# ASSESSMENT OF INDUSTRIAL WASTEWATER EFFLUENTS INTO URBAN ECOSYSTEM KIGALI, RWANDA


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## DECLARATION

"This thesis is my original work and has not been presented for a Degree or any other academic award in any University or Institution of Higher Learning"

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Dec 11th, 2013

**Date**

## APPROVAL

"I/We confirm that the work reported in this thesis was carried out by the candidate under my/our supervision".

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## ABSTRACT

Rwanda is developing its industrial sector for economic development; those industries are regularly generating wastes, either solid, liquid and gas which can in one way or another harm the living species. For the purpose of this study, an assessment of industrial wastewater effluents into urban wetland ecosystem was done and City of Kigali is considered. The objectives of the study was to establish the pollutants in the effluent of key point sources of Kigali and then assess the effluent discharge management methods and treatments regimes, if any, of three key identified pollution point sources.

The pollution due to discharge of untreated industrial effluent into environment is a disturbing environmental crisis of Kigali City. Industries do not have effluent treatment facilities and where the system exists, it does not meet the requirement for effluent standard before their dumping into surface water. It is for this endeavor that effluents from some industries were analyzed through laboratory experiments and then compare the results to the national standards maximum limits required for effluents to be discharged to environment. It was found that the urban wetland is polluted by the presence of a higher concentration of TSS, COD, Faecal Coliforms, Cd, Cu, CN, Ni and Phenol in all the tree sampling sites. And Pb at Kabuye and UTEXRWA, As at UTEXRWA and RUGANWA and then TDS at UTEXRWA, BOD at KABUYE, Fe at UTEXRWA, Cr (VI) at UTEXRWA and Hg is higher at UTEXRWA. The pH value was found to be higher at UTEXRWA and lower at Kabuye.

The problem of unplanned settlement leads to having many human activities near those effluents point. Both animal and plant communities are highly affected by the pollulated effluents, so all concerned industries should treat their effluents to protect the biodiversity and reuse them for saving costs, then water is regulated, and the industry's public image is improved. Government should ensure that the fixed standards are respected by monitoring wastewater discharges. The principle of intergeneration equity should guide all of us, as environmental protection is concerned. This is the wise use of environment, natural resources for present and future generations.

# DEDICATION

To almighty God

and

To my beloved wife, Claudine UWIRAGIYE.

## ACKNOWLEDGEMENT

I extend my sincere thanks to my wife, parents and relatives. I owe respect to my supervisor Prof. Dominic BYARUGABA (PhD) and my reviewer Dr. Paul Ssegawa who helped me so much for the success of this work. Thanks to the government of Rwanda through Rwanda Education Board (REB) for its financial support.

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**Date**

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## ABBREVIATIONS

| | |
|---|---|
| % | per cent |
| °C | degree Celsius |
| µg/l | micrograms per liter |
| 1M | 1 mole per gram |
| As | Arsenic |
| BOD | Biochemical Oxygen Demand |
| Cd | Cadmium |
| COD | Chemical Oxygen Demand |
| Cr | Chromium |
| Cu | Copper |
| Fe | Iron |
| HCl | Hydrogen chloride |
| Hg | Mercury |
| mg/kg | milligram per kilogram |
| mg/l | milligrams per litter |
| MPN/100ml | Most probable number per 100 milliliters |
| N | Ammonia ( as N) |
| Ni | Nickel |
| Pb | Lead |
| pH | The power of hydrogen |
| RBS | Rwanda Bureau of Standards |
| REB | Rwanda Education Board |

| | |
|---|---|
| REMA | Rwanda Environment Management Authority |
| TDS | Total dissolved solids |
| TSS | Total Suspended Solids |
| UTEXRWA | Usine Textile du Rwanda |
| Zn | Zinc |

# CHAPTER ONE: INTRODUCTION

## 1.1 The Context Of The Study

One of the most critical problems of developing countries is improper management of vast amount of wastes generated by various anthropogenic activities and the more challenging is the unsafe disposal of these wastes into the ambient environment (Fakayode, 2005). River systems are the primary means for disposal of waste, especially the effluents, from industries that are near them. The effluent from industries affects water bodies through altering the physical, chemical and biological nature of the receiving water body (Osibanjo, *et al*; 2011).

Increased industrial activities have led to pollution stress on surface waters both from industrial, agricultural and domestic sources (Saad, *et al*; 1984). Wastes entering these water bodies are both in solid and liquid forms. As a result, water bodies which are major receptors of treated and untreated or partially treated industrial wastes have become highly polluted. The resultant effects of this on public health and the environment are usually great in magnitude (Glyn and Gary; 1996).

Unfortunately, there are very few water quality studies for most African inland waters. In general, the available data come from scattered investigations, which were carried out by individuals and by very few scientific projects concerned with African waters. Few reviews exist on the state of pollution of African inland waters (Burgis and Symoens, 1987; Calamari, 1985; ROR, 2000). According to Tolba, it is in these countries that the quality of water, and often the quantity, is lowest, sanitation and nutrition the worst and disease most prevalent (Egborge and Fagade, 1999). However, as societies throughout the world become more aware of the issues involved in water pollution, there has been considerable public debate about environmental effects of effluents discharged into aquatic environments (NISR, 2006)

Effluent discharge practices in Rwanda are especially in the industrialized part of the City of Kigali. Industrialization and human resource development are part of the Government of Rwanda's strategy for achieving the Vision 2020. As it is typical in developing countries, most of the industries are located in urban areas. About 63 per cent of the industries are located in and around the City of Kigali (NISR 2006)

A significant number of factories which form the industrial base in Kigali are located in a low-lying area, the Gikondo-Nyabugogo wetland. The factories, as well as the densely populated homesteads located on the adjacent hill slopes, have no proper liquid-waste disposal systems, and consequently pollute soils, groundwater and the surface water. Many of the factories use out-dated technologies that are associated with energy demands and waste generation to levels that have adverse impact on the environment, and render the operations expensive and unsustainable.

### 1.2 Statement Of The Problem

Industries, petroleum depots and garages have to date been established in unplanned locations which render pollution control untenable. Lack of planning has resulted in locating industries in the proximity of residential areas which constitute an additional threat to human health and environment. On the other hand, almost all the industries, garages and workshops are located in valleys or marshes bordered by heavily populated areas (KIEM, 2006).

The industrial effluents and by-products are discharged in the water bodies. A number of industries in the Kigali City wetland eco-system include the textile industry, the iron industry which makes iron sheets, paint factories and the Kabuye sugar factory among others. These factories have been responsible for water pollution by the chemical discharges from the industries. The pollutants are for the most part toxic to humans and animals and in some instances and also interfere with the environment by polluting soils. With competing demands on limited water resources, industrial wastewater effluent pollution remains one of the major problems facing the City of Kigali (NISR, 2006).

The polluted waters from the industrial park in the Gikondo-Nyabugogo wetland eco-system drain into the Nyabarongo River and its tributaries. The Nyabarongo feeds into the Akagera River, which flows into Lake Victoria. Thus, the industrial effluents and other pollutants generated in the Gikondo-Nyabugogo wetland, Kabuye-Nyabugogo wetland and Gacuriro-Nyabugogo wetland eco-system pose environmental challenges that extend well beyond the national borders of Rwanda.

## 1.3 The Goal And Objectives Of The Study

### 1.3.1 Goal

This study is to contribute to a keen awareness of the need to identify measure, monitor and control the wastewater effluent into urban wetland ecosystem of Kigali for the wellbeing of present and future generation.

### 1.3.2 Specific Objectives

This study is to:

- Establish the pollutants in the effluent of key point sources of Kigali.
- Assess the effluent discharge management methods and treatments regimes, if any, of three key identified pollution point sources.

## 1.4 Research Questions

The following are research questions of the study:

- Does the urban wetland ecosystem polluted by wastewater effluent of the key point sources of Kigali?
- Is there any treatment regime of effluent?

### 1.5 Significance Of The Study

This study contributes to a better understanding of the pollution sources and characteristics of industrial wastewater effluents in Kigali and help in policy makers and city managers in making proper decisions from an informed position about effluent management in Kigali City. Whereas the general public learns about the dangers of polluted industrial effluents and the way to minimize their potential effects on their wellbeing as environmental protection in general is concern.

### 1.6 Scope, Assumption Of The Study

#### 1.6.1 Scope Of The Study

The research concerns the effective protection of wetland ecosystem against harmful effluent of some industries in City of Kigali. Are considered effluent from UTEXRWA, KABUYE SUGAR WORKS and a common point of Gikondo industrial park where many industries' effluent of the area converged. These because they are situated in the wetland where there are so many human activities. And assessment of physical- chemical parameters is done for water samples collected in July and August 2013. All the tree points are in the City of Kigali.

#### 1.6.2 Assumptions Of The Study

- The industrial wastewater effluent into urban wetland pollutes the ecosystem of Kigali.
- There is no any wastewater effluent treatment regime for the key identified pollution points.

### 1.7 Limitations Of The Study

The limitation of this study was the delay to get the laboratory result of the sample; and it required the researcher to do the best at minimizing the time so that much time is allocated to external limitations.

## 1.8 Definitions of The Terms

- **Environment**

The environment includes the surroundings, conditions or influences that directly or indirectly affect the life of an individual or community (Chenn, 1999).

- **Pollution**

Pollution is the presence in the environment of substances or energy in quantities that endanger human health, harm living organisms, diminish the amenity value of the environment or interfere with the natural functioning of ecosystems (Chenn, 1999)

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Introduction

This section helps the readers to understand the existing knowledge related to the present study. In this chapter there are Concepts, Opinions, and Ideas from Authors / Experts as well as related studies.

### 2.2 Concepts, Opinions, Ideas from Authors/ Experts

Various devastating ecological and human disasters of the last four decades implicate industries as a major contribution to environmental degradation and pollution (Ademoroti and Sridhar, 1979; Asia and Ademoroti, 2001; Abdel-Shafy and Abdel-Basir, 1991).

Environmental pollution due to increase of industrial activities are one of the most significant problems of the century. Pollution in soil and water is strictly related to human activities such as industry, agriculture, burning of fossil fuels, mining and metallurgical processes and their waste disposal (Guiliano *et al,* 2007).

An industry which uses the large amount of water in their processes includes chemical manufactures, steel plants, metal processors, etc. All types of effluents and most of by products from any kind of industry create a most serious pollution to the water and soil bodies (Baskaran *et al*, 2009) The contamination of soil is often a direct or indirect consequence of industrial activities (McLaughlin Parker *et al*, 1999).

Industries are the major sources of pollution in all environments. Based on the type of industry, various levels of pollutants can be discharged into the environment directly or indirectly through public sewer lines. Wastewater from industries includes employees' sanitary waste, process wastes from manufacturing, wash waters and relatively uncontaminated water from heating and cooling operations (Phiri *et al*, 2005).

High levels of pollutants in river water systems causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals such as Cd, Cr, Ni and Pb and fecal coliform and hence make such water unsuitable for drinking, irrigation and aquatic life. Industrial wastewaters range from high biochemical oxygen demand (BOD) from biodegradable wastes such as those from human sewage, pulp and paper industries, slaughter houses, tanneries and chemical industry. Others include those from plating shops and textiles, which may be toxic and require on-site physiochemical pre-treatment before discharge into municipal sewage system (Otokunefor and Obiukwu, 2005; Tolba, 1982; Dejoux *et al*, 1981).

For as far as we know, lead fulfills no essential function in the human body, it can merely do harm after uptake from food, air or water. Lead can cause several unwanted effects, such as: disruption of the biosynthesis of haemoglobin and anaemia, a rise in blood pressure, kidney damage, miscarriages and subtle abortions, disruption of nervous systems, brain damage, declined fertility of men through sperm damage, diminished learning abilities of children, behavioral disruptions of children, such as aggression, impulsive behavior and hyperactivity. Lead can enter a foetus through the placenta of the mother. Because of this it can cause serious damage to the nervous system and the brains of unborn children (http://www.lenntech.com/periodic/elements/pb.htm).

Nickel is a dietary requirement for a number of organisms; therefore it might be of significance to humans. Nickel cannot be resorbed in the digestive gland, unless it is a complex. Nickel inhalation poses a greater risk than nickel in water. This may cause lung cancer, or nasal tumors. Nickel carcinogenity is probably caused by nickel replacing zinc and magnesium ions on DNApolymerase. These observations were mainly made in nickel working employees. Usually only smoking may cause this problem. Many people develop dermatitis upon skin contact with nickel. The same goes for nickel solutions. Nickel allergies are more common among women than among men. Nickel compounds may be toxic in high concentrations, but these are often water insoluble, limiting potential harm. For example, nickel tetra carbonyl is water insoluble, but is toxic and carcinogenic nevertheless. Upon intake of higher doses of nickel one usually vomits, resulting in rapid removal from the body (http://www.lenntech.com/periodic/water/nickel/nickel-and-water.htm).

Arsenic related illness is usually caused by consumption of contaminated drinking water. In the old days it was applied as a poison, because symptoms of arsenic poisoning resemble cholera symptoms, and therefore the intentional factor was shaded. Under conditions of prolonged exposure, many organs may be damaged, skin pigmentation may occur, hair may fall out and nail growth may stop. Arsenic related health effects are usually not acute, but mostly encompass cancer, mainly skin cancer. Arsenic may cause low birth weight and spontaneous abortion.

Arsenic in drinking water is an issue of global importance; therefore the legal limit was decreased to 10 μg/L. This legal limit is not met in countries such as Vietnam and Bangladesh, where millions of people consume drinking water with an arsenic content of over 50 μg/L. This problem results in long-term chronic health effects, such as skin disease, skin cancer, and tumours in lungs, bladder, kidneys and liver (http://www.lenntech.com/periodic/water/arsenic/arsenic-and-water.htm).

Long-term exposure to copper can cause irritation of the nose, mouth and eyes and it causes headaches, stomachaches, dizziness, vomiting and diarrhea. Intentionally high uptakes of copper may cause liver and kidney damage and even death. There are scientific articles that indicate a link between long-term exposure to high concentrations of copper and a decline in intelligence with young adolescents. Industrial exposure to copper fumes, dusts, or mists may result in metal fume fever with atrophic changes in nasal mucous membranes. Chronic copper poisoning results in Wilson's Disease, characterized by a hepatic cirrhosis, brain damage, demyelization, renal disease, and copper deposition in the cornea (http://www.lenntech.com/periodic/elements/cu.htm)

High levels of COD in water often correlate with threats to human health including toxic algae blooms bacteria from organic wastes and seafood contamination. High COD levels decrease the amount of dissolved oxygen available for aquatic organisms. Low (generally under 3 mg/L) dissolved oxygen, or hypoxia, causes reduced cell functioning, disrupts circulatory fluid balance in aquatic species and can result in death of individual organisms as well as large dead zones. Hypoxic water can also release pollutants stored in sediment. Chemical oxygen demand (COD) is often used to measure organic matter in wastewater, treated effluent, and receiving waters. Although COD measures more than organic constituents, the organic fraction usually predominates and is the constituent of interest. Chemical oxygen demand was developed as an alternative to the more lengthy BOD analysis (http://www.stormwaterx.com/Resources/IndustrialPollutants/COD.aspx)

Phenol can have beneficial effects when used for medical reasons. It is an antiseptic (kills germs) when applied to the skin in small amounts and may have antiseptic properties when gargled as a mouthwash. It is an anesthetic (relieves pain) and is a component of certain sore-throat lozenges and throat sprays or gargles. Small amounts of phenol in water have been injected into nerve tissue to lessen pain associated with certain nerve disorders. Phenol destroys the outer layers of skin if allowed to remain in contact with skin, and small amounts of concentrated solutions of phenol are sometimes applied to the skin to remove warts and to treat other skin blemishes and disorders (http://www.eoearth.org/view/article/153418/).

Cyanide is used in a number of industries and is found at low levels in air from car exhaust. Cyanide is extremely toxic to humans. Chronic (long-term) inhalation exposure of humans to cyanide results primarily in effects on the central nervous system (CNS). Other effects in humans include cardiovascular and respiratory effects, an enlarged thyroid gland, and irritation to the eyes and skin. No data are available on the carcinogenic effects of cyanide in humans via inhalation. Animal studies have suggested that oral exposure to cassava (a cyanide-containing vegetable) may be associated with malformations in the fetus and low fetal body weights. The United States Environmental Protection Agency has classified cyanide as a Group D, not classifiable as to human carcinogenicity (http://www.epa.gov/ttnatw01/hlthef/cyanide.html)

Over the last years, in many African countries a considerable population growth has taken place, accompanied by a steep increase in urbanization, industrial and agricultural land use. This has entailed a tremendous increase in discharge of a wide diversity of pollutants to receiving water bodies and has caused undesirable effects on the different components of the aquatic environment and on fisheries (Emongor *et al*, 2005). As a result, there is growing appreciation that nationally, regionally, and globally, the management and utilization of natural resources need to be improved and that the amount of waste and pollution generated by human activities need to be reduced on a large scale.

People in developing countries have been using wetlands for water purification for quite a long time (Denny 1987; Mitsch and Jørgensen 1989, 2004; Blackwell *et al*, 2002; Zedler and Kercher 2005; Verhoeven *et al*, 2006).

Judith and Peddrick (2004) stressed the importance of knowing the processes of metal removal, uptake, and distribution in the wetland. The extent of uptake and how metals are distributed within plants can have important effects on the residence time of metals in plants, in wetlands and the potential release of metals when conditions change. Knowing this, one could understand these systems and ensure that wetlands do not themselves become sources of metal contamination. When using wetlands for wastewater treatment, intentionally or not, it is necessary to be aware of the amounts of pollutant that can be sequestrated by the wetland.

Ewers and Schlipkoter (1991), Denny *et al*, (1995) and Monday *et al* (2003) reported on the negative impact of heavy metals where they enter the food chain and accumulate in fish tissues, particularly into the liver; and Fleming and Trevors (1989) reported that copper in its ionized form could be lethal to fish. The physico-chemical parameters like pH, redox potential, and salinity affect the (im)mobility of heavy metal as reported by Kelderman *et al*, (2000), Kelderman and Osman (2007), and Du Laing *et al* (2008).

Industrial effluents contribute so much to the pollution of surface water by dumping solids waste and releasing liquid wastes containing pollutants in general like heavy metals (cadmium, chromium, lead, zinc, iron, mercury, copper and so on..) and other chemicals resulting from industrial processing. The other factor affecting also much the surface water quality is the erosion contributing to water pollution by sediments transport and suspended matters. As most of Rwandan hills and mountains have a steep slope, hence the soil moves to the valleys and reach the surface water (Niyigena & Masengesho, 2010).

## 2.3 Related Studies

Nowadays catchments are becoming polluted by various human activities, including littering, pouring chemicals down drains and industrial discharges, all of which are washed into creeks and stormwater drains. There is a clear link between population growth, urbanization, industrial development and human activities that are likely to generate pollution. Rwanda is one of the most densely populated African countries and after the 1994 genocide the population of the country continues to grow. On the other hand City of Kigali, the capital of Rwanda, is rapidly expanding with increased population growth and industrial development (KIEM, 2006).

The population of Kigali City is estimated to be over 1.2 million people (MINEFRA, 2007). This expansion has negatively affected water quality management in the city, especially wastewater management. Elevated levels of pollution have been reported in some of the major rivers passing through the City of Kigali, such as Nyabugogo River (Brenniman *et al*, 1997; Nkuranga, 2007; Usanzineza *et al*, 2009, 2011) and the Mpazi River (Usanzineza *et al*, 2010). The Nyabugogo Swamp feeds into the Nyabarongo River and is major outlet of the City of Kigali and it receives all the wastewater from City.

A number of authors (Usanzineza *et al* 2009, 2011) and (Mukankomeje *et al*, 1993) studied pollution in Lake Muhazi and attributed it to landuse activities in the catchment. Nkuranga (2007) observed that the Nyabugogo wetland receives all kinds of untreated wastewaters, including industrial discharges. He showed that wastewater from industrial areas that are discharging into the Nyabugogo Swamp is polluted with heavy metals beyond acceptable environmental standards. Muhirwa *et al* (2010) characterized wastewater from the Nyabugogo Abattoir which discharges into the Mpazi River, a tributary of the Nyabugogo River. They concluded that the effluent from the Nyabugogo Abattoir is heavely loaded with degradable organics and other pollutants that pose an environmental risk to the receiving Mpazi River (Usanzineza *et al*, 2010).

Further, Muhirwa *et al* (2010) identified Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), nutrients, chloride, calcium, total coliforms and TSS as the major pollutants from that abattoir (Usanzineza *et al*, 2010). Nshimiyimana (2008) studied another tributary of the Nyabugogo River, the Yanze River and he reported high levels of flooding, erosion, sedimentation and high levels of turbidity.

The Nyabugogo River is a tributary of the Nyabarongo River which in turn is the tributary of Akagera transboundary River which drains into Lake Victoria. Potentially this means that the Nyabugogo River contributes pollution to the

Lake Victoria. Lake Victoria is one of the major lakes in Africa but is greatly affected by increasing loads of pollution from anthropogenic activities, rendering the massive water body eutrophic (Scheren *et al*, 2002; Campbell *et al*, 2004)

## CHAPTER THREE: MATERIALS AND METHODS

### 3.1 Introduction

The research methodology is a systematic way of solving a problem. The chapter spells out the area of the study, location of sampling points, research design, and research instrument. Included also is the data analysis.

### 3.2 Description of the Study Area

The researcher tests effluent from UTEXRWA, Kabuye Sugar Works Factory and that of Gikondo industrial park. This area is located in the central eastern part of Rwanda. The climate of this area is mostly of temperate and equatorial type with average temperature ranging between 16°C and 23°C, depending on the altitude of the area.

The annual rainfall in Rwanda varies from about 800 mm to 1,600 mm. There are normally four seasons in Rwanda. The first is a long dry season that spans from June to September, followed by a short rainy season spanning from October to December. This season receives 30% to 40% of the annual rainfall with the highest rains falling in November. The third is a short dry season starting in December and ending in January. The fourth is a rainy season spanning from February to end of May. This season receives around 60% of annual the rainfall.

### 3.3 Location of Sampling Points

Three sampling sites were selected for the monitoring of pollution trends in the effluent from UTEXRWA, Kabuye Sugar Work Factory and Gikondo industrial park.

The following are sites' coordinates in meters, of the three sampling sites as per below Fig. 1

**Table 1: Sampling sites' coordinates**

| Sites | X | Y |
|---|---|---|
| Ruganwa | 507641 | 4785526 |
| UTEXRWA | 508341 | 4787086 |
| Kabuye | 507735 | 4790848 |

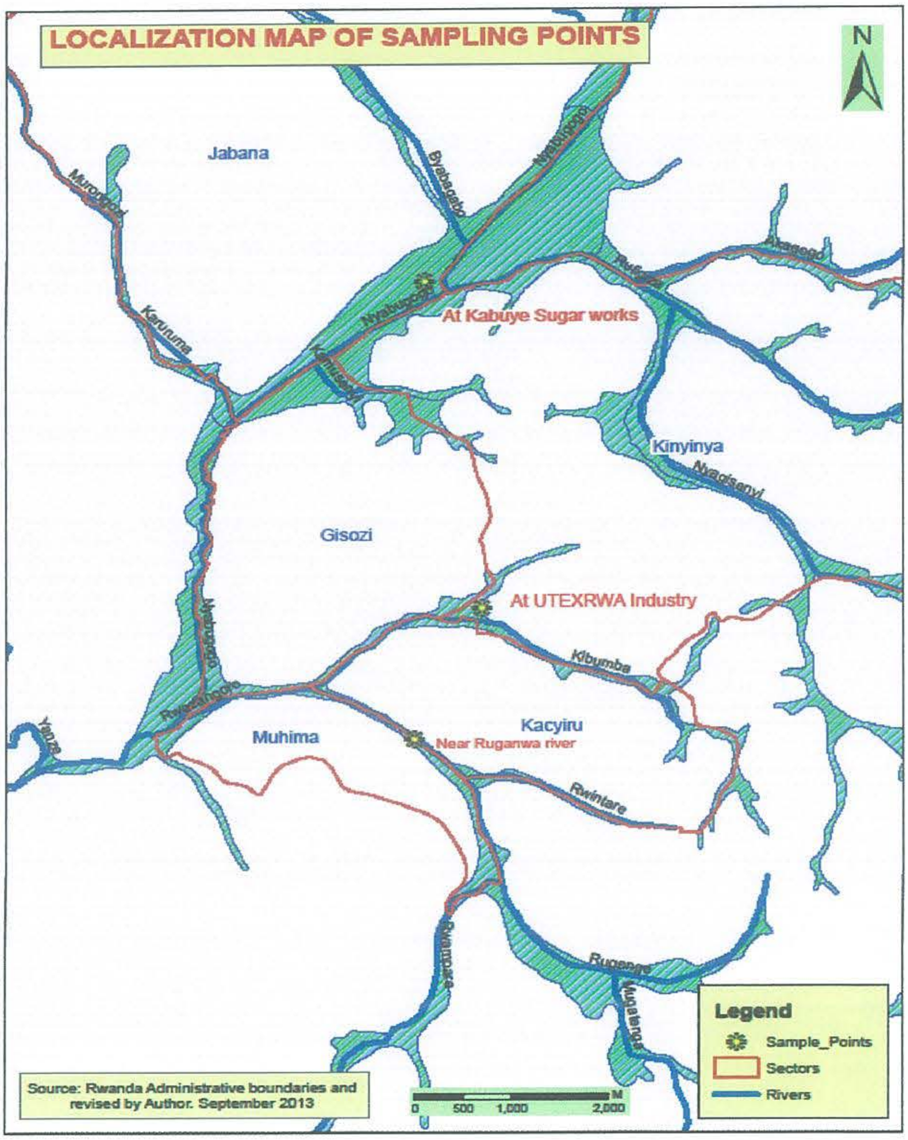


**Figure 1: Location of the three sampling points**

The rationale for choosing these sites was to ensure that the targeted industries by kind of their production could be isolated in order to be able to assess their contributions and effect.

### 3.4 Research Design

The data are either qualitative or quantitative in nature and they were analyzed according to different themes as identified in the literature and along with objectives of the study.

To establish the pollutants in the effluent of key point sources of Kigali, a laboratory analysis of effluent was done through experiment. Whereas to assess the effluent discharge management methods and treatments regimes, if any, of three key identified pollution point sources.

The three sampling point were frequently visited and local population proven the willing to talk to researcher. And the results from laboratory gives an insight on what observed and discussed with the population around.

#### 3.4.1 Samples Collection

The water samples were collected twice over 2 months using the grab sample method. Samples were collected and stored in 600 ml plastic bottles. The plastic bottles were rinsed overnight with 1M HCl and then with distilled water. The bottles were also rinsed thrice with sample water before final collection. And all parameters are analyzed in laboratory, no parameter analyzed directly on site.

The parameters analyzed were pH, total suspended solids (TSS) (mg/l), total dissolved solids (TDS) (mg/l), Chemical Oxygen Demand (COD) (mg/l), Biochemical Oxygen Demand (BOD) (mg/l) (20 C), Lead (Pb) (mg/l), Iron (Fe) (mg/l) and Zinc (Zn) (mg/l).

Then Oil and Grease (mg/l), Faecal Coliforms (mg/l), Ammonia ( as N) (mg/l), Arsenic (mg/l), Benzine (mg/l), Cadmium (mg/l), Hexavalent Chromium (mg/l), Copper (mg/l), Cyanide (mg/l), Mercury (mg/l), Nickel (mg/l), Phenol (mg/l), Sulphide (mg/l) and Total amount of heavy metals (mg/l).

### 3.4.2 Research Instruments

The following instruments were used to measure the concentration of different parameters in a sample of effluents from the three sites at different moment; Digital D.O meter for the measurement of dissolved oxygen, Didital TDS meter for the measurement of TDS, pH meter marque WTW pH 3110 set 2 for the measurement of Ph, Gas chromatography GC series 2010 for the measurement of organic compound and Spectrophotometer AAS; AA-7000 (Atomic Absorption Spectrophotometer) for the measurement of the rest heavy metals

## 3.5 Analysis of Results

Data analysis involves the assessment of the variation of pollutants at each sampling. For the above parameters the instrument gave the reading then recoded and presented in Table 2.

The deviation to the maximum permissible limits of Rwanda Bureau of Standard (RBS) was isolated by comparing what given by the instrument to the RBS standard of the industrial discharge wastewater.

The testimonies of the local population and what observed on ground were analyzed according to different themes and support in concluding.

# CHAPTER FOUR: RESULTS AND DISCUSSIONS

## 4.1 Presentation of the results

The water samples were analyzed to measure concentration of total suspended solids (TSS) (mg/l), total dissolved solids (TDS) (mg/l), Chemical Oxygen Demand (COD) (mg/l), Biochemical Oxygen Demand (BOD) (mg/l) (20 C), Lead (Pb) (mg/l), Iron (Fe) (mg/l) and Zinc (Zn) (mg/l).

The Oil & Grease (mg/l), Faecal Coliforms (mg/l), Ammonia ( as N) (mg/l), Arsenic (mg/l), Benzene (mg/l), Cadmium (mg/l), Hexavalent Chromium (mg/l), Copper (mg/l), Cyanide (mg/l), Mercury (mg/l), Nickel (mg/l), Phenol (mg/l), Sulphide (mg/l),Total amount of heavy metals (mg/l) and the level of pH. The measured values of the parameters were recorded two times over the two months.

Although UTEXRWA and Kabuye Sugar Work factory have a system of recycling wastewater, the following results were observed. Total dissolved solids (TDS) parameter at UTEXRWA site was found to be beyond the maximum permissible limit of the laboratory instrument and then no data recoded.

No benzene trace was detected in all the three sampling sites. And mercury is not present in both sites, Kabuye and Ruganwa whereas at UTEXRWA, it was found in very small amount.

Sometimes, Faecal Coliforms are absent at UTEXRWA site, and when they are available, they were found to be beyond the permissible limit of RBS.

The following are values of measured parameters, presented along with the permissible limits of Rwanda Bureau of Standard (RBS) for comparison (Table 1) some of the parameters presented here under exceed the maximum permissible limits of RBS.

Table 2: Values of measured parameters per site

| RBS | RUGANWA | | UTEXRWA | | KABUYE | | Sites / parameters |
|---|---|---|---|---|---|---|---|
| 5-9 | 7.8 | 7.4 | 10.8 | 11.5 | 4.1 | 4.4 | pH |
| 50 | 52.02 | 81.3 | 71.8 | 54.1 | 112.3 | 83 | TSS |
| 2000 | 146 | 390 | greater | greater | 427 | 237 | TDS |
| 250 | 350 | 364 | 398 | 483 | 233 | 274 | COD |
| 50 | 43 | 47 | 20 | 13 | 56 | 64 | BOD |
| 0.1 | 0.1 | 0.1 | 0.53 | 0.64 | 0.16 | 0.18 | Pb |
| 3.5 | 2.9 | 3.2 | 3.4 | 4.3 | 3 | 2.8 | Fe |
| 5 | 0.1 | 0.1 | 0.73 | 0.49 | 0.3 | 0.16 | Zn |
| 10 | 6.4 | 5.3 | 3.7 | 3.2 | 4.1 | 4.3 | Oil & Grease |
| 400 | 31000 | 14000 | 1000 | 0 | 28000 | 1000 | Faecal |
| 20 | 15.7 | 17.1 | 17.9 | 18.2 | 16.3 | 14 | $NH_4^{1+}$ |
| 0.01 | 0.07 | 0.05 | 0.2 | 0.3 | 0.003 | 0.001 | As |
| 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | Benzene |
| 0.01 | 0.03 | 0.06 | 0.07 | 0.41 | 0.08 | 0.02 | Cd |
| 0.05 | 0.03 | 0.05 | 0.02 | 0.07 | 0.02 | 0.03 | Cr (VI) |
| 3 | 4.5 | 5.6 | 6.65 | 6.19 | 4.5 | 4.32 | Cu |
| 0.1 | 0.3 | 0.1 | 0.5 | 0.6 | 0.1 | 0.2 | CN |
| 0.0002 | 0 | 0 | 0.0001 | 0.0003 | 0 | 0 | Hg |
| 3 | 4.1 | 4.9 | 3.6 | 2.18 | 3.7 | 3.5 | Ni |
| 0.2 | 0.55 | 0.53 | 0.25 | 0.23 | 0.47 | 0.43 | Phenol |
| 1 | 0.51 | 0.57 | 0.78 | 0.82 | 0.31 | 0.31 | $S^{2-}$ |
| 10 | 0.65 | 0.43 | 2.38 | 2.07 | 0.24 | 0.26 | Total Heavy metals |

Based on permissible limits of industrial discharge of Rwanda Bureau of Standards (RBS), the three sampling sites are being polluted mainly because they have a higher concentration of TSS, COD, Faecal Coliforms, Cd, Cu, CN, Ni and Phenol.

Two sites may share the same situation of having a higher concentration of the following, Pb is higher at Kabuye and UTEXRWA, As at UTEXRWA and RUGANWA and for another hand one site has the particularity of having a higher concentration, TDS is higher at UTEXRWA, BOD at KABUYE, Fe at UTEXRWA, Cr (VI) at UTEXRWA and Hg is higher at UTEXRWA. All the above were compared to the maximum permissible limits of RBS. The pH value was found to be higher at UTEXRWA and lower at Kabuye which means that the UTEXRWA site is more alkaline whereas the Kabuye site is more acidic.

However, other parameters were found to be in range or lower permissible limits of RBS or even absent at the time of sampling, those are: Zn, Oil and Grease, ammonia (as N), sulphide, benzene and the total amount of heavy metals.

The adverse effects of those pollutants are a critical environmental problem on the surrounding community since those points are located in wetland and the concentration of anthropogenic activities can be observed around as shown in Fig 2, 3 and 4.

At all the three sampling points, so many agriculture activities are observed; near the point local population used the water for so many household activities including washing cloths and so on. Three people who ware cultivating around the UTEXRWA point testified that, it is so painful when that water arrived on wound and one man said that the sweet potato from around are sweeter comparing to others from any way.

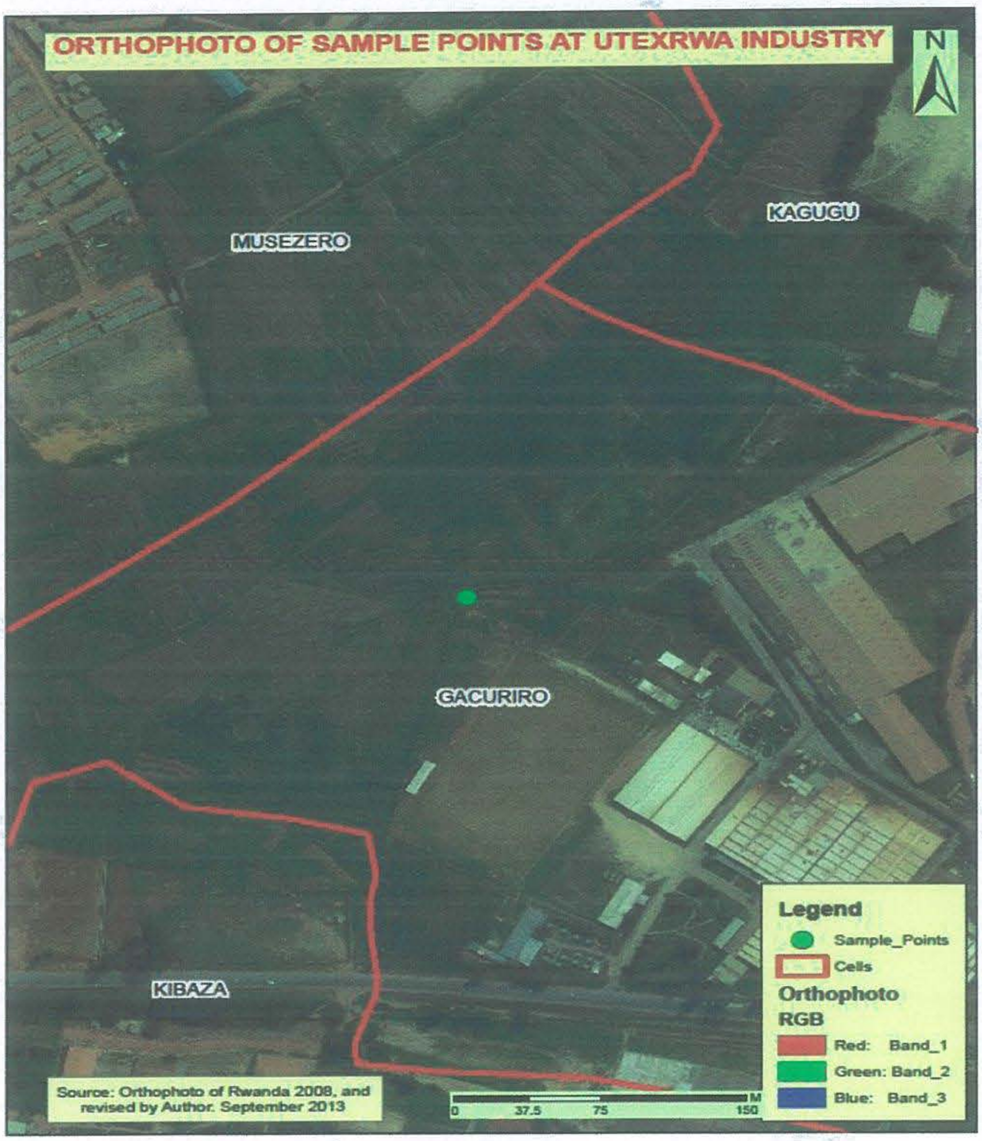


Figure 2: An orthophoto of sampling point at UTEXIRWA


Figure 3: An orthophoto of sampling point at RUGANWA


Figure 4: An orthophoto of sampling point at KABUYE

### 4.2 Interpretation and discussion of results

The comparison between the industrial effluents and the national standards for industrial discharge reveals that there is a significant concentration difference between different values at sampling site and their related standards limit from RBS; for TDS, Fe, Zn, Oil & Grease, Arsenic, Hexavalent Chromium, total amount of heavy metals, Pb, Cu, Ni, and Phenol at Kabuye site; BOD, Zn, Oil & Grease, Ammonia ( as N), Total, COD, Arsenic ,Cu and Cyanide at UTEXRWA site and for Ruganwa site, TDS, Oil & Grease, Ammonia ( as N), Sulphide, total, COD and Phenol.

For the purpose of this study the researcher continued with those parameters exceeding the permissible limits of RBS which are Pb, Cu, Ni, and Phenol at Kabuye site; COD, Arsenic ,Cu, TDS and Cyanide at UTEXRWA site and , COD and Phenol at Ruganwa site.

The COD is a measure of the oxygen, equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant. It is widely used as a measure of the susceptibility to oxidation of the organic and inorganic materials present in water bodies and in the effluents from sewage and industrial plants. According to Chapman (1996), the concentrations of COD in surface waters range from 20 mg/l oxygen or less in unpolluted waters and 200 mg/l oxygen or greater in the waters that receiving effluents. The COD was high when compared to the standard for the two sites, UTEXRWA and Ruganwa. These high values of COD are an indication of the water pollution mainly due to the surrounding human activity occurring near the sites (at Ruganwa). And it is due to the dumping of wastewater coming from industrial activity in the surrounding area at UTEXRWA.

Lead is found naturally in the environment, though usually at very low concentrations unless affected by inputs from human activities, with uncontaminated soils and freshwater sediments typically containing less than 30 mg/kg of lead (Alloway, 1990; ATSDR 2007).

Results from this study show that lead concentration is higher at Kabuye and UTEXRWA site than the required standard limit of lead concentration of RBS. This is due to industrial discharges of KABUYE SUGAR WORKS and UTEXRWA; from lead piping in the water distribution system, paint pigments at UTEXRWA. This high presence of lead in effluent contaminates the wastewater to the extent that the surrounding is affected.

Lead has no known biochemical or nutritional function and is highly toxic to humans as well as many animals and plants (ATSDR, 2007; WHO, 1989). Levels can build up in the body through repeated exposure and have irreversible effects on the nervous system, which is of particular concern for the developing nervous system in young humans. Other effects include damage to the blood system and impacts on the kidneys and on reproduction (ATSDR, 2004; Sanders *et al*, 2009). Recent studies indicate that there may be no safe level of exposure, particularly in the developing central nervous system (Canfield *et al*, 2003).

Nickel has many industrial uses, including in the manufacture of printed circuit boards (ATSDR, 2005; USEPA, 1998). Levels of nickel in the environment are typically low, with uncontaminated soils and sediments generally containing below 60 mg/kg (Alloway, 1990; ATSDR, 2005).

The results from this study again, are showing that nickel concentration is higher at Kabuye site than the required standard limit of RBS and this is due to the fact that nickel is used in sugar processing as powdered nickel-aluminum alloy thus polluting the wetland because it is so concentrated in the effluent from Kabuye Sugar Works.

Very small amounts of nickel are essential for normal growth and reproduction in most animals and plants, and this is most likely also true for humans (ATSDR, 2005; Alloway, 1990). However, toxic and carcinogenic effects can result from exposure to higher concentrations for a wide range of life forms, including gastrointestinal and cardiac effects (ATSDR, 2005; Cempel and Nikel, 2006). In humans, around 2-5% of the populations are nickel sensitive, and toxic effects can occur in sensitized individuals at far lower concentrations than usual (ATSDR, 2005). For some aquatic organisms, impacts can occur at very low nickel concentrations (Deleebeeck *et al*, 2008). Furthermore, some nickel compounds have been classified as carcinogenic to humans, and there is also evidence of carcinogenicity in animals (DHHS, 2005; IARC, 1990).

Arsenic (As) is found in the environment in ever increasing amounts, in both soils and groundwater, due to both natural and anthropogenic causes (Smith *et al*, 1998). The arsenic concentration is higher at UTEXRWA site than the required limits of industrial effluent standards of RBS. This higher concentration results from washing products, old paints and pigments from UTEXRWA industry as effluent. Arsenic is present mainly as DMAA (dimethylarsinic acid) and as As (III) (arsenite) in urban effluents and sewage sludge (Carbonell-Barrachina *et al*, 2000).

According to the World Health Organization (WHO, 2004) contamination of ground and surface water by As from soils and aquifers poses a significant threat to human health. Arsenic is a toxic trace element of great contemporary concern due to its contamination of ground and surface water throughout the world (Blumbla and Keefer, 1994; USEPA, 2001; Mead, 2005). Because arsenic readily changes valence states and reacts to form species with varying toxicity and mobility, effective, long term treatment of arsenic can be difficult. Arsenic was identified as the second most common contaminant of concern at Superfund Sites (USEPA, 2002).

Copper (Cu) is a widely used metal, including uses in the manufacture of electronics products, primarily due to its high electrical conductivity as a pure metal or as part of mixtures (alloys) with other metals. Copper compounds are also used as components of dyes and printing inks (ATSDR, 2004; OECD, 2003; TAPPI, 2008). Levels of copper in the environment are typically quite low, commonly less than 50 mg/kg in uncontaminated freshwater sediments (ATSDR, 2004). Background concentration of copper in uncontaminated surface waters can vary significantly, but levels are typically below 10 µg/l (ATSDR, 2004; Comber *et al*, 2008).

Copper was found to be higher than the required limits of industrial effluent standards of RBS at both Kabuye and UTEXRWA sites. It comes mainly from corrosion and leaching of plumbing, fungicides (cuprous chloride), pigments, larvicides (copper acetoarsenite) and antifouling paints due its presence at higher quantity in effluent from UTEXRWA and Kabuye Sugar Works.

Copper is an important element for humans and animals in low doses, though exposure to high levels can lead to bioaccumulation and toxic effects (ATSDR, 2004). However, many aquatic organisms are extremely sensitive to copper, particularly in soluble forms which are generally far more bioavailable and toxic to a wide range of aquatic plants and animals (ATSDR, 2004, Adams and Chapman, 2006); with some effects occurring at extremely low concentrations (Sandahl *et al*, 2007).

Phenols are an important group of pollutants which enter water bodies in the waste discharges of many different industries (Chapman, 1996). The most common anthropogenic sources of phenol in natural water include coal tar (Thurman, 1982) and waste water from manufacturing industries such as resins, plastics, fibers, adhesives, iron, steel, aluminum, leather, rubber (EPA, 1981b), and effluents from synthetic fuel manufacturing (Parkhurst *et al* 1979). Phenol is also released from paper pulp mills (Keith, 1976) and wood treatment facilities (Goerlitz *et al*, 1985). Other releases of phenol result from commercial use of phenol and phenol-containing products, including slimicides, general disinfectants (Budavari *et al*, 1989; Hawley, 1981), and medicinal preparations such as throat lozenges, mouthwashes, gargles, and antiseptic lotions (Darisimall, 2006). This is the case of Ruganwa site, where the higher concentration phenol was found to be significantly higher than the standard of RBS because all effluent from Gikondo Industrial park passes through, the pollution of that river phenol is attributed to so different industries located in Gikondo-Nyabugogo wetland before the point.

The higher concentration of phenol at Kabuye site comparing to the required standards limits of RBS is due to the fact that Phenol red glucose (dextrose) broth is thus used to determine whether the microbe can use the sugar glucose for carbon and energy.

Phenol is also formed naturally during the metabolism of aquatic organisms, biochemical decay and transformation of organic matter, in the water column and in bottom sediments. Phenols are aromatic compounds with one or few hydroxy groups.

They are easily biochemically, photochemically or chemically oxidised. As a result, they have detrimental effects on the quality and ecological condition of water bodies through direct effects on living organisms and the significant alteration of biogeneous elements and dissolved gases, principally oxygen.

The presence of phenols causes a marked deterioration in the organoleptic characteristics of water and as a result they are strictly controlled in drinking water and drinking water supplies. Concentrations of phenols in unpolluted waters are usually less than 0.02 mg/l. However, toxic effects on fish can be observed at concentrations of 0.01 mg/l and above (Chapman, 1996).

Compounds of cyanide enter freshwaters with wastewaters from industries such as the electroplating industry. Cyanide was found to be higher at UTEXRWA with an average concentration of 0.55 mg/l because it is used in textile industry. UTEXRWA is polluting the wetland by its effluent containing a high dose of cyanide.

Cyanides occur in waters in ionic form or as weakly dissociated hydrocyanic acid. In addition, they may occur as complex compounds with metals. Concentrations of cyanides in waters intended for human use, including complex forms, are strictly limited because of their high toxicity. The World Health Organization recommends a maximum concentration of 0.07 mg/l cyanide in drinking water, but many countries apply stricter standards of cyanide concentration both for drinking waters and natural water of importance for fisheries (Chapman, 1996).

Hexavalent chromium, Cr (VI), is the toxic form of chromium released during many industrial processes including electroplating, leather tanning, and pigment manufacture. Chromium is an essential element required for normal carbohydrate and lipid metabolism (Anderson, 1998).

Its deficiency leads to increase in risk factors associated with diabetes and cardiovascular diseases including elevated circulating insulin, glucose, triglycerides, total cholesterol and impaired immune function. Contrary to deficiency symptoms, several factors make chromate contamination as a matter of intense concern, particularly its toxic, mutagenic (Cheng and Dixon, 1998), carcinogenic (Shumilla *et al*, 1999) and terartogenic (Asmatullah *et al*, 1998) effects.

The Hexavalent chromium was found to be higher at UTEXRWA site because it is a textile industry which uses it. Then UTEXRWA is polluting the environment by the presence of higher amount of Hexavalent chromium in its effluent.

Biochemical Oxygen Demand (BOD) is common measure of water quality that reflects the degree of organic matter pollution of a water body. BOD is a measure of the amount of oxygen removed from aquatic environments by aerobic micro-organisms for their metabolic requirements during the breakdown of organic matter. Systems with high BOD tend to have low dissolved oxygen concentrations. Increased BOD can result in the death of fish and other animals (UNEP, 1999). The Kabuye site was found to have a higher value because of the effluent from Kabuye Sugar Work Factory

The presence of iron in natural waters can be attributed to the weathering of rocks and minerals, acidic mine water drainage, landfill leachates, sewage effluents and iron-related industries (Hem, 1972; Bell, 1975; James 1977; Oliver and Cosgrove, 1975). At UTEXRWA site, the concentration of iron was found to be higher comparing to the standard of RBS due to its activities of textile.

Coliforms come from human and animal wastes (feces). During rainfalls, snow melts, or other types of precipitation, fecal bacteria may be washed into rivers, streams, lakes, or ground water. When these waters are used as sources of drinking water and the water is not treated or inadequately treated, fecal bacteria may end up in drinking water. Breaks in sewage infrastructure and septic failures also can lead to contamination. The presence of coliform bacteria in water is an indicator of possible pollution by fecal material (UNEP,1999). All the three sampling sites have exceeded the maximum permissible limits of fecal coliform, but it was observed that when the pH was high at UTEXRWA sites, no fecal coliform observed.

# CHAPTER FIVE: CONCLUSIONS, RECOMMENDATIONS

## 5.1 Conclusions

This study was carried out according to the objectives: to establish the pollutants in the effluent of key point sources of Kigali and then assess the effluent discharge management methods and treatments regimes, if any, of three key identified pollution point sources.

The effective management of industrial effluent is a critical component of a comprehensive approach of treatment of wastewater and essential to long term success of the safety environment, as far as, the environment of Kigali city is concerned.

The first chapter introduces the study, the second one helps the readers to understand the existing knowledge related to the present study whereas the third is the research methodology which is a systematic way of solving a problem. Data are presented, analyzed and interpreted in chapter four then conclusions and recommendations are found in chapter five.

Industrial wastewaters are contributing so much to the pollution of water resources. This is mainly due to the lack of on-site treatment system and where the system exists, it does not meet the requirement for effluent standard before their dumping into surface water. UTEXRWA and KABUYE SUGAR WORKS are examples for such industries.

It was found that there is a higher concentration of TSS, COD, Faecal Coliforms, Cd, Cu, CN, Ni and Phenol in all the tree sampling sites. And Pb at Kabuye and UTEXRWA, As at UTEXRWA and RUGANWA and then TDS at UTEXRWA, BOD at KABUYE, Fe at UTEXRWA, Cr (VI) at UTEXRWA and Hg is higher at UTEXRWA. The pH value was found to be higher at UTEXRWA and lower at Kabuye. All those are compared to the maximum permissible limits of RBS.

The comparison gives an insight and it the conclusion of this study that the urban wetland is polluted by untreated or partial treated industrial wastewater effluents.

All the three sampling sites are surrounded by so many anthropogenic activities, agriculture activities, car washing, clothes washing, the list is not exhaustive. In addition to this, when there is a shortage of water around those rivers; the surrounding population uses it for household activities.

The excessive concentration of those chemicals in those effluents causes several unwanted effects to human health including death, they can be accumulated in the bodies of water organisms and soil organisms due so many divers effect to flora and fauna and lack of aquatic life.

The government of Rwanda, through its different agencies should do the best to ensure that effluents are not damaging our environment for safety of the whole local community. And the population should not be exposed to effluent to avoid to be contaminated.

The principle of intergeneration equity should guide us, as environmental protection is concerned. This is the use of environment, natural resources for the present and future generations.

## Recommendations

### To government

- Government should a set up a mechanism to remove heavy metals in urban wetland.

Government should monitor wastewater discharges.

**To local community**

- They should stop using the wastewater which has a connection with effluent from KABUYE SUGAR WORKS, UTEXRWA and Gikondo industrial park unless those effluents have been first treated by generating industries and authorized by RBS or REMA.

**To private sector**

- They should ensure that environment is safeguarded, by processing first in treating effluent and not discharging poisons.

- The installation of powerful treatment regime and analytical laboratory are required to all industries.

**Areas for further studies are:**

- Removal of contaminants in the environment surrounded the discharge point of generating industries

- Public health problems of the people who are always exposed to the effluent from UTEXRWA, Kabuye Sugar Works and Gikondo industrial park.

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## APPENDIX I

## TRANSMITTAL LETTER

KAMPALA INTERNATIONAL UNIVERSITY

Ggaba Road, Kansanga
P.O BOX 20000 Kampala, Uganda
Tel: +256-414-266813
Mob: +256-701-088552
Fax: +256 414 501974
E-mail: [illegible]
Website: www.kiu.ac.ug

OFFICE OF THE HEAD

DEPARTMENT OF BIOLOGICAL & ENVIRONMENTAL SCIENCE,
COLLEGE OF APPLIED SCIENCE & TECHNOLOGY (CAST)

Date: 18th March, 201[illegible]

[illegible]

RE: REQUEST FOR EDWIN BYUSA MEM/37091/121/DF TO CONDUCT RESEACH IN YOUR ORGANISATION

[illegible] Kampala International University [illegible] Environmental Management & Development.

[illegible] for his dissertation entitled: **Pollution Control of Industrial Effluent and its Impact on the Surrounding Communities of [illegible]**

[illegible] research project. The purpose of this letter is to request you to avail him with the pertinent information he may need.

Any information shared with him from your organization shall be treated with utmost confidentiality.

Any assistance rendered to him will be highly appreciated.

Yours truly,

[illegible] PhD
Head of Department

[illegible]

## APPENDIX II

## AUTHORIZATION LETTER FOR CONDUCTING A RESEARCH IN KIGALI CITY

[illegible]  Kigali, [illegible]

Edwin BYUSA
Kigali-Rwanda

Re: **Authorisation to conduct a research in the City of Kigali**

Reference is made to your letter dated [illegible] June 201[illegible] requesting for authorisation to conduct a research in the City of Kigali.

Reference is also made to Kampala International University letter dated 18th March 201[illegible]

The City of Kigali, hereby, gives you the authorization to conduct your research. Kindly get in touch with the Director of Infrastructure who shall guide you on how to carry out that research.

Regards,

[illegible] Jean Marie
Executive Secretary City of Kigali

Cc

His Worship the Mayor, City of Kigali
Vice Mayors
Director of Human Resources and Administration
Director of Infrastructure
KIGALI

[illegible]

# APPENDIX III

## PERMISSIBLE LIMITS FOR INDUSTRIAL DISCHARGE WASTEWATER FROM RWANDA BUREAU OF STANDARDS (RBS)

RS 461:2009

### 4. Permissible limits

[illegible] following table gives permissible limits for industrial discharge wastewater

Table 1: Discharge standard for Industries in general

| S/N | Parameter | Permissible limits | Test methods |
|---|---|---|---|
| 1 | Temperature increase °C | [illegible] | Thermometer |
| 2 | Total suspended solids mg/l | 50.0 | ISO 11923:1997 |
| 3 | Total Dissolved Solids mg/l | [illegible] | ISO 7888:1985 |
| 4 | Oil and grease mg/l | 10.0 | ISO 9377-2:2000 |
| 5 | BOD₅ mg/l (20 °C) | 50.0 | ISO 5815-2:2003 |
| 6 | COD mg/l | 250.0 | ISO 6060:1989 |
| 7 | Faecal Coliforms MPN/100ml | 400 | ISO 4831:2006 |
| 8 | Ammonia (as N) mg/l | 20.0 | ISO 6778:1984 |
| 9 | Arsenic mg/l | 0.01 | ISO 11969:1996 |
| 10 | Benzene mg/l | 0.1 | ISO 11423-2:1997 |
| 11 | Cadmium mg/l | 0.01 | ISO 5961:1994 |
| 12 | Hexavalent Chromium mg/l | 0.05 | ISO 23913:2006 |
| 13 | Copper mg/l | 3.0 | ISO 8288:1986 |
| 14 | Cyanide mg/l | 0.1 | ISO 6703-1:1984 |
| 15 | Iron mg/l | 3.5 | ISO 6332:1988 |
| 16 | Lead mg/l | 0.1 | ISO 8288:1986 |
| 17 | Mercury mg/l | 0.0002 | ISO 5666:1999 |
| 18 | Nickel mg/l | 3.0 | ISO 8288:1986 |
| 19 | Phenol mg/l | 0.2 | ISO 8165-1:1992 |
| 20 | Sulphide mg/l | 1.0 | ISO 13358:1997 |
| 21 | Zinc mg/l | 5.0 | ISO 8288:1986 |
| 22 | pH | [illegible] | ISO 10523:1994 |

[illegible]

[illegible] National Measurement Act

Appendix III. Received from RBS in June 2013

## APPENDIX IV

## PROPOSED DATA PRESENTATION THROUGH TABLES

Kigali Institute of Education
Faculty of Sciences
P.O Box 5039 Kigali - Rwanda
Tel: (250) 0255100589
Fax: (250) 586890
E-mail: deanfs@kie.ac.rw

Names of Student: EDWIN BYUSA MEM/37091/121/DF

Department of biological & Environmental science,

College of applied science & technology (CAST)

Date: 22/08/2013

Name of site [illegible]

[illegible]

| Parameter Analyzed | Units | Results |
|---|---|---|
| pH | | [illegible] |
| TSS (Total suspended Solids) | mg/l | [illegible] |
| TDS (Total dissolved solids) | mg/l | [illegible] |
| COD (Chemical oxygenDemand) | mg/l | 274 |
| BOD (Biochemical oxygen Demand) | mg/l | 94 |
| Pb (Lead) | mg/l | 0.18 |
| Fe (Iron) | mg/l | 2.8 |
| Oil & grease | mg/l | 1.1 |
| Ammonia | mg/l | 4 |
| Arsenic | mg/l | 0.007 |
| Benzene | mg/l | 0 |
| Cadmium | mg/l | 0.02 |
| Hexavalent Chromium | mg/l | 0.03 |
| Copper | mg/l | [illegible] |
| Cyanide | mg/l | [illegible] |
| Mercury | [illegible] | [illegible] |
| Nickel | [illegible] | [illegible] |

## APPENDIX IV cont…

| | | |
|---|---|---|
| Phenol | [illegible] | [illegible] |
| Sulphide | mg/l | [illegible] |
| Total heavy metals | mg/l | [illegible] |
| Faecal coliforms | /100 ml | [illegible] |
| Zinc | | [illegible] |

**Name of site:** BH/01 SAMPLED ON 31.07.2013

| Parameter Analyzed | Units | Results |
|---|---|---|
| pH | | 11.5 |
| TSS (Total suspended Solids) | mg/l | 54.14 |
| TDS (Total dissolved solids) | mg/l | 2000 |
| COD (Chemical oxygenDemand) | mg/l | 483 |
| BOD (Biochemical oxygen Demand) | mg/l | 13 |
| Pb (Lead) | mg/l | 0.64 |
| Cadmium | mg/l | [illegible] |
| Oil & grease | mg/l | [illegible] |
| Ammonia | mg/l | [illegible] |
| Arsenic | mg/l | [illegible] |
| Benzene | mg/l | [illegible] |
| Chromium | mg/l | [illegible] |
| Hexavalent Chromium | mg/l | [illegible] |
| Copper | mg/l | [illegible] |
| Cyanide | mg/l | [illegible] |
| Mercury | mg/l | [illegible] |
| Nickel | mg/l | 2.18 |
| Phenol | mg/l | [illegible] |
| Sulphide | mg/l | [illegible] |
| Total heavy metals | mg/l | [illegible] |
| Faecal coliforms | /100 ml | [illegible] |
| Zinc | | 0.19 |

**Name of site:** CH/01 SAMPLED ON 31.07.2013

| Parameter Analyzed | Units | Results |
|---|---|---|
| pH | | [illegible] |
| TSS (Total suspended Solids) | mg/l | 81.34 |
| TDS (Total dissolved solids) | mg/l | [illegible] |
| COD (Chemical oxygenDemand) | mg/l | [illegible] |
| BOD (Biochemical oxygen Demand) | mg/l | [illegible] |
| Pb (Lead) | mg/l | [illegible] |
| Cadmium | mg/l | [illegible] |
| Oil & grease | mg/l | [illegible] |
| Ammonia | mg/l | [illegible] |
| Arsenic | mg/l | [illegible] |

**APPENDIX IV cont…**

| | | |
|---|---|---|
| Benzene | mg/l | 0 |
| Cadmium | mg/l | 0.06 |
| Hexavalent Chromium | mg/l | 0.05 |
| Copper | mg/l | 8.6 |
| Cyanide | mg/l | 0.1 |
| Mercury | mg/l | 0 |
| Nickel | mg/l | [illegible] |
| Phenol | mg/l | 0.53 |
| Sulphide | mg/l | 0.57 |
| Total heavy metals | mg/l | 0.43 |
| Feacal coliforms | Cfu/ml | 1.4X102 |
| Zinc | | 0.1 |

Approved by Gilles KARASIRA
In charge of Laboratories

**APPENDIX IV cont…**

Kigali Institute of Education
Faculty of Sciences
P.O Box 5039 Kigali – Rwanda
Tel: (250) 0255100389
Fax: (250) 586890
E-mail: deanfs@kie.ac.rw

Names of Student: EDWIN BYUSA MEM/37091/121/DF

Department of biological & Environmental science,

College of applied science & technology (CAST)

Date: 22/08/2013

PHYSICOCHEMICAL AND MICROBIOLOGICAL ANALYSIS REPORT

Name of site: A/0/02 SAMPLED ON 01/08/2013

| Parameter Analyzed | Units | Results |
|---|---|---|
| pH | | 4.1 |
| TSS (Total suspended Solids) | mg/l | 112.26 |
| TDS (Total dissolved solids) | mg/l | 427 |
| COD (Chemical oxygen demand) | mg/l | 233 |
| BOD (Biochemical oxygen Demand) | mg/l | 96 |
| Pb (Lead) | mg/l | 0.16 |
| [illegible] | mg/l | [illegible] |
| Oil & grease | mg/l | 13 |
| Ammonia | mg/l | 36 |
| Nitrate | mg/l | 0.002 |
| Benzine | mg/l | 0 |
| Cadmium | mg/l | 0.08 |
| Hexavalent Chromium | mg/l | 0.02 |
| Copper | mg/l | 3.5 |
| Cyanide | mg/l | 0.1 |
| Mercury | mg/l | 0 |
| Nickel | mg/l | 3.7 |

## APPENDIX IV cont…

| | | |
|---|---|---|
| Phenol | mg/l | 0.47 |
| Sulphide | mg/l | 0.51 |
| Total heavy metals | mg/l | 0.24 |
| Feacal coliforms | Cfu/ml | 2.8x102 |
| Zinc | | 0.3 |

Name of site: [illegible] SAMPLED ON 01-08-2013

| Parameter Analyzed | Units | Results |
|---|---|---|
| pH | | 6.8 |
| TSS (Total suspended Solids) | mg/l | 7.8 |
| TDS (Total dissolved solids) | mg/l | 2000 |
| COD (Chemical oxygen Demand) | mg/l | [illegible] |
| BOD (Biochemical oxygen Demand) | mg/l | 20 |
| Pb (Lead) | mg/l | 0.53 |
| Fe (Iron) | mg/l | 3.4 |
| Oil & grease | mg/l | 3.7 |
| Ammonia | mg/l | 13.9 |
| Arsenic | mg/l | 0.2 |
| Benzine | mg/l | 0 |
| Cadmium | mg/l | 0.07 |
| Hexavalent Chromium | mg/l | 0.02 |
| Copper | mg/l | 6.65 |
| Cyanide | mg/l | 0.5 |
| Mercury | mg/l | 0.00013 |
| Nickel | mg/l | 3.6 |
| Phenol | mg/l | [illegible] |
| Sulphide | mg/l | [illegible] |
| Total heavy metals | mg/l | [illegible] |
| Feacal coliforms | Cfu/ml | [illegible] |
| Zinc | | [illegible] |

Name of site: [illegible] SAMPLED ON 01-08-2013

| Parameter Analyzed | Units | Results |
|---|---|---|
| pH | | 7.8 |
| TSS (Total suspended Solids) | mg/l | 52.02 |
| TDS (Total dissolved solids) | mg/l | 140 |
| COD (Chemical oxygenDemand) | mg/l | [illegible] |
| BOD (Biochemical oxygen Demand) | mg/l | 13 |
| Pb (Lead) | mg/l | 0.1 |

**APPENDIX IV cont…**

| | | |
|---|---|---|
| Fe (Iron) | mg/l | 2.9 |
| Oil & grease | mg/l | 6.4 |
| Ammonia | mg/l | 5.7 |
| Arsenic | mg/l | 0.07 |
| Benzene | [illegible] | [illegible] |
| Cadmium | [illegible] | [illegible] |
| Hexavalent Chromium | [illegible] | [illegible] |
| Copper | [illegible] | [illegible] |
| Cyanide | [illegible] | [illegible] |
| Mercury | [illegible] | [illegible] |
| Nickel | [illegible] | [illegible] |
| Phenol | mg/l | [illegible] |
| Sulphide | mg/l | 0.51 |
| Total heavy metals | mg/l | [illegible] |
| Faecal coliforms | Cfu/ml | [illegible] x 102 |
| Zinc | | 9.1 |

Approved by Gilles KARASIRA
In charge of Laboratories