna bridge
3.90	C Mbarara bridge

The average volume used on different samples as shown in the Table 4.3 above decreased downstream, showing that content of iron in water decreased downstream. Using the data in Table 4.3, concentrations of iron (ll) ions were calculated and tabulated in Table 4.4.

Table 4.4; shows the concentrations of iron (11) ions in mg/l

peeve	Place
60.04	A Kirigime bridge
58.20	B Katuna bridge
54.40	C Mbarara bridge

As shown in Table 4.4, the mean concentrations of iron (II) decreased as we moved downstream river Rwabakazi indicating that the river was relieving itself of pollution as the water flowed. So,

to some extent this water body undergoes self-purification.

Presence of iron in very large quantities in Rwabakazi waters resulted from flooding upstream where heavy rains washout open laterite soils. Surface run-off corroded iron in rocks and accumulated it in the flowing waters that were sampled downstream. As the iron levels were more than 0.05-0.1mg/L in the waters. high turbidity and intense colour developed. It was reported that if the concentration is more than 0.3 mg/l staining of laundry and water systems may be damaged

(Annex, (2017).

The concentration of iron in drinking water should be less than 0.3 ppm (0.3 mg/L); however, it may be higher in countries where various iron salts are used as coagulating agents in water treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution. "According to US EPA, the recommended limit for dissolved iron in drinking water is 0.30ppm. As per the results, all the samples concentrations are much higher than the limit of

iron in drinking water.

Since the mean concentrations of iron in all the samples tested are higher than allowed limit for drinking water. Rwabakazi water should not be drank without prior treatment to remove excess

Iron.

4.2 DETERMINATION OF IRON (III) IONS

The data on determination of iron (lll) is shown in Table 4.5

SAMPLE A; KIRIGIME BRIDGE (Typical results)

periment number	l	2	.)
al burette reading (cm)	15.60	5.80	25.70
:ial burette reading (cm)	10.00	0.00	20.00
.:,lume of KMnO4 used (cm^3)	5.60	5.80	5.70

Table 5: shows the results for obtaining the concentration ofFe"in san#eK Titre values:

5.60. 5.70. 5.80

Average volume of KMnO4 = $\underline{5.60 + 5.70 + 5.80}$

17.10

$$3 \qquad\qquad 3$$

$$= 5.70 \text{ cm}$$

Standard deviation of volume used to determine Fe^{3+} in the water sample A

Variance= $\underline{(5.60\text{-}5.70)^2 + (5.70\text{-}5.70)^2 +(5.80\text{-}5.70)}$

3-1

$$= \underline{(\text{-}0.1)^2 + (0.0)^2 + \textit{(0.1)}\,2}$$

0.0l

$$= \underline{0.02}$$

2

Standard deviation for lron (Ill) ions= (Variance)^{05} =

$$(0.01)\%°$$

$$= 0.1$$

Volume of KMnO4 that reacted to form Fe^{3+}= (5.70±0.1) - (4.30±0.1) = 1.40 ±

$$0.2 \text{ cm}^3$$

Typical calculation for concentration of iron **(III)** ions.

Calculating tor iron (Ill) ions concentration in sample from Kirigirne bridge I 000 cm^3 of

KMnO4 Contains 0.00 I Moles

1.7

1.40±0.2 cm^3 of KMnO4 Contains <u>0.00 I</u> x (1.40±0.2) Moles 100

Moles of KMnO, = 1.4x10±2x107

From the equation,

MnO' + 5Fe" +8H»Mn? +5Fe" +4I1O

I Mole of MnO4- reacts to produce 5 moles of Fe^{31}

1.4 XI 0-^{6} ± 2x I 0-^{7} moles of MnO4· react with 5 (1.4 X 1 0-^{6} ± 2x 10-^{7}) moles of Fe^3+

Moles of Fe^3+ = 7.0 x 10-^{6} ± Ix 10°

20 Ml ofFe^3+solution contains 7.0 x 10-^{6} ± 1xt0·^{6} moles 1000 Ml

of Fe3+ contains <u>7.0 x 10-^{6} ± lxJ0-^{6}</u>

20103   20x10°

Molarity of Fe? (3.510'+ 5x10)M

Concentration of Fe^3+ in grams per liter= Molarity RFM = (3.Sx I 0-^{4}

∶± 5x I 0-^{5}) x55.85

= 0.0195 ± 2.793x I0 grams.

= I 9.50± 2.793mg

Table 4.6: Mean volumes ofMnO4· used on determination of iron (III).

[MnOr]/MI	Place
1.40	A Kirigime bridge
1.36	B Katuna bridge
1.20	C Mbarara bridge

The mean volumes in Table 4.6 decreased as we moved down steam indicating fall in concentration of iron (Ill) as we move down stream. The decrease in content of iron must have resulted from natural purification tendencies of the flowing water stream.

Table 4.7; showing concentration of iron **(fII)** ions in mg/I

[Fe"]/mg/I	Place
19.50	A Kirigime Bridge
18.90	B3 Katuna Bridge
16.80	C Kabale Mbarara bridge

Generally, the concentrations of iron **(III)** ions in water samples are high and the water is brown in color implying that the water from Rwabakazi River is highly polluted.

Dissolved iron in water, causes the water to taste metallic. The water may also be colored due to suspended solids containing minerals of iron that appear brownish in color (Nordberg et al.,2014). Iron will leave red or orange rust stains in the sink, toilet and bathtub. It can build up in your dishwasher and discolor ceramic dishes. It can also enter into the laundry equipment and cause

stains on clothing (Ibrahim et al.. 2014).

The results shown above were also in line with the results obtained internationally. (EPA, 2017). "Even though the EPA says that the iron in the drinking water is safe to drink, the iron sediments. other trace impurities may support bacteria that are harmful, and these bacteria are mostly found in wells where the water has not been chlorinated". Iron also promotes undesirable bacteria growth within a water works and distribution system because of large deposition of iron minerals on

piping.

4.3 DETERMINATION OF CALCIUM ION CONCENTRATION IN WATER

The mean volumes of EDTA used on water samples from river Rwabakazi to which dilute sodium hydroxide solution had been added are shown in Table 4.8 below.

SAMPLE A: KIRIGIME BRIDGE (Typical results)

Volume of pipette used= 20 c1T1³

Table 4.8: Volumes of EDTA used

Experiment number	1	2	1
Final burette reading (cm³)	5.10	24.80	5.00
Initial burette reading (cm³)	00.00	20.00	0.00
Volume of EDTA used (cm³)	5.10	4.80 19	5.00

Table 4.8: shows the results for obtaining the concentration of Ca^{2+} in sample A

Titre values   4.80, 5.0. and 5.10

Average volume of EDTA = $\underline{4Jrn + 5.00 + 5.10}$ $\underline{14.9}$

-4.97 cm^3

Standard deviation of volume of EDTA used to determine Calcium ions in sample A

Variance= $\underline{(4.8\text{-}4.97)^2 + (5.00\text{-}4.97)^2 + (5.10\text{-}4.97}\}$:

3-1

= $\underline{(-0.17)^2 + (0.03)^2 + (0.13)^2}$ 2

= $\underline{0.0467}$ = 0.02335

2

Standard deviation for Iron **(III)** ions= (Variance)^{o5}

=(0.02335)%$^\circ$

= 0.1528

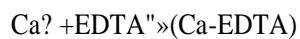Other typical results on determination of calcium ions are presented in appendix 5. Typical

calculation for concentration of calcium ions in water sample.

I 000 cm^3 of EDT A Contains 0.0 I Moles

4.97±0.1528 cm^3 of EDTA Contains $\underline{0.0\,I}$ x (4.97±0.1528) Moles 1 000

Moles of EDTA= 4.97 810± 1.528x10

From the equation,

Ca? +EDTA"»(Ca-EDTA)

1 Mole EDTA4-reacts with I mole of Ca?

20

Moles of Ca^{2+} = Moles of EDTA $^{4-}$ that reacted

Moles ofC"= 4.97 10° 1.528x10°

20 MI of Ca solution contains 4.97 10°+ 1.52810 moles I000 MI of Ca

contains <u>4.97 10?± L528x10</u>

$$\frac{}{2010°} \qquad 20x10°$$

Molarity of Ca? = (2.485x 10^{-3} ± 7.64xl $0^{.5}$) M Concentration of

Ca? in grams per liter= Molarity x RFM =(2.485x10?±

7.64x10)x55.85

= 0.0994 ± 3.056x 10^{-3} grams.

=99.4± 3.056 mg

The mean volumes EDTA used on all water samples from river Rwabakazi are shown in Table 4.9 below.

Table 4.9: Mean volumes of EDTA used

[EDTA]/Ml	Place
4.97	A Kirigime bridge
3.90	B Katuna bridge
3.30	C Mbarara bridge

As shown in Table 4.9, the volumes of EDTA decreased downstream river Rwabakazi indicating diminution in concentration of calcium ions in the water. Content of calcium in water may have decreased as a result precipitation of salts of calcium like the carbonate sulphates. phosphate or hydroxide which are sparingly soluble.

The data in lab le 4.9 was used to calculate the concentrations 0ŕ calcium ions in water and the obtained results were tabulated in Table 4.10, shown below.

Table 4.1 0; showing concentration of calcium ions in mg/l

[ca?ymgL.	Place
99.00	A Kabale Kirigime bridge
78.00	B Kabale Katuna Bridge
68.00	C Kabale -Mbarara highway bridge

The concentrations of calcium ions are very high as observed in Table 4. l0 above. The mean concentrations of calcium ions are very high showing Rwabakazi waters are hard. Presence ol calcium ions in such large quantities in Rwabakazi water indicates either presence ol gypsumlimestone, dolomite, calcite in the hinterlands upstream or/and unsustainable agricultural practices. Soil erosion in the agricultural fields washed down the components in fertilizers used upstream thereby polluting the water and increasing the content of calcium in the river. Calcium is an essential element to plants and is present in NPK and super phosphate fertilizers commonly used by vegetable farmers in the Kabale region. The concentration of calcium fell as we moved downstream due to the possibility of precipitation of insoluble calcium salts in addition to selfpurification tendencies of the river. The decrease in concentration is significant.

4.4 DETERMINATION OF TOTAL CONCENTRATION OF CALCIUM AND MAGNESIUM IONS IN WATER SAMPLES

SAMPLE A: KIRIGIME BRIDGE (typical results)

Volume of pipette used= 20 em'

Table 4. l l; showing volume of EDTA used for sample A.

Experiment number	1	2	'''' »
Final burette reading (cm')	5.40	15.60	25.70
Initial burette reading (cm^3)	0.00	10.00	20.00
Volume of EDTA used (cm') Titre values 5.40, 5.60, and 5.70	5.40	5.60	5.70

Average volume of EDTA $\underline{5,40+5.60\_15.70}$ $\qquad \underline{16.70}$

$$3 \qquad\qquad 3$$

$$= 5.57cm$$

Standard deviation of the total volume of EDT A that reacted with both Ca and Mg

Variance= $\underline{(5.40\text{-}5.57)^2 + (5.60\text{-}5.57)^2 + (5.70\text{-}5.57)^2}$

$$3\text{-}1$$

$$\underline{\text{--0I7yr(0.03)} \pm (0.13)}$$

$$2$$

$$= \underline{0.0467} \qquad = 0.02335$$

$$2$$

22

Standard deviation for Iron (II) ions (Variance)"?

$$-(0.02335)^\circ =$$

$$0.1528$$

Table 4.12: Mean volumes of EDT A that complexed with both Ca and Mg ions.

[EDTA]/Ml	Place
5.57	A Kirigime bridge
4.43	B Katuna bridge
3.90	C Mbarara bridge

In the results obtained in Table 4.12 above, the mean volumes of EDTA that complexed with Calcium and Magnesium ions are greater than the mean volumes that reacted with calcium ions alone in the samples. This also indicates that calcium and magnesium are present in the river water and the magnitude of their concentrations shows that the water is hard and polluted.

Hardness is caused by all divalent metal cations which react with certain anions such as carbonate and sulphate to form a precipitate. The principal metal cations causing hardness are calcium and magnesium, with the sum of these cation concentrations referred to as total hardness. The salts of calcium (found in carbonate and sulphate bearing rocks) and magnesium (found in carbonate rocks and rocks containing ferromagnesium minerals), and their associated soils are leached by acidic rainwater. Calcium is particularly abundant in surface and ground waters. In addition, industrial water and wastewater treatment processes both contribute calcium to surface waters, although they have little influence on total magnesium concentrations (Mac Adam & Parsons, 2004).

4.5 DETERMINATION OF CONCENTRATION IN GRAMS PER LITER OF MAGNESIUM IONS

Volume of EOTA used to determine [Mg?]= Total volume of EDTA that complexed with both Mg and Ca- volume of EDT A that reacted with Ca alone

SAMPLE A: KIRIGIME BRIDGE

Volume of EOTA used to determine $[Mg^2+]$ = (5.57±0.1528) - (4.97±0.1528)

$$=0.60:J:0.3056 \text{ cm}^3$$

Typical calculations for molar concentration of magnesium ions in the sample 1000

cm^3 of FDTA Contains 0.0 I Moles

0.60±0.3056 cm^3 of EOTA Contains <u>0.01</u> x (0.60:.!.:_0.3056) Moles 1000

Moles of EDTA = 6.0 x 10^{-6} ± 3.056x10^{-6}
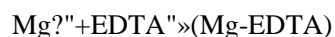
From the equation,

Mg?"+EDTA"»(Mg-EDTA)

I Mole EDT A' reacts with I mole ofMg" Moles of

Mg^2+ = Moles of $EDTA^{4-}$ that reacted Moles of

Mg?'= 6.05 $10°$/ 3.056x10

20 Ml of Mg^2+ solution contains 6.0 x 10^{-6} ± 3.056x 10moles 1000 Ml of Mg^2+

contains <u>6.0x 10± 3056 10^{-0}</u>

20103   20x10°

Molarity of Mg^2+ = (3.0xl 0-4 ± 1.528x 1 0-^{4}) M Concentration of

Mg" **in** grams per liter= Molarity x RFM

= (3.0x 10^{-4} ± 1.528x 10)x24

= 7 .2x 10^{-3} ± 3 .667x 10-3 grams.

-7.2+3.66710°mg

6.

Table 4.13: Mean volumes of EDTA used to determine [Mg?] in selected samples

[EDTA)/MI	Place
0.60	A Kirigime bridge
0.53	B Katuna bridge
0.50	CKabale Mbarara bridge

Table 4.14; concentration of magnesium ions in mg/l

[Mg"lmgL	Place
7.20	/\ Kirigime bridge
6.40	BKatuna bridge
6.00	C Kabale Mbarara bridge

The high concentration at Kirigime bridge is due to the dumping and disposal of magnesium containing waste materials into the river water especially the ones from Kirigime composite pit and the nearby washing bay. Thus, the concentration is greater with a value of7.20 mg/I in sample

A.

The concentration of magnesium ions in sample R collected from Katuna bridge is 6.40 mg/land is less than that collected at Kirigime bridge because the rate of pollution at Katuna bridge is minimal compared to that one at Kirigime bridge. The presence of a nursery bed near Katuna bridge where seedlings are sprayed using fertilizers containing many ions magnesium inclusive contributes to the concentration levels of magnesium ions at this point thus the results.

The concentration of magnesium ions in sample C is 6.0 mg/l and is less compared to that one in samples A and B due to a low degree of pollution at this point. Kabale Mbarara bridge is isolated from homesteads and municipal wastes thus the only source of pollution may be from moving

vehicles and pedestrians moving along the road.

By comparing the concentration of calcium and magnesium ions in the samples collected, the concentration of magnesium ions is less than the concentration of calcium ions in all samples

because magnesium is less soluble in water than calcium ions.

4.6 DETERMINATION OF TOTAL SUSPENDED SOLIDS IN WATER SAMPLES

The mean masses of suspended solids in Rwabakazi water samples are shown in Table 4.15 below.

SAMPLE A: MBARARA KABALE ROAD

Volume of water sample= 100 em3

Mass of empty filter paper= 1.027 g

Mass of tilter paper and solids after 8 days of drying 2.587g

Mass of suspended solids= Mass of filter paper and solids after 8 days of drying - Mass of empty tilter paper

Mass of suspended solids= 2.587 1.027 Mass of

suspended solids= 1.560 g

Table 4.15; showing concentration of TSS in water samples in g/I00ml

Total Suspended solids in g/100cm^3	Place
1.56	A Kirigime bridge
1.48	B Katuna bridge
1.05	CKabale Mbarara bridge

As observed from the Table 4.15 above every I 00 mL of water from river Rwabakazi contained more than 1.0 g of suspended solids. This indicated high level of soil erosion upstream. Soil erosion may have resulted from heavy rains upstream to the west of Kabale town which is hilly

and mountainous. So, the river was carrying much silt.

The data in Table 4.15 were used to calculate mean concentration of TSS in g/L in Table 4.16 below

Table 4.16; shows mean concentrations of TSS in g/1 in water samples.

[TTsSal

14.8

10.5

Place
A Kirigime bridge
B Katuna bridge
Kabale Mbarara bridge

J

lt can be observed from Table 4.16 that the concentration of TSS is high and decreased as we moved downstream. The high TSS values resulted from massive soil erosion in agricultural fields and exposed laterite soils in the mountains upstream. Western Kabale receives heavy rains that form very large volumes of surface runoff water and result in flash flooding upstream of river Rwabakazi. Coupled to very extensive, but poor agricultural methods, water dissolved a lot of soils which it carried downstream. Growing vegetables and common food items in the area has resulted in clearing of trees and draining of marsh lands. Since the surface soil is largely devoid of plant cover, much soil is carried to the river valleys. High TSS must lead to mass death of phytoplankton on which fish living in the water feed. It would not be surprising to find very few

 fish species in this river because of the high TSS.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Conclusions

Waters of river Rwabakazi are highly polluted as shown by high concentrations of iron, calcium.

magnesium and TSS.

Since the concentrations Ca, Fe, Mg and TSS decreased downstream, purity of the water can be

improved through damming sections of the river to increase residence time.

Water from river Rwabakazi is not safe for human consumption unless treated because it is

polluted.

The concentrations decreased downstream as follows; lron (II) from 60.04 to 54.40 mg/L; iron

(111) from 19.50 to 16.50 mg/L; calcium from 99.00 to 68.00 mg/L; magnesium from 7.20 to 6.0 mg/L and TSS

from 15.6 to 10.5 mg/L all of which exceeded the allowed limits by EPA and WHO

guidelines.

The study findings showed that there is much variation among the selected water pollutants for the

samples collected at different points of River Rwabakazi hence providing the basics and the reason

for carrying out this research.

5.1 Recommendations

Basing on the findings of the study I recommend that:

1. Separate studies should be carried out to establish whether fish can survive in river Rwabakazi.

2. Nitrogen and phosphate levels of the water should be studied to assert the source of hardness

   of the water.

8. There is need to restore green cover on the mountains and hills upstream to reduce erosion.

9. There is need for sustainable agricultural practices in the Kabale region to reduce pollution

   levels in river Rwabakazi.

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Appendix 1: Titration results for iron (11) ions in water samples

SAMPLE B; KA TUNA ROAD

Volume of pipette used= 20.0 ml

Experiment number	1	2	" .)
Final burette reading (cm)	4.10	14.20	24.20
Initial burette reading (cm^3)	0.00	10.00	20.00
Volume of KMnO4 used (cm^3)	4.10	4.20	4.20

Table 1.1: shows the results for obtaining the concentration of Fe^2+ in sample B
10.

Titre values   4.10, 4.20. and 4.20

Average volume of KMnO $\frac{4.10+4.20+4.20}{3}$ $\frac{12.50}{3}$

4.17cm

Standard deviation for iron (I) irons in water sample B

Variance= $\frac{(4.10\text{-}4.17)^2 + (4.20\text{-}4.17)^2 + (4,20\text{-}4.17)}{3\text{-}1}$

$= \frac{(-0.07)^2 + (0.03)^2 +(0.03)}{2}$

$\frac{-6.710°}{2}$ $= 3.35\text{x}10°$

Standard deviation for Iron (II ions (Variance)

$=(3.355103)/°$

$= 0.0579$

SAMPLE C: MBARARA- KABALE ROAD (Typical results)

\ Experiment number	1	2	" »
\ Final burette reading (cm^3)	3.80	14.00	18.90
\Initial burette reading (cm^3)	0.00	10.00	15.00
/Volume of KMnOi used (cm?)	3.80	4.00	3.90
		3Ĭ	

Table 1.2: shows the results for obtaining the concentration of Fe^2+ in sample C

Titre values   3.80, 3.90. and 4.00

Average volume of KMnO4 $\underline{3.80 + 3.90 + 4.00}$ $= \mathbf{i11}$

                                           3   3

                              $= 3.9 \text{ cm}^3$

Standard deviation for iron (II) irons in water sample c

Variance= $\underline{(3.80\text{-}3.90)^2 + (3.90\text{-}3.90)^2 + (4.00\text{-}3.90)^2}$

                              3-1

$= \underline{(\text{-}0.1)^2 + (0.00)^2 \, 1 \, (0.1 \, Q\}: 2}$

                              $= 0.01$
$= \underline{0.02} \, 2$

Standard deviation for Iron **(II)** irons = (Variance)"

                              $=(0.01)\%°$

                              $= 0.1$

Appendix 2: Calculations for concentrations of iron (II) ions in water samples

Calculating for iron **(II)** ions for Katuna bridge **I**

000 cm^3 of KMnO4 Contains 0.00 **I** Moles

4.17±0.0579 cm^3 of KMnO4 Contains $\underline{0.00\,I}$ x (4.17±0.0579) Moles 1000

    Moles of KMnO   4.17 10± 5.79x10

From the equation,

    MnO' + 5Fe?' + 8H' »Mn +5Fe? + 4.O

I Mole of MnO_4^- reacts with 5 moles of Fe^{2+}

$4.17 \times 10^{-6} \pm 5.79 \times 10^{-8}$ moles of MnO react with 5 $(4.17 \times 10^{-6} \pm 5.79 \times 10^{-8})$ moles of Fe"

Moles of $Fe^{2+} = 2.085 \times 10^{-5} \pm 2.895 \times 10^{7}$

20 Ml of Fe^{2+} solution contains $2.085 \times 10^{-5} \pm 2.895 \times 10^{-7}$ moles

1000 Ml of Fe^{2+} contains $\underline{2.085 \times 10° \pm 2.895 10^{-7}}$

$$\qquad\qquad 20103 \qquad 2010°$$

Molarity of $Fe^{21} = (1.0425 \times 10' \pm 1.4475 \times 10)M$ Concentration of

Fe^{2+} in grams per liter= Molarity x RFM = $(1.0425 \times 10? \pm 1.4475 \times$

$10^{-5}))$ x55.85

$= 0.0582 \pm 8.08 \times 10^{-4}$ grams.

$= 58.2 \pm 0.808$ mg

Calculating for iron (II) ions concentration in sample from Kabale Mbarara bridge 1000 cm^3 of

KMnO Contains 0.001 Moles

3.90 ± 0.1 cm^1 of $KMnO_4$ Contains $\underline{0.00 \text{ I}} \times (3.9 \text{ J}:0.1)$ Moles 1000

Moles of KMnO, $= 3.90 \times 10° \pm 1 \times 10'$ From the

equation,

MnO" + 5Fe? + 8H'»Mn" +5Fe? + 4H.O

1 Mole of MnO; reacts with 5 moles of Fe"

$3.90 \times 10^{-6} \pm \text{Ix } 10$ moles of MnO4- react with S $(3.90 \times 10^{-6} \pm \text{Ix } 10^{7})$ moles of Fe"

Moles of $Fc^{2\cdot} = 1.95 \times 10° \text{ Sx } 10^{-7}$

20 Ml of Fe^{2+} solution contains $1.95 \times 10° \pm 5 \times 10^{-7}$ moles

33

1000 MI of Fe? contains $\underline{1.95 \times 10° \pm 5 \times 10'}$

$$20103 \qquad 20 \times 10°$$

Molarity of Fe" = $(9.755101 + 2.5510°)$ M

Concentration of Fe in grams per liter= Molarity x RFM

$-(9.75510' + 2.5510°)) \times 55.85$

$-0.05445 \; 1 \; 1.39610$grams.

$=54.45 \pm 1.396$ mg

Appendix 3: Results on titration for iron (III) ions in water samples

SAMPLE B; KATUNA BRIDGE

Experiment number	1	2	
Final burette reading (cm^3)	27.50	33.60	15.50
Initial burette reading (cm^3) Titre values	5.50, 5200 6.60	28.00	10.00
Average volume of KMnO4= Volume of KMnO4 used (cm^3)	5.50 + 5.50 + 5.60 / 5.50	= 16.60 / 5.60 / 3	5.50

Table 2.1: shows the results for obtaining the concentration of Fe" in sample B

Volume of KMnO4 = 5.53 cm^3

Standard deviation for iron (Ill) irons in water sample B

Variance= $\underline{(5.50\text{-}5.53)2 + (5.50\text{-}5.53)^2 + (5.60\text{-}5.53)^2}$

$$3\text{-}1$$

$= L\underline{-0.03)^2 + (0.03)2_t(0.07)^2}$ 2

$$=\underline{6.7 \times 10^{\circ}} \qquad = 3.35 \times 10^{\circ}$$

$$2$$

Standard deviation for Iron **(111)** irons= $(Variance)^{05}$

$$=(3.35103)^{\circ}$$

$$= 0.0579$$

Volume of $KMnO4$ that reacted to produce Fe? (5.53/0.0579)-(4.17+0.0579) -1.36±0.1158 cm

SAMPLE C: KABALE MBARARA BRIDGE

Experiment number	1	2	"" ⌐
Final burette reading (cm^3)	5.00	10.20	15.10
Initial burette reading (cm)	0.00	5.00	10.00
Volume of KMnO; used (em?)	5.00	5.20	5.10

Table 2.2: shows the results for obtaining the concentration of Fe^{31} in sample A

Titre values $\qquad$ 5.00, 5.10. 5.20

Average volume of KMnO4 $\underline{5.00 + 5. IO+ 5.20}$. $\qquad = \qquad \underline{15.30}$

$$3 \qquad\qquad 3$$

$$=5.lcm^3$$

Standard deviation for iron (III) irons in water sample C

Variance= $\underline{(5.00-5.10)^2 + (5.10-5.10)^2 + (5.20-5.10)2}$

$$3-1$$

$$= \underline{(-0.10)^2 + (0.00)2 + (0.10)2}\ 2$$

$$\underline{O.O2} \qquad O.O\ I$$

$$2$$

Standard deviation for Iron (II) irons= $(Variance)^{05}$ =(0.01)%$^{\circ}$

$$= 0.1$$

Volume of $KMnO_4$ that reacted to produce Fe" (5.10+0.1)-(3.90+0.1) 1.20±0.20

$$cm^3$$

Appendix 4: Calculations for concentration of iron (lll) ions in sample B I 000

cm^3 of KMnO4 Contains 0.001 Moles

1.36±0.1158 cm^3 of KMnO4 Contains <u>0.001</u> x (1.36±0.1158) Moles 1000

Moles of KMnO= $1.36 \times 10 \pm 1.158 \times 10^{-7}$

From the equation,

MnO'+ 5Fe? +8H»Mn? +5Fe? + 4H.O

I Mole of MnOf reacts to produce 5 moles of $Fe^{3}+$

$1.36 \times I 0^{-6} \pm 1.158 \times I 0^{-7}$ moles of MnO produces $5 \times (1.36 \times I 0^{-6} J_{-} 1.158 \times I 0^{-7})$ moles of Fe²"

Moles of Fe"= $6.8 \times 10° + 5.79 \times 10$

20 Ml of $Fe^{3}+$ solution contains $6.8 \times 10° \pm 5.79\ 107$moles

I 000 Ml of $Fe^{3}+$ contains <u>$6.8 \times I 0^{-6} \pm 5.79 \times I 0^{-7}$</u>

$$20103 \qquad 20 \times 10°$$

Molarity of $Fe^{3}+ = (3.4 \times I 0-4 \pm 2.895 \times I 0^{·5})$ M Concentration of

Fe" in grams per liter= Molarity x RFM

$= (3.4 \times I 0-4 \pm 2.895 \times I 0^{·5})) \times 55.85$

$= 0.0189\ j_{-}1 .6 1 7 \times I 0^{-3}$ grams.

=18.9±1.617 mg

Calculation for concentration of iron (Ill) ions in water sample C I 000

cm^3 of KMnO Contains 0.00 I Moles

1.20±_0.20 cm^3 of KMnO4 Contains 0.00 I x (1.20::±:0.20) Moles

$$1000$$

Moles of KMnO,= 1.20 x10± 2.0x10

From the equation,

MnO" + 5Fe? + 8H'»Mn?+5Fe? + 4H.O

1 Mole of MnO; reacts to produce 5 moles of Fe"

1.20 x10± 2.0x10 moles of MnOr produces 5 (1.20 x10±2.0x107)moles of Fe

Moles of Fe"   6.0 10± 1.0xI0

20 Ml of Fe' ^{1} solution contains 6.0 x 10±l .Ox I0^6 moles

I 000 Ml of Fe^3+ contains 6.0x I 0-^{6} ±. I .Ox 10°

$$20103 \quad\quad 20x10°$$

Molarity of Fe" = (3.0510± 5.0x10°) M

Concentration of Fe^3+ in grams per liter= Molarity x RFM

= (3.0x I0-^{4} ±. 5.0x I 0-^{5})) x55.85

= 0.0168 ±. 2.793x I0-^{3} grams.

= I6.8±_2.793 mg

Appendix 5: Results on determination of calcium ions

SAMPLE B: KATUNA BRIDGE

Volume of pipette used= 20 cm3

[Experiment number	1	2	3
Final burette reading (cm^3)	4.00	13.90	23.30
tlnitial burette reading (cm')	00.00	10.00	20.00
Volume of EDTA used (cm^3)	4.00	3.90	3.80

Table 3.2: shows the results for obtaining the concentration of Ca^2+ in sample B 37

Titre values   3.80. 3.90. and 4.00

Average volume of EDT A= $\underline{3.80 + 3.90 + 4.00}$ **i11**

$$\frac{}{3} \qquad \frac{}{3}$$

$$= 3.9 \text{ cm}^3$$

Standard deviation for volume of EDTA that reacted with Calcium ions in water sample B

$$\text{Variance} = \frac{(3.80\text{-}3.90)^2 + (3.90\text{-}3.90)^2 + (4.00\text{-}3.90)^2}{3\text{-}1}$$

$$= \frac{(-0.10)^2 + (0.00)^2 + (0.10)^2}{2} \; 2$$

$$= \frac{0.02}{2} \qquad \text{O.OI}$$

Standard deviation for the volume of Calcium ions= $(\text{Variance})^{05} = (0.01)\%^{\circ}$

$$= 0.1$$

SAMPLE C: MBARARA- KABALE ROAD

Experiment number	I	2	''; .)
Final burette reading (cm^3)	13.30	11.90	13.50
Initial burette reading (cm^3)	10.00	8.50	I 0.00
Volume of EDTA used (cm^3)	3.30	3.40	3.50

Table 3.1. shows the results for obtaining the concentration of Ca$^2+$ in sample A

Titre values   3.30, 3.40, and 3.50

Average volume of EDTA $\underline{3.30 + 3.40 + 3.50}$

$$\frac{}{3} \qquad \frac{}{3}$$

$$-3.40 \text{ cm}^3$$

Standard deviation for the volume of EDTA that reacted with Calcium ions in water sample C

Variance= (3.30-3.40)^2 **+** (3.40-3.40)^2 **+** (3.50-3.40)^2

3-I

= (-0.10)^2 **+** (0.00)^2 **+** (0.10)

2 =

= 0.01

0.02 2

Standard deviation for the volume of Calcium ions (Variance)'

=(0.01/%°

= 0.1

Appendix 6: Calculations for concentrations of calcium ions I 000

cm^3 of EDT A' contains 0.01 Moles

3.90±0.10 cm^3 of EDTA ^{4}-Contains 0.01 x (3.90±0. I0) Moles 1000

Moles of EDTA'= 3.90 x 10°±1.0x I0-^{6}

From the equation,

ca" +EDTA' ·(Ca-EDT)

I Mole EDTA' reacts with I rnole of Ca^2+ Moles of

Ca^2+ = Moles of EDT A ^{4}- that reacted Moles of Ca?

= 3.90 x10°± 1.0x10 moles

20 MI of Ca solution contains 3.90 x10± 1.0x **IO** moles I 000 Ml

of Ca contains 3 .90x I 0-^{5} ± 1.0x I 0-^{6}

20103   20x10°

Molarity of Ca^2+ = (I .95x I 0-^{3} ± 5.0x 10)M

Concentration of Ca^2+ in grams per liter= Molarity RFM

39

$= \left(1.95 \times 10^{-3} \pm 5.0 \times 10^{-5} \right) \times 40$

$= 0.078 \pm 2.0 \times 10^{-3}$ grams.

$= 78 \pm 2.0$ mg per litre

Calculation for mean concentration of calcium ions in sample C

1000 cm^3 of $EDTA^{4-}$ contains 0.01 Moles

$3.40 \pm 0,10$ crn^3 of $EDTA^{4-}$ Contains $\underline{0.01} \times (3.40 \pm 0.10)$ Moles

$\qquad\qquad\qquad\qquad 1000$

Moles of EDT' $3.40 \times 10° \pm 1.0 \times 10$ From the

equation,

ca? + EDTA'(Ca-EDTA)

1 Mole EDTA reacts with 1 mole of Ca^{2+} Moles of

$Ca? =$ Moles of $EDTA^{4-}$ that reacted Moles of Ca?

$= 3.40 \times 10° \pm 1.0 \times 10°$ moles

20 Ml of Ca^{2+} solution contains $3.40 \times 10^{-5} \pm 1.0 \times 10^{-6}$ moles

1000 Ml of Ca^{2+} contains $\underline{3.4Q \times 10^{-5}} \pm \underline{1.0 \times 10^{-6}}$

$\qquad\qquad\qquad\qquad 2010'\qquad\quad 20 \times 10°$

Molarity of $Ca^{2+} = \left(1.7 \times 10^{-3} \pm 5.0 \times 10^{-5} \right)$ M

Concentration of ca? in grams per liter = Molarity x RFM

$= \left(1.70 \times 10^{-3} \pm 5.0 \times 10^{-5} \right) \times 40$

$= 0.068 \pm 2.0 \times 10?$ grams.

$= 68 \pm 2.0$ mg per litre

12.

Appendix 7: Determination of Magnesium ions in water samples

SAMPLE B: KATUNA BRIDGE

Volume of pipette used= 20 em

riment number		2		19.50
1 burette reading (cm^3)	14.40	4.50		\ 5.00
al burette reading (cm^3)	I 0.00	0.00		4.50

is_rrri_it» ta 4so

Table 4.1 showing volume of EDT A used in sample B

Titre values 4.40, 4.50. and 4.50

Average volume of EDT A= $\underline{4.40 + 4.50 + 4.50}$ = $\underline{13.3}$

   3   3

= 4.43 cm

Standard deviation for the volume of EDT A that was used to determine magnesium ions in water sample B

Variance= $\underline{(4.40\text{-}4.43)^2 + (4.50\text{-}4.43)^2 +(4,50\text{-}4\underline{43})}$'

3-1

$(\underline{-0.03})/ (0.07) (0.07)$

   2

= $\underline{0.0107}$ = 5.35510°

   2

Standard deviation for the volume of magnesium and Calcium ions= $(Variance)^{0.5}$

$$= (5.35x10^{-3})^{0.5}$$

$$= 0.0731$$

SAMPLE B: KATUNA BRIDGE

volume ofEDTA used to determine $[Mg'']$ (4.43+0.0731)(3.90+0.1) =0.53:±_0.1731

cm^3

41

SAMPLE C: MBARARA- KABALE ROAD

Volume of pipette used= 20 cm3

Experiment number		2	3
Final burette reading (cm)	13.80	3.90	24.00
			-----+- - ---------- 1
Initial burette reading (cm³)	10.C_)0	±0.00	20.00
Volume of EDTA used (cm³)	3.80	3.90	4.00

Table 4.2; showing volume of EDTA used in sample C

Titre values   3.80, 3.90, and 4.00

Average volume of EDTA= $\underline{3.80 + 3.90 + 4.00}$ 11.

3   7 3

$= 3.90 \text{ cm}^3$

Standard deviation for the volume of EDTA that was used to determine magnesium ions in water sample C

Variance= $\dfrac{(3.80\text{-}3.90)^2 + (3.90\text{-}3.90)^2 + (4.00\text{-}3.9Qf}{3\text{-}1}$

$=(\underline{-0.})+(0.0)y \pm (0.L)\ 2$

$= 0.01$

=

0.

Standard deviation for the volume of magnesium and Calcium ions = (Variance)" = (0.01)%°

02

2     $= 0.1$

Volume of EDTA used to determine **[Mg]-** (3.90+0.10) (3.40/0.10) =0.50/0.20 cm

Appendix 8; Calculations for concentrations of calcium and magnesium ions in water sampled for Katuna Bridge (Sample B)

Typical calculations for molar concentration of magnesium ions in the sample

1000 em of EDTA Contains 0.0 I Moles

0.53 ± 0.1731 cm^3 of EDTA Contains <u>0.0 I</u> x (0.53:t:0.1731) Moles 1000

MolesofEDTA $= 5.3\text{xl}0^{-6}\pm 1.73\text{lxl}0^{-6}$

From the equation,

Mg? +EDTA'(Mg-EDTA)

I Mole EDTA' reacts with 1 mole otMg^{2+} Moles of

Mg^2,_ = Moles of EDTA $^{4-}$ that reacted Moles

of'Mg"= $5.3\text{x}10°\pm 1.73110°$

20 MI of Mg solution contains $5.3\,\text{I}0^{-6}\pm1.73\text{Ix}\,\text{I}0^{-6}$ moles 1000 MI of

Mg contains <u>5.3x 10^{-6} $\pm$ 1.731xl0^{-6}</u>

               20103   20x10°

Molarity of Mg?= $(2.65\text{x}10\pm8.655\text{x }10^{-5})$ M Concentration of Mg?

in grams per liter= Molarity x RFM = $(2.65\text{x I}0^{-4} \pm 8.655\text{x }10^{-5})$

x24

=6.36x10?± 2.077210? grams.

=$6.4\pm2.0772\text{x I}0^{-3}$ mg

Calculation for molar concentration of Magnesium ions in sample from Kabale Mbarara Bridge (Sample C)

I 000 cm^3 of EDT A Contains 0.01 Moles

0.50 ± 0.2 cm^3 of EDTA Contains $\underline{0.01}$ x (0.50 ± 0.2) Moles

$$1\ 000$$

Moles of EDTA $= 5.0$ x $10^{-6} \pm. 2$x 10^{-6} From

the equation,

Mg?"+EDTA' ·(Mg-EDT

1 Mole EDTA' reacts with l mole of Mg?

Moles of Mg?'= Moles of EDT A' that reacted

Moles of Mg"= $5.0 \times 10^{\circ} \pm 2 \times 10^{\circ}$

20 MI of Mg?' solution contains $5.0 \times 10^{\circ} \pm 2 \times 10$ moles 1000 Ml

of Mg? contains $\underline{5.0 \times 10^{-6}} \pm \underline{2 \times 10^{-6}}$

$$20103 \qquad 20 \times 10^{\circ}$$

Molarity of Mg?= $(2.5 \times 10^{-4}$ $i.$ 1 x $10)$ M

Concentration of Mg in grams per liter= Molarity x RFM

$= (2.5 \times 10 \pm I \times 10^{-4})$ x24

$= 6.0 \times 10^{-3} \pm 2.4 \times 10^{-3}$ grams.

$=6.0 \pm :2.4 \times 10^{-3}$ mg per litre

Appendix 9: Results of TSS in samples from river Rwabakazi
SAMPLE B; KATUNA BRIDGE

Volume of water sample= 100 cm3

Mass of empty filter paper= 0.901 g

Mass of filter paper and sol ids after 8 days of drying= 1 .049g

Mass of suspended solids= Mass of filter paper and solids after 8 days of drying- Mass of empty filter paper

Mass of suspended solids= 1.049 - 0.901

Mass of suspended solids = 1.48g

SAMPLE C: KABALE MBARARA BRIDGE

Mass of empty filter paper= 0.759 g
Mass of filter paper and solids after 8 days of drying= 1.809 g

Mass of suspended solids Mass of filter paper and solids after 8 days of drying - Mass of empty filter paper

Mass of suspended solids= 1.809 0.759 Mass

of suspended solids = 1 .OS g