# IMPACT OF INDUSTRIAL EFFLUENTS ON WATER QUALITY OF RECEIVING STREAMS IN NAKAWA-NTINDA, UGANDA

**BY**

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## DECLARATION

I Walakira Paul do here by declare that this research work is my own and all the contents presented are original except where stated by the references and that the same work has not been submitted for award of a degree at this or any other University or institution of higher learning.

Signed………………………………… Date…………………………………..

**SUPERVISORS:**

This dissertation has been submitted for examination with the approval of the following supervisors:

**Dr. James Okot-Okumu** **Dr. J.R.S. Tabuti**

Signed………………………… Signed…………………………

Date…………………………… Date……………………………

## Dedication

This dissertation is dedicated to my dear wife, Maria Walakira and the entire family of Ms. Mary Nagawa.

**Acknowledgement**

I am highly indebted to the management and staff of the Uganda National Bureau of Standards (UNBS) and National Water and Sewerage Corporation (NWSC) analytical laboratory for the kind assistance offered to me at various stages during the research. Special thanks are further extended to Dr. James Okot-Okumu and Dr. J.R.S. Tabuti, my supervisors, for their sincere commitment and guidance during the research work and writing up of the dissertation.

**ACRONYMS**

| | |
|---|---|
| APHA: | American Public Health Association |
| NEMA: | National Environment Management Authority |
| NTUs: | Nephelometric Turbidity Units |
| WHO: | World Health Organization |
| AOAC: | Association of Official Analytical Chemists |
| TDS: | Total Dissolved Solids |

## ABSTRACT

The impact of industrial effluents on water quality of receiving streams in Nakawa -Ntinda industrial area was assessed so that preventive measures may be taken. The streams pass through Kinawataka wetland that is being degraded thus increasing the degree of pollution into Lake Victoria. Water samples were taken from areas with active industrial activities and from an area where there is no industrial activity.

Both the effluents and the water samples at selected points in the stream were analysed for pH (ranged from 3.68±0.17 to 12.41±4.68 mg/l), EC (ranged from 212±51.31 to 4633±154.42 $\mu Scm^{-1}$), turbidity (ranged from 20.9±0.42 to 715.9±9.31 NTU), colour (ranged from 72±2.11 to 958±86.52 TCU), BOD (ranged from 16.4±0.45 to 325.5±40.32 mg/l), COD (ranged from 39±1.22 to 1351±321.04 mg/l), TN (ranged from 0.45±0.18 to 32.63±4.17 mg/l), TP (ranged from 0.078±0.01 to 1.674±0.22 mg/l), Na (ranged from 0.59±0.27 to 53.04±1.74 mg/l), Cl (ranged from 11.68±0.14 to 31.08±1.48 mg/l), Ca (ranged from 6.38±0.66 to 38.75±7.41 mg/l), Pb (ranged from 0.039±0.01 to 0.256±0.14 mg/l), Cu (ranged from 0.015±0.01 to 0.52±0.16 mg/l) and Cd . These were compared with the standards set by NEMA for waste water. Cadmium was below the detection limits at all sampling sites.

It was found that there is a high degree of pollution in the stream and recommendations on reduction of pollution in the streams were made. Sources of water pollution include effluents from a fish filleting industry (high TN), foam mattress manufacturing/metal fabricating industry (high Cu), soft drinks manufacturing industry (high pH), pharmaceutical industry (high Pb) and food processing industry (high EC and BOD)

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# CHARPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background

Water is essential to all forms of life and makes up 50-97% of the weight of all plants and animals and about 70% of human body (Allan, 1995). Water is also a vital resource for agriculture, manufacturing, transportation and many other human activities. Despite its importance, water is the most poorly managed resource in the world (Chutter, 1998).

The availability and quality of water always have played an important role in determining the quality of life. Water quality is closely linked to water use and to the state of economic development (Chennakrishnan *et al*., 2008). Ground and surface waters can be contaminated by several sources. In urban areas, the careless disposal of industrial effluents and other wastes may contribute greatly to the poor quality of water (Mathuthu *et al*., 1997). Most of the water bodies in the areas of the developing world are the end points of effluents discharged from industries.

Considering the water streams in Nakawa-Ntinda industrial area that receive untreated effluents from industries in this area, the water quality of these streams has been tremendously affected as result of the industrial activities. These streams drain parts of Naguru Hill, Ntinda, Kyambogo, Banda, Kireka and feed into Kinawataka wetland and then finally into Lake Victoria.

Nakawa-Ntinda is one of the areas zoned for industrial development in and around Kampala. The industrial activities in this area among others include factories of fish filleting, Foods and Beverages, plastics, foam mattresses, pharmaceuticals, corrugated iron sheets and paints.

Effluents from the above industries are disposed into the streams almost exclusively without adequate treatment, which is likely to affect the water quality of the receiving streams and subsequently that of Lake Victoria, given the fact that the streams pass through Kinawataka wetland that is being degraded due human activities and finally into Lake Victoria.

The changes in the nutrient concentrations of water may lead to harmful effects to humans and aquatic life. Most heavy metals in streams of water are commonly associated with industrial discharges (Mdamo, 2001) and almost heavy metals common in industrial effluents have cumulative toxins to aquatic life. The physical-chemical parameters of an aquatic body not only reflect the type and diversity of aquatic biota but also the water quality and pollution (Birley and Lock, 1999).

A study carried out by the Management of Industrial and Municipal Effluents and Urban Run-off component of the Lake Victoria Environmental Management Project (LVEMP, 2002), indicated that most factories in Uganda do not have effluent treatment plants, even where they are existing, most industrial wastewater treatment plants are poorly designed and constructed. Of those that have wastewater treatment plant, few, if any, of those examined were achieving effluent discharge standards. Also a similar study carried out by Muwanga and Barifaijo (2006) established industrial effluents as one of the main pollution sources of Kinawata wetland, which receive water from Nakawa-Ntinda streams.

The study was therefore undertaken to assess the current status of water quality of receiving streams in Nakawa-Ntinda so that preventive measures may be taken.

### 1.2. Problem statement

Industrial effluents are discharged into Nakawa-Ntinda streams almost exclusively without adequate treatment which results in nutrient enrichment, the accumulation of toxic compounds in biomass and sediments (Dunbabin, 1992), loss of dissolved oxygen in water and other nuisances.

Downstream, the water is highly coloured, turbid and the vegetation along the streams appears scorched despite the fact that water from these streams is a major resource in the area. It is used for cleaning, construction of buildings, irrigation of vegetables, drunk by animals and birds, and children use it for recreation.

Wetlands are known to act as natural filters for nutrients and contaminants that originate from the catchment area, thereby protecting the water quality (Kansiime and Nalubega, 2000). Regrettably, Kinawataka wetland that is expected to filter contaminants carried by Nakawa-Ntinda streams has been degraded and reduced in size due to increased human activities causing a reduction in its cleaning potential thus allowing waste to seep into Lake Victoria. This creates an urgent need to assess the impact of wastewater from Nakawa-Ntinda industries on water quality of receiving streams.

### 1.3. General objective

To assess the impact of industrial effluents on water quality of Nakawa - Ntinda streams.

### 1.4. Specific objectives

1. To determine the physiochemical characteristics (COD, BOD, pH, EC turbidity, colour, TP, TN, Cl) and metals ($Na^{+}$, $Ca^{2+}$, $Pb^{2+}$, $Cd^{2+}$ and $Cu^{2+}$) in effluents from industries and at selected points in Nakawa-Ntinda streams.

2. To evaluate the impact of industrial effluents on the quality of water in Nakawa-Ntinda streams.

### 1.5. Significance of the study

The study assessed the current status of water quality in Nakawa-Ntinda streams and it is hoped that the results of this study will assist the relevant industries and authorities in designing appropriate preventive measures to ensure that the water quality in the streams is improved.

# CHAPTER TWO

## 2. 0 LITERATURE REVIEW

### 2.1 Water pollution due to industrial activities

Water pollution due to discharge of untreated industrial effluents into water bodies is a major problem in the global context (Mathuthu *et al.*, 1997). The problem of water pollution is being experienced by both developing and developed countries. Human activities give rise to water pollution by introducing various categories of substances or waste into a water body. The more common types of polluting substances include pathogenic organisms, oxygen demanding organic substances, plant nutrients that stimulate algal blooms, inorganic and organic toxic substances (Cornish and Mensahh, 1999).

Wastewater from industries and sewage spillages from burst pipes in urban centres in Uganda are released into streams and wetlands which finally discharge into Lake Victoria. With the prevailing hard economic situation in the country, most of the trade waste effluents are released into the environment untreated or partially treated. Industrialists have adopted the use of substandard treatment methods that partially treat and in some instances, forego the effluent treatment process.

Industrialisation is expanding rapidly in Uganda particularly in Kampala District and Nakaw- Ntinda area happens to be one of the areas with rapid industrial growth. Industry is growing in this area because the Uganda Government has reinforced the policy of industrialisation to help recovery of the economic status lost in the 1970s. However, there has been little regard to the effects of most industrial wastes to the environment and to whether the industries would leave the environment as it were or would have some adverse impact.

Today, the most affected part of the environment is the water resources. A study carried out by the Management of Industrial and Municipal Effluents and Urban Run-off component of the Lake Victoria Environmental Management Project (LVEMP, 2002), indicated that most factories in Uganda do not have effluent treatment plants, even where they are existing, most industrial wastewater treatment plants are poorly designed and constructed.

In addition, it was found that solid waste, which is indiscriminately, dumped in wetlands in the suburbs of Kampala city was one of the sources of chemicals that end up in drinking water. These results indicated directly the high possibility of pollution to Kampala's waterways mainly from industrial establishments due to careless and improper disposal of wastes. Furthermore, this can be the major cause of industrial pollution to water resources in the country and makes humans vulnerable to toxic substances through drinking water.

Along with the increase in industrial activity there is an increase or occurrence of pollution in the nearby environment through industrial effluents and gaseous emissions. For example increasing concentration of chemical substances originating from industrial sources and other human activities has been detected in the water in the Nakivubo swamp and channel (Kayima and Kyakula, 2008). Nevertheless, from the late 1980s on wards, Uganda has been characterised by a high economic and industrial growth in the most parts of the country. This has led to tremendous changes in the nutrient chemistry of the water resources, particularly of the Lake Victoria (LVEMP/COWI, 2002). These tremendous changes in the nutrient concentrations may lead to harmful effects to humans and aquatic life. For example most heavy metals in streams of water are commonly associated with industrial discharges and almost all heavy metals common in industrial effluents are cumulative toxins to aquatic life (Taylor and Crowder, 1983).

A study carried out by Muwanga and Barifaijo (2006) established the main pollution sources of Kinawata stream and the Nakivubo channel were due to industrial effluents and domestic waste run off. The major causes of pollution in the Nakivubo channel have been subsequently identified as raw sewage from public sewage systems, particularly untreated sewage from sewage works, abattoir effluent and garbage collection.

Pollutants in Nakivubo channel enter Lake Victoria through the Nakivubo swamp at the inner Murchison Bay (Kansiime *et al*., 1995), the quality and quantity of wastewater entering Nakivubo swamp via Nakivubo channel varies with rainfall and varying discharges of treated and untreated sewage into channel.

**2.2 Effluent characteristics and water quality**

Water pollution is commonly 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 (UNEP/WHO, 1988). Some of the major categories of beneficial uses of water resources include public water supply, irrigation, recreation, industrial production and nature conservation.

Occasionally, pollution may derive from natural processes such as weathering and soil erosion. In the vast majority of cases, however, impairment of water quality is either directly or indirectly the result of human activities (Dix, 1981). Virtually all categories of water use contribute to pollution. Every time water is used, it acquires one or more contaminants and its quality declines. Whenever any resource is processed or consumed, some of it becomes waste and is disposed of in the environment. In a large number of cases the waste materials are or become water borne and contribute to water pollution.

Both the nature of a pollutant and the quantity of it are important considerations in determining its environmental significance (UNDTCD, 1991). Generally, readily degradable substances are quickly broken down in the environment and are of great concern only when they are disposed of in sufficiently large quantities that a significant burden is placed on the natural purification processes.

On the other hand, industries produce and use a multitude of synthetic substances, a great many of which are non-biodegradable or degrade extremely slowly. Such recalcitrant substances persist in the environment for prolonged periods of time and may therefore become progressively more concentrated (UNDTCD, 1991). Many of these substances are toxic or carcinogenic and may accumulate in the tissues of organisms. Such pollutants are particularly worrisome, as they tend to build up in successive trophic levels of a food web. When characterizing pollution and for formulating control and management strategies, it is useful to distinguish between "point" and "non-point" sources.

Point sources are discrete and readily identifiable and, as a result, they are relatively easy to monitor and regulate (Stumm and Mogarn, 1981). Most sewage (wastewater of mainly domestic origin, containing among others, human excreta) from urban areas and industrial wastewaters are discharged from point sources.

Non-point sources, on the other hand, are distributed in a diffused manner. The location and origin of non-point sources are sometimes difficult to establish and they are therefore less amenable to control. Runoff from large urban or agricultural catchments carrying loads of sediments and nutrients, are examples of non-point sources of water pollution.

### 2.2.1 Biodegradable Organic Substances

Human and animal wastes as well as effluents from industries processing plant or animal products contain a mixture of complex organic substances such as carbohydrates, proteins and fats as their major pollution load (DANIDA, 1998). These substances are readily biodegradable and when introduced into the environments are quickly decomposed through the action of natural microbial populations.

Some of the organic matter is oxidised to carbon dioxide and water while the rest is assimilated and used for the synthesis of new microbial cells. In due course, these organisms will also die and become food for other decomposers. Eventually virtually all of the organic carbon will be oxidised (Lamb, 1985).

When a biodegradable organic waste is discharged into an aquatic ecosystem such as a stream, estuary or lake, oxygen dissolved in the water is consumed due to the respiration of microorganisms that oxidise the organic matter (Davies and Walker, 1986). The more biodegradable a waste is, the more rapid is the rate of its oxidation and the corresponding consumption of oxygen. Because of this relationship and its significance to water quality (dissolved oxygen levels in the water), the organic content of waste waters is usually measured in terms of the amount of oxygen consumed during its oxidation, termed the Biochemical Oxygen Demand (BOD).

In an aquatic ecosystem, a greater number of species of organisms are supported when the dissolved oxygen (DO) concentration is high. Oxygen depletion due to waste discharge has the effect of increasing the numbers of decomposer organisms at the expense of others.

When oxygen demand of a waste is so high as to eliminate all or most of the dissolved oxygen from a stretch of a water body, organic matter degradation occurs through the activities of anaerobic organisms, which do not require oxygen (Meertens *et al.*, 1995).

Not only does the water then become devoid of aerobic organisms, but anaerobic decomposition also results in the formation of a variety of foul smelling volatile organic acids and gases such as hydrogen sulphide, methane and mercaptans (certain organic sulphur compounds). The stench from these can be quite unpleasant and is frequently the main cause of complaints from residents in the vicinity.

Chemical Oxygen Demand (COD) is the measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. It does not differentiate between biologically available and inert organic matter. COD values are always greater than BOD values, but COD measurements can be made in a few hours while BOD measurements usually take five days ($BOD_5$).

### 2.2.2 Plant Nutrients

The availability of plant nutrients, particularly nitrogen and phosphorus are important determinants of the biological productivity of aquatic ecosystems. Nutrient deficient aquatic environments are called "oligotrophic" and those rich in nutrients, "eutrophic". Young lakes are generally oligotrophic (Nyanda, 2000), but they naturally accumulate nutrients over time, derived from drainage and sediment run off from its catchments. When human activities greatly accelerate nutrient enrichment of water bodies, the process is called "cultural eutrophication".

Sewage, animal wastes and many industrial effluents contain high levels of nitrogen and phosphorus. Another major source is fertilizer run off from urban and agricultural catchments.

While in the long term, cultural eutrophication accelerates the natural successional progress of aquatic ecosystems towards a terrestrial system; in the short term problems arise due to cyclic occurrences of algal blooms and decay. In warm weather, nutrients stimulate rapid growth of algae and floating aquatic weeds. The water often becomes opaque and has unpleasant tastes and odours (Katima and Masanje, 1994).

When these organisms die they become food for decomposer bacteria. Depletion of dissolved oxygen leads to anaerobic conditions and a general decline in the ecological and aesthetic qualities of the water body.

According to Perry *et al*, (2007), nitrogen, phosphorus, or both may cause aquatic biological productivity to increase, resulting in low dissolved oxygen and eutrophication of lakes, rivers, estuaries, and marine waters. Besides adding to nutrient-content of the water, addition of some forms of nitrogen and phosphorus will increase BOD and COD (Mahdieh and Amirhossein, 2009). Increased nitrogen levels adversely affect cold-water fish more than they do warm water fish. The study carried out by Barnes *et al*, (1998) on sedimentation and Georgia's fishes revealed that nitrogen concentrations of 0.5 mg/liter are toxic to rainbow trout.

In the natural world phosphorus is never encountered in its pure form, but only as phosphate. Phosphorous is one the key elements necessary for growth of plants and animals. Phosphorus in its pure form has a white colour. White phosphorus is the most dangerous form of phosphorus that is known to us (Mosley *et al*., 2004). When white phosphorus occurs in nature, this can be a serious danger to our health because it is extremely poisonous. White phosphorus enters the environment when industries use it to make other chemicals and when the military uses it as ammunition.

Through discharge of wastewater, white phosphorus ends up in surface waters near the factories that use it. Phosphorus is generally the limiting nutrient in fresh water systems and any increase in phosphorus usually results in more aquatic vegetation. Phosphates can also be found commonly in plants. Concentrated phosphoric acids are used in fertilizers for agriculture and farm production. Phosphates are used for special glasses, sodium lumps, in steel production, in military applications (incendiary bombs and smoke screening), and in other applications such as pyrotechnics, pesticides, toothpaste and detergents.

In oceans, the concentration of phosphates is very low, particularly at the surface. The reason lies partly within the solubility of aluminium and calcium phosphates, but in any case in the oceans phosphate is quickly used up and falls into the deep Sea as organic debris. There can be more phosphate in rivers and lakes, resulting in excessive algae growth (USEPA, 1986). Phosphates enter waterways from human and animal waste, laundry cleaning, industrial effluents, and fertilizer runoff. These phosphates become detrimental when they over fertilize aquatic plants and cause stepped up eutrophication.

If too much phosphate is present in the water, the algae and weeds will grow rapidly, may choke the waterway, and use up large amounts of precious oxygen (in the absence of photosynthesis and as the algae and plants die and are consumed by aerobic bacteria). The result may the death of many aquatic organisms (USEPA, 1986) such as the zooplankton and fish.

The net result of the eutrophic condition and excess growth in water is the depletion of oxygen in the water due to the heavy oxygen demand by microorganisms as they decompose the organic material. Little attention has been given to management strategies to minimise the nonpoint point movement of phosphorus in the landscape because of the easier identification and control of point source inputs of phosphorus to surface waters and lack of direct human health risks associated with eutrophication.

Phosphates exist in three forms: orthophosphate, metaphosphate (polyphosphate) and organically bound phosphate (Barnes *et al*., 1998). Each compound contains phosphorus in a different chemical formula. Ortho forms are produced by natural processes and found in sewage. Poly forms are used for treating water boilers and in detergents. In water, they change into the ortho form. Organic phosphates are important in nature; their occurrence may result from the breakdown of organic pesticides which contain phosphates.

Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate (USEPA, 1986). Though total phosphate loading is a problem in the entire Lake Victoria, it is evidently an acute one in Murchison bay. Therefore efforts should be made to minimise the loading of Total phosphorus whenever possible using properly designed sedimentation basins to treat urban storm water and reducing phosphorus levels in detergents and soap.

For many years, the main goal of treating municipal waste water was simply to reduce its content of suspended solids, oxygen demanding materials, dissolved inorganic compounds and harmful bacteria. In recent years, however more stress has been placed on improving means of disposal of the solid residues from the municipal treatment processes (Chennakrishnan *et al*., 2008).

The basic methods of treating municipal wastewater follows into tree stages; primary treatment, including grit removal, screening, grinding and segmentation; secondary treatment, which entails oxidation of dissolved organic matter by means of using biological active sludge, which is then filtered off; and tertiary treatment, in which advanced biological methods of nitrogen removal and physical chemical methods such as granular filtration and activated carbon absorption are employed.

The handling and disposal of solid residues can account for 25% - 50% of the capital and operation costs of treatment plant. The characteristics of industrial waste can differ considerably both within and among industries. The impact of industrial discharges depends not only on their collective characteristics, such as biochemical oxygen demand and the amount of suspended solids, but also on their content of specific inorganic and organic substances (Lamb, 1985).

Three options are available in controlling industrial waste water. Control can take place at the point of generation in the plant; waste water can be pre-treated for discharge to municipal treatment sources; or waste water can be treated completely at the plant and either reused or discharged directly into receiving waters which is not the case with industries in Uganda.

The importance of providing safe and adequate supply and sanitation has gained increasing international attention over the last decade. The concern of National and International organisations with the gross shortfall in the delivery of basic services especially to the low income urban and rural poor was expressed during the United Nations Conference on Human settlements held in Vancouver, Canada in 1996.

### 2.2.3 Pathogenic Organisms

Many serious human diseases such as cholera, typhoid, bacterial and amoebic dysentery, enteritis, polio and infectious hepatitis are caused by water-borne pathogens. In addition, malaria, yellow fever and filariasis are transmitted by insects that have aquatic larvae.

Faecal pollution of water resources by untreated or improperly treated sewage is a major cause for the spread of water-borne diseases (Mott Mac Donald and M & E Associates, 2001). To a lesser extent, disease-causing organisms may also be derived from animal rearing operations and food processing factories with inadequate wastewater treatment facilities.

In most developed nations, the spread of water-borne infectious diseases has been largely arrested through the introduction of water and sewage treatment facilities and through improved hygiene. But in many developing countries, such diseases are still a major cause of death, especially among the young (Lamb, 1985). A strong correlation exists between the infant mortality rates of various countries and the percentage of the population with access to clean water and sewage disposal facilities.

### 2.2.4 Turbidity

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through a water sample (Smith and Davies-Calley, 2001). Turbidity in water is caused by the presence of suspended matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms.

Turbidity units are supposed to correspond to TSS concentrations, but this correlation is only approximate. Waters with turbidity in excess of 50 NTU are quite cloudy, and waters with turbidities exceeding 500 NTU are downright muddy. Suspended sediment is a ubiquitous water pollutant, with a multitude of environmental impacts on water bodies, including transport of other pollutants such as adsorbed nutrients and toxic materials.

Effects on aquatic organisms include benthic smothering once sediment settles out of the water column (Smith and Davies-Calley, 2001). However, the most visually and ecologically significant, impact of suspended sediment is optical/increased light attenuation through water, decreasing algal growth, and low algal productivity can reduce the productivity of aquatic invertebrates, a food source of many fish.

High turbidity levels affect fish feeding and growth. Light attenuation by suspended particles in water has two main types of environmental impact: reduced penetration into water of light for photosynthesis and reduced visual range of sighted animals and people. High turbidity also due to total suspended solids supports high numbers of foreign microbiota in the water body, accelerating microbial pollution.

### 2.2.5 Electrical Conductivity (EC)

Electrical conductivity is a function of total dissolved solids (TDS) known as ions concentration, which determines the quality of water (Tariq *et al*., 2006). Electric Conductivity or Total Dissolved Solids is a measure of how much total salt (inorganic ions such as sodium, chloride, magnesium, and calcium) is present in the water (Mosley et al., 2004), the more ions the higher the conductivity. Conductivity itself is not a human or aquatic health concern, but because it is easily measured, it can serve as an indicator of other water quality problems. If the conductivity of a stream suddenly increases, it indicates that there is a source of dissolved ions in the vicinity.

Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems. All natural waters contain some dissolved solids due to the dissolution and weathering of rock and soil. Some but not the entire dissolved solids act as conductors and contribute to conductance. Waters with high TDS are unpalatable and potentially unhealthy.

According to Nadia (2006) discharge of wastewater with a high TDS level would have adverse impact on aquatic life, render the receiving water unfit for drinking and domestic purposes, reduce crop yield if used for irrigation, and exacerbate corrosion in water networks.

### 2.2.6 pH

The pH is a measure of the acid balance of a solution and is defined as the negative of the logarithm to the base 10 of the hydrogen ion concentration (UNESCO, WHO & UNEP, 1996). In waters with high algal concentrations, pH varies diurnally, reaching values as high as 10 during the day when algae are using carbon dioxide in photosynthesis.

pH drops during the night when the algae respire and produce carbon dioxide. As reported in Salequzzaman *et al*, (2008), pH changes can tip the ecological balance of the aquatic system and excessive acidity can result in the release of hydrogen sulfide.

The pH of water affects the solubility of many toxic and nutritive chemicals; therefore, the availability of these substances to aquatic organisms is affected. According to Mosley et al., (2004), water with a pH > 8.5 indicates that the water is hard. Most metals become more water soluble and more toxic with increase in acidity. Toxicity of cyanides and sulfides also increases with a decrease in pH (increase in acidity). The content of toxic forms of ammonia to the untoxic form also depends on pH dynamics.

**2.2.7 Heavy metals (Lead, Copper and Cadmium)**

Heavy metals (Pb, Cu, Cd) are among the major toxic pollutants in surface water (Chino, 1981). Theses have been found to be a problem in streams abutted by catchments with factories dealing with tanning, smelting, welding, renovation, manufacture and disposal of car batteries, petroleum and oil.

Cadmium is a non-essential element and it is both bioavailable and toxic. It interferes with metabolic processes in plants and can bioaccumulate in aquatic organisms and enters the food chain (Adriano, 2001). The principle long-term effects of low level exposure to cadmium are chronic obstructive pulmonary disease and emphysema and chronic renal tubular disease. Ingestion of high concentration of cadmium leads to nausea, vomiting, and abdominal pain. About three quarters of cadmium is used in batteries (especially Ni-Cd batteries) and most of the remaining quarter is used mainly for pigments, coatings and plating, and as stabilizers for plastics (Wallace, 2000).

Cadmium derives its toxicological properties from its chemical similarity to zinc an essential micronutrient for plants, animals and humans. Cadmium is biopersistent and once absorbed by an organism, remains resident for many years although it is eventually excreted. The presence of copper, lead, zinc and cadmium in fish is of serious health concern to human consumers (Mdamo, 2001).

Lead, a metal found in natural deposits, is a highly toxic metal that was used for many years in products found in and around homes (Chino, 1981). Lead is among the most recycled non-ferrous metals and its secondary production has therefore grown steadily in spite of declining lead prices. Its physical and chemical properties are applied in the manufacturing, construction and chemical industries.

Acute effects of lead are inattention, hallucinations; delusions, poor memory, and irritability are symptoms of acute intoxication. Lead absorption in children may affect there development and also results in bone stores of lead. It is associated with behavioural effects, nephropathy, and plumbism.

The broad categories of use of lead include; batteries, petrol additives (rolled and extruded products, alloys, pigments and compounds, sheathing, and ammunition). The past use of leaded gasoline, only recently banned in Uganda contributed greatly to a number of cases of childhood lead poisoning in the United States during the last sixty years or so. The lead produced by vehicle emissions continues even today to present a hazard, as much of that lead now remains in soil where it is deposited over the years, especially near well travelled roads and highways.

In 1974, Congress passed Safe Drinking Water Act. This law requires the Environment Protection Agency (EPA) of the United States to determine safe levels of chemicals in drinking water which do or may cause health problems. These non enforceable levels, based solely on possible health risks and exposure are called Maximum Contaminant Level Goals (MCLG) (USEPA, 1986).

The MCLG for cadmium has been set at 5 parts per billion (ppb) because EPA believes this level of protection would not cause any of the potential health problems described below. Based on this MCLG, EPA has set an enforceable standard called Maximum Contaminant Level (MCL). MCLs are set as close to MCLGs as possible, considering the ability of public water systems to detect and remove contaminants using suitable treatment technologies.

The MCL has also been set at 5 ppb because EPA believes, given present technology and resources, this is the lowest level to reach water systems can reasonably be required to remove this contaminant if it occurs in drinking water. Since the 1980's , EPA and its federal patterns have phased out lead in gasoline, reduced lead in drinking water, reduced lead in industrial air pollution, and banned or limited lead used in consumer products including residential paint.

The Agency's Lead Awareness Programme continues to work to protect human health and the environment against dangers of lead by developing regulations, conducting research and designing educational outreach efforts and materials.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 study area

Ntinda stream is the main stream while Kyambogo and Mukabya are tributaries to this stream. The layout of the study area and the sample collection sites are shown in Fig. 3.1. The study was carried out in streams that drain Nakawa-Ntinda industrial area locally known as Ntinda, Kyambogo and Mukabya streams and in effluent channel from five industries (Table 3.1).

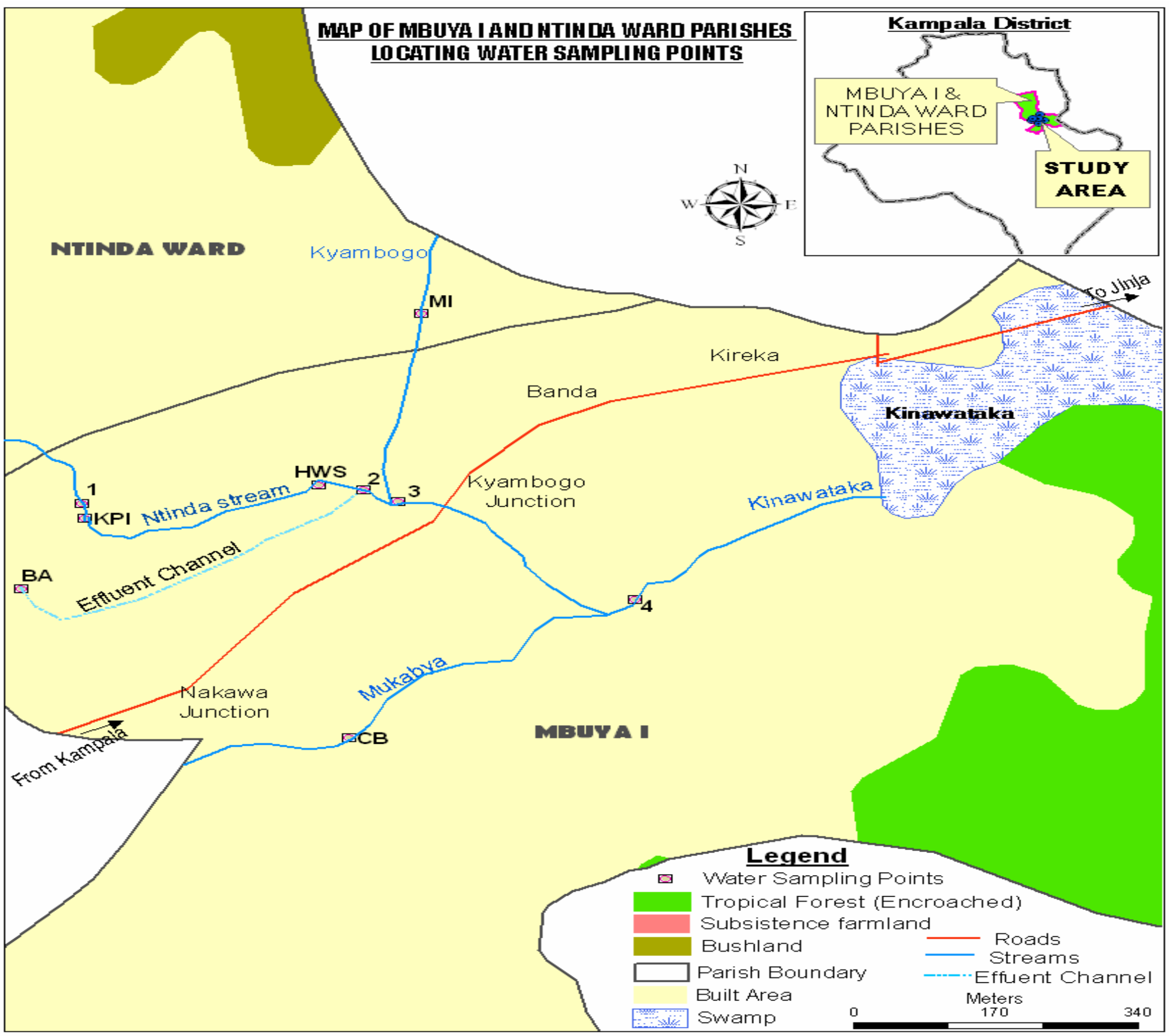


**Figure 3.1: Map of the study area showing the location of sampling sites**

**Table 3.1: Industries assessed and their respective production activities**

| INDUSTRY | ACTIVITY |
|---|---|
| Britannia Allied Industry (BA) | Food industry ie manufacture of biscuits, confectioneries and beverages. |
| Kampala Pharmaceutical Industry (KPI) | Manufacture of pharmaceuticals/drugs |
| Hwan Sung Fish Industry (HWS) | Fish filleting |
| Crown Bottlers (CB) | Manufacture of soft drinks |
| Megha Industries (MI) | Manufacture of form Mattresses and metal fabrication |

## 3.2 Study design

The study involved sampling of effluents from five industries ie Hwan Sung Fish Processing Industry, Britannia Allied Company Ltd, Megha Industries Ltd, Kampala Pharmaceutical Industries, Crown Bottlers and at four selected points along the receiving streams that drain Nakawa-Ntinda industrial area (Fig. 3.1). The above industries mainly discharge their untreated effluents into the streams.

## 3.3 Sampling

Samples were collected in duplicate in the morning and afternoon for a period of two months (March and April, 2010) from effluent channels leading to the stream and from four Sampling sites 1, 2, 3 and 4 along the stream (Appendix 1). The GPS co-ordinates in UTM were recorded for each sampling site. Site 1 was at Stretcher road bridge and upstream of Ntinda stream, before industrial waste discharge points. This was taken as reference point with relatively clean water.

Site 2 was about 90 m away from Hwan Sung fish industry and close to a point where industrial effluent from Britania is discharged into the stream. Site 3 is where Kyambogo tributary joins Ntinda stream while site 4 is about 150 m downstream of 3 and close to Oxy-gas (U) Ltd (Fig. 3.1).

The sampling points were designed in relation to industries as depicted by Fig. 3.2. All samples for laboratory analysis were placed into thoroughly cleaned (cleaned with dilute nitric acid and rinsed with distilled water before use) one litre plastic bottles and tightly closed. Each bottle was rinsed with the appropriate amount of sample before final sample collection. These samples were placed in a cooler box and protected from direct sunlight and then taken to the laboratory for analysis.

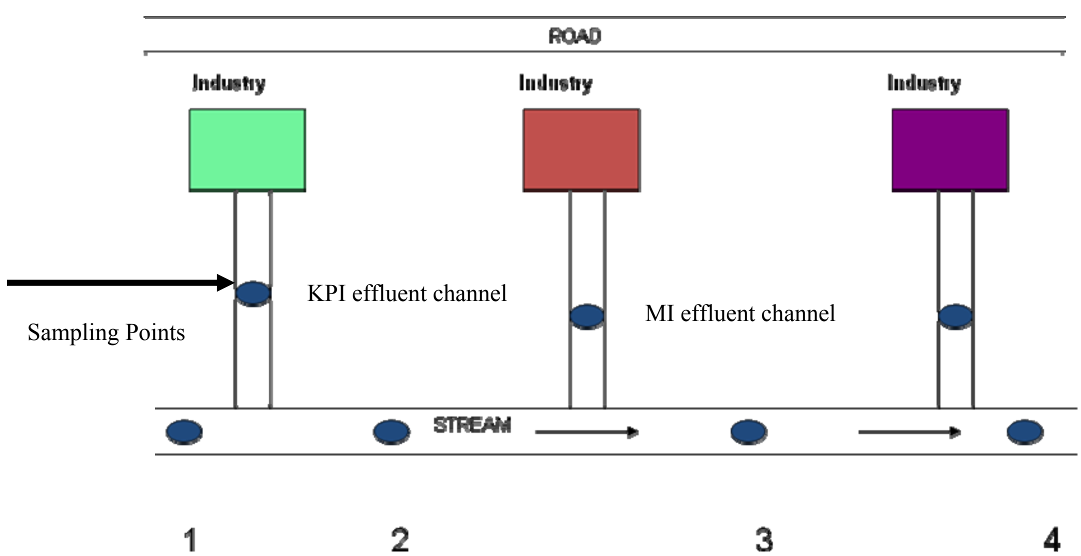


**Fig 3.2:** Indicating **s**chematic representation of some of the selected sampling sites

### 3.4 Sample analysis

$Na^{+}$, $K^{+}$, Cl,$^{-1}$$Ca^{2+}$, $Pb^{2+}$, $Cd^{2+}$ and $Cu^{2+}$ were determined from the Uganda National Bureau of Standards (UNBS) Chemistry Laboratory while COD, BOD, turbidity, colour, TP, and TN were determined from National Water and Sewerage Corporation (NWSC) analytical laboratory. Samples were analysed according to Standard Methods for

Examination of Water and Waste water (APHA, 1998) and the Association of Official Analytical Chemists (AOAC).

**pH**

pH was measured in situ directly in the effluent channel and in the stream using a pH meter (Mettler Toledo 320 model) according to APHA (1998).

**Electrical conductivity (EC)**

Electrical conductivity (EC) is a measure of the ability of ions in a solution to carry electric current. This ability depends on the presence of ions, their total concentration and temperature. EC was measured in-situ both in the effluent channel and in the stream using a Mettler Toledo MC 226 conductivity meter. The EC meter was switched on and its probe dipped into the sample contained in a beaker. The electrical conductivity was read directly and recorded in $\mu Scm^{-1}$

**Turbidity**

Turbidity levels were measured in Nephelometric units (NTUs) using the HACH 2100A turbidity meter.

**Colour (apparent colour)**

Colour was determined using a Spectrophotometer (DR 20800 model) according to APHA (1998).

**Chemical Oxygen Demand ($BOD_5$)**

Chemical oxygen demand (COD) is the amount of oxygen required to completely oxidize the organic matter in waste water by use of a strong oxidant and to convert it to carbon dioxide and water. Potassium dichromate was used in this test because of its superior oxidizing ability. A known quantity of water sample was mixed with a known quantity of standard solution of potassium dichromate ($K_2Cr_2O_7$) and the mixture heated. The organic matter was oxidized by the potassium chromate in the presence of sulphuric acid ($H_2SO_4$) and the oxygen used in oxidizing the water was determined.

**Biochemical Oxygen Demand (BOD)**

Biochemical oxygen demand (BOD5) was determined by conventional methods according to Association of Official Analytical Chemists (AOAC), 2002. A sample of the solution (50 ml) was placed in a 500 ml BOD bottle and filled to the mark with previously prepared dilution water. A blank solution of the dilution water was similarly prepared and placed in two BOD bottles.

A control solution without dilution water was also prepared and placed in a BOD bottle. The bottles were stoppered, sealed and incubated for five days at room temperature. BOD was calculated from the relation: BOD= (D1-D2)/P, where D1= dissolved oxygen 15 minutes after preparation, D2= dissolved oxygen in diluted sample after incubation and P= amount of sample used.

**Total Nitrogen (TN)**

25 ml of the sample was mixed with 45 ml of concentrated ammonium chloride solution, 25 ml were collected and 1.0 ml of coloring reagent was added to it. The TN concentration was read directly using DR4000 spetrophotometer at 543 nm.

**Total Phosphorus**

Total Phosphorus was determined calorimetrically method using visible spectrophotometer (model DR 3800- HACH) according to APHA (1998).

**Chloride**

This anion was determined by titration of the sample with silver nitrate. To 100ml sample was added potassium chromate (5%, 1ml) and titrated with 0.1 M silver nitrate solution to the first appearance of a buff colour (AOAC, 2002).

**Sodium**

Sodium was determined using a flame photometer (Model CORNING M410) according to APHA, 1998.

**Heavy metals and Calcium**

Calcium, lead, copper and cadmium were determined using Atomic Absorption Spectrometer (model AA6800- SHIMADZU) according to APHA, 1998

### 3.5 Data analysis

MS Excel and Gen Stat were used to analyse data. Mean, variance and standard error were used to assess the spread of the data. The mean of parameters (±SE) and one-way analysis of variance (ANOVA) followed by a post hoc multiple comparison (Tukey's test) were calculated to compare the mean values of observation based on sites. Differences in mean values obtained were considered significant if calculated P-values were $< 0.05$.

Correlation analysis was done to test the association between various parameters along sampling site.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSIONS

This section presents the results of physio-chemical parameters as determined in samples collected from effluent channels and along the streams at site 1 (Upstream), Kampala pharmaceutical Industry (KPI), Britania allied (BA), site 2, Hwan Sung fish industry (HWS), Megha Industries (MI), site 3 and site 4 (downstream). The results of analysis obtained are summarized in Table 4.1.

## 4.1 pH trend

pH is a measure of the acid balance of a solution. The pH of water affects the solubility of many toxic and nutritive chemicals.

pH ranged from 6.28 to 7.11 with a mean of value of 6.73 ± 0.17 at site 1 (Upstream), from 6.10 to 7.08 with a mean value 6.73± 0.24 at Kampala Pharmaceutical Industry, from 3.21 to 4.01 with a mean value of 3.68 ±0.17 at Britania, from 3.21 to 4.42 with a mean value of 3.91±0.11 at site 2, from 6.59 to 7.32 with a mean value of 6.87±0.68 at Hwan Sung Fish Industry, from 5.98 to 9.07 with a mean value of 6.78±0.49 at Megha industry, from 7.89 to 9.41 with a mean value of 8.47±0.84 at site 3, from 11.89 to 13.02 with a mean value of 12.41±4.68 at Crown Bottlers and from 4.64 to 5.38 with a mean value of 5.07±0.14 at site 4 as shown Table 4.1.

**Table 4.1: Mean ± SE for parameters measured at selected sampling sites**

| Parameter | Site 1 | KPI | BA | Site 2 | HWS | MI | Site 3 | CB | Site 4 | NEMA (MPL) |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | 6.73 ± 0.17$^{c}$ | 6.73 ± 0.24$^{c}$ | 3.68 ± 0.17$^{a}$ | 3.91 ± 0.11$^{a}$ | 6.87 ± 0.68$^{c}$ | 6.78 ±0.49$^{c}$ | 8.47 ± 0.84$^{d}$ | 12.41 ± 4.68$^{e}$ | 5.07 ± 0.14$^{b}$ | 6.0 –8.0 |
| EC (µs/cm) | 280±58.21$^{b}$ | 337±74.13$^{b}$ | 4633±154.42$^{e}$ | 373±88.61$^{b}$ | 1929±471.73$^{d}$ | 212±51.31$^{a}$ | 341±58.26$^{b}$ | 984±132.84$^{c}$ | 362±105.95$^{b}$ | 400 |
| Colour (TCU) | 72±2.11$^{a}$ | 101±4.32$^{b}$ | 499±51.18$^{e}$ | 958±86.52$^{g}$ | 302±5.92$^{c}$ | 123±2.74$^{b}$ | 113±2.13$^{b}$ | 777±59.86$^{f}$ | 319±5.98$^{d}$ | 300 |
| Turbidity (NTU) | 29.7±0.91$^{b}$ | 20.9±0.42$^{a}$ | 715.9±9.31 | 39.1±0.83$^{c}$ | 615.7 ±94.27$^{f}$ | 30.7 ±0.51$^{b}$ | 38.3 ±0.14$^{c}$ | 492.6±109.48$^{d}$ | 551.7±118.11$^{e}$ | 300 |
| COD (mg/l) | 76±14.19$^{a}$ | 71±12.28$^{a}$ | 1105±412.76$^{c}$ | 2104±218.21$^{e}$ | 1351±321.04$^{d}$ | 39±1.22$^{a}$ | 35±7.09$^{a}$ | 94±4.31$^{a}$ | 278±5.19$^{b}$ | 100 |
| BOD (mg/l) | 46.2±2.86$^{a}$ | 32.6±7.61$^{a}$ | 325.5±40.32$^{d}$ | 35.2±1.22$^{a}$ | 180.6±24.11$^{c}$ | 16.4±0.45$^{a}$ | 17.7±1.84$^{a}$ | 35.2±1.39a | 93.2±5.78$^{b}$ | 50 |
| TN (mg/l) | 0.45±0.18$^{a}$ | 1.29±0.24$^{a}$ | 25.67±1.58$^{c}$ | 10.7±1.34$^{b}$ | 32.63±4.17$^{c}$ | 6.52±1.19$^{a}$ | 15.17±2.12$^{b}$ | 5.13±0.46$^{a}$ | 13.75±1.64$^{b}$ | 10 |
| TP(mg/l) | 0.078±0.01$^{a}$ | 0.144±0.17$^{a}$ | 1.674±0.22$^{d}$ | 1.293±0.27$^{c}$ | 0.394±0.14$^{b}$ | 0.345±0.19$^{b}$ | 0.424±0.22$^{b}$ | 1.629±1.28$^{d}$ | 0.521±1.71$^{b}$ | 10 |
| $Na^{+}$ (mg/l) | 13.30±6.87$^{b}$ | 20.85±2.47$^{d}$ | 26.11±2.11$^{f}$ | 16.54±1.74$^{c}$ | 21.15±3.36$^{d}$ | 0.59±0.27$^{a}$ | 18.56±1.67$^{d}$ | 53.04±1.74$^{g}$ | 24.84±2.67$^{e}$ | - |
| $Cl^{-}$ (mg/l) | 12.51±4.06$^{a}$ | 19.24±1.01$^{b}$ | 30.48±2.13$^{c}$ | 11.68±0.14$^{a}$ | 28.14±3.18$^{c}$ | 20.21±4.24$^{b}$ | 12.51±1.27$^{a}$ | 31.08±1.48$^{c}$ | 20.79±6.49$^{b}$ | 500 |
| $Ca^{2+}$ (mg/l) | 17.49±1.86$^{b}$ | 38.75±7.41$^{f}$ | 20.19±1.38$^{b}$ | 19.09±1.47$^{b}$ | 29.62±3.46$^{d}$ | 20.03±1.64$^{b}$ | 21.26±1.22$^{c}$ | 6.38±0.66$^{a}$ | 30.72±7.44$^{e}$ | 100 |
| Pb (mg/l) | 0.05±0.01$^{a}$ | 0.256±0.14$^{d}$ | 0.039±0.01$^{a}$ | 0.051±0.01$^{a}$ | 0.048±0.01$^{a}$ | 0.074±0.01$^{b}$ | 0.112±0.02$^{c}$ | 0.082±0.01$^{b}$ | 0.154±0.02$^{c}$ | 0.1 |
| CU (mg/l) | 0.015±0.01$^{a}$ | 0.05±0.01$^{a}$ | 0.05±0.01$^{a}$ | 0.05±0.01$^{a}$ | 0.029±0.01$^{a}$ | 0.52±0.16$^{b}$ | 0.05±0.01$^{a}$ | 0.05±0.01$^{a}$ | 0.059±0.01$^{a}$ | 0.1 |
| Cd (mg/l) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.1 |

MPL means Maximum Permissible Limits

SE means Standard Error

<0.01 Implies that the value for Cadmium was below the minimum detectable limit of 0.01

Values followed by the same letters in a row are not significantly different at P <0 .05

pH varied significantly (p= 0.02, ANOVA) along sampling sites and ranged between 3.68 ±0.17 and 12.41 ±4.68 (Fig 4.1). pH values above NEMA (1999) permissible limits (range, 6-8) were observed at site 3 (8.47±0.84) and in effluent from Crown bottlers (12.41±4.68). The high value of pH at site 3 is attributed to the basic effluent from a nearby coffee factory (Kawa Com) that is discharged close to this point. Coffee extracts are alkaline in nature due the presence of a compound known as caffeine.

The high value observed in the effluent from Crown bottlers is probably due to the use of alkaline sodium hydroxide (NaOH) as a cleaning agent in this industry.

The study revealed that the pH value of the water downstream is slightly acidic (5.07±0.14) and outside the permissible limits by NEMA (1999) standards. This is due to the fact that the area downstream is used as a urinal. Urine contains uric acid that can increase the acidity of water (Kayima and Kyakula, 2008).

Low pH values outside NEMA permissible limits were observed in effluent from Britania (3.68 ±0.17) and at site 2 (3.91±0.11). The low pH levels in effluent from Britania could be due to the raw materials such enzymes, lactic acid, benzoic acid and yeast that are mainly used by food industry (Chennakrishnan, 2008).

The reduction in pH levels along the sream observed at site 2 is probably due to the effluent from Britania containing organic waste which is discharged into the stream close to this point. The pH can be decreased by the carbondioxide released by the bacteria breaking down the organic wastes (Matovu, 2010). Carbondioxide dissolves in water to form carbonic acid. Although this is a weak acid, large amounts of it will lower the pH and when waters with low pH values come into contact with certain chemicals and metals, this often makes them more poisonous than normal.

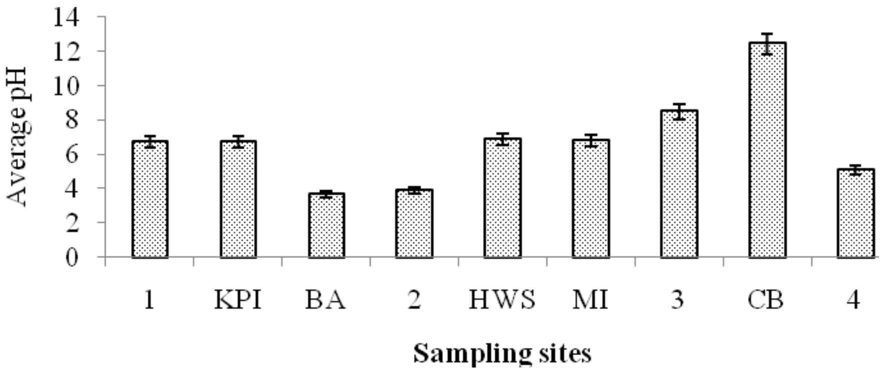


**Fig 4.1**: pH trend along the stream. NEMA standard = 6-8

**4.2 Electrical Conductivity (EC)**

Electrical Conductivity is a measure of how much total salt is present in the water. The more the ions, the higher the conductivity (Mosley et al., 2004).

Figure 4.2 shows the trends of Electrical conductivity (EC). EC ranged from 298 $\mu Scm^{-1}$ to 401 $\mu Scm^{-1}$ with a mean value of 280 ±58.21 $\mu Scm^{-1}$ at site 1 (Upstream), 284 $\mu Scm^{-1}$ to 402 $\mu Scm^{-1}$ with a mean value of 337 ±74.13 $\mu Scm^{-1}$ at Kampala Pharmaceutical, 3986 $\mu Scm^{-1}$ to 5257 $\mu Scm^{-1}$ with a mean value of 4633 ±154.42 $\mu Scm^{-1}$ at Britania, 312 $\mu Scm^{-1}$ to 394 $\mu Scm^{-1}$ with a mean value of 373 ±88.61 $\mu Scm^{-1}$ at site 2, 1799 to 1999 with a mean value of 1929 ±471.73 $\mu Scm^{-1}$ at Hwan Sung Fish Industry, 179 to 234 $\mu Scm^{-1}$ with a mean value of 212 ±51.13 $\mu Scm^{-1}$ at Megha Industry, 298 to 374 $\mu Scm^{-1}$ with a mean value of 341 ±58.26 $\mu Scm^{-1}$ at site 3, 916 $\mu Scm^{-1}$ to 995 $\mu Scm^{-1}$ with a mean value of 984 ±132.84 $\mu Scm^{-1}$ at Crown Bottlers and 298 $\mu Scm^{-1}$ to 401 $\mu Scm^{-1}$ with a mean value of 362 ±105.95 $\mu Scm^{-1}$ at site 4 (Downstream).

Electrical conductivity ranged between 164.5 $\mu Scm^{-1}$ and 1929 $\mu Scm^{-1}$ and varied significantly ($p = 0.001$, ANOVA) along the sampling sites. High EC values exceeding EC guidelines of 400 $\mu Scm^{-1}$ for drinking water were recorded in effluents from Britania, Hwan Sung Fish and Crown Bottlers industries. A study carried out by Muwanga and Barifaijo (2006) in Kinawataka stream and Ntinda industrial area also revealed that EC in runoff from industries was exceeding the permissible limits (WHO guidelines, 1984) for EC.

The highest value of EC was measured in the effluent from Britania (4633 ±154.42 $\mu Scm^{-1}$) indicating high Total Dissolved Solids (TDS) emanating from the various chemicals used as food preservatives in food processing industry. The high values of EC in effluent from Hwan Sung Fish Industry (1929 ±471.73 $\mu Scm^{-1}$) could be due to release of fresh fish remains and blood containing nitrogenous compounds into their waste effluent, which are nitrified to ammonium-nitrogen and nitrate resulting in high EC (Koushik and Saksena, 1999).

The high value of EC in the effluent from Crown Bottlers (984 ±132.84 $\mu Scm^{-1}$) is attributed to the high content of ions in sodium hydroxide chemicals used a cleaning detergent in this industry. Discharge of wastewater with a high TDS level would have adverse impact on aquatic life and exacerbate corrosion in water networks (LVEMP, 2002). EC was generally within permissible limits along the stream and this attributed to the dilution effect and other natural processes along the stream.

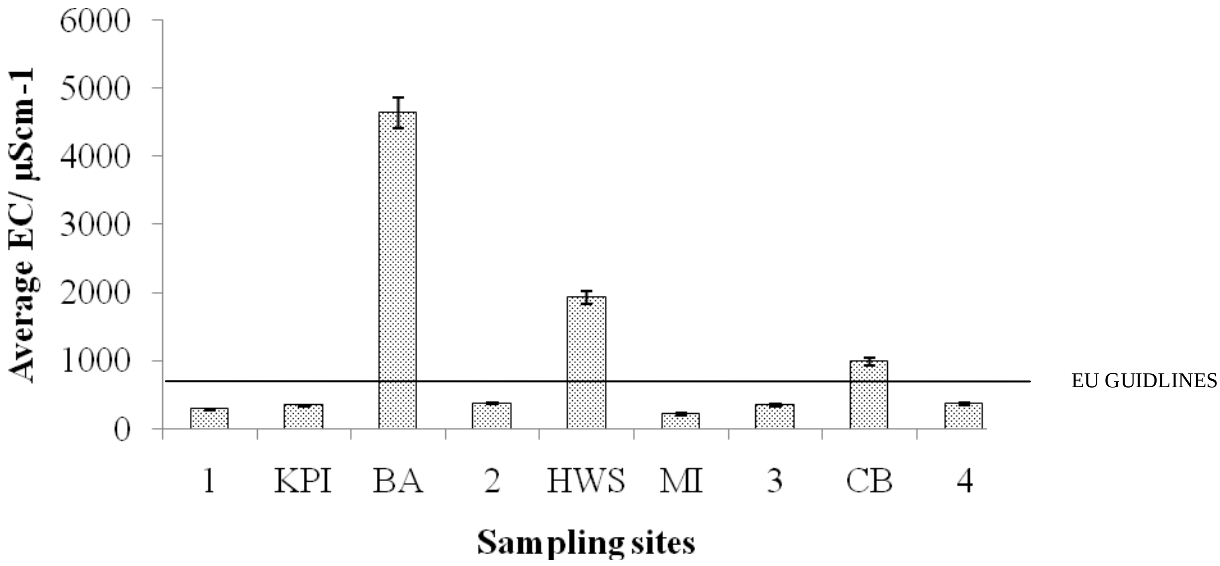


**Fig 4.2:** Electrical conductivity trend along the stream. WHO/EU Guidlines = 400 µScm$^{-1}$

**4.3 Turbidity**

Turbidity in water is caused by the presence of suspended matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms.

Turbidity was 29.7±0.91 NTU at site 1 (Upstream), 20.9 ±0.24 NTU at Kampala pharmaceutical, 715.9 ±9.31 NTU at Britania. 39.1 ±0.83 NTU at site 2, 615.7 ±94.27 NTU at Hwan Sung Fish processing industry, 30.7 ±0.51 NTU at Megha industries, 38.3 ±0.14 NTU at site 3, 492.6 ±109.48 NTU at Crown Bottlers and 551.7± 118.11 NTU at site 4 (Table 4.1).

Turbidity was below NEMA (1999) standards upstream, high values of turbidity exceeding NEMA (1999) standards effluent discharge of 300 NTU were recorded in effluents from Britania (715.9 ±9.31 NTU), Hwan Sung Fish processing industry (615.7 ±94.27 NTU) and downstream (551.7± 118.11 NTU). This is also in agreement with

Muwanga and Barifaijo (2006) findings.

Turbidity affects fish and aquatic life by interference with sunlight penetration. Water plants need light for photosynthesis. If suspended particles block out light, photosynthesis and the production of oxygen for fish and aquatic life will be reduced. If light levels get too low, photosynthesis may stop altogether and algae will die (Smith and Davies-Colley, 2001).

The high value of turbidity at Britania is probably due to the presence organic particulate matter in the effluents from this industry. Turbidity in natural waters is commonly caused by the presence of clay, silt, organic matter, algae and other microorganisms (Lamb, 1985) and this is evidenced by the strong correlation coefficient (R= 0.60) observed between Turbidity and Biochemical Oxygen Demand contents along sampling sites as shown in Table 4.2.

**Table 4.2: Correlation analysis indicating (R) values between parameters measured**

| | EC | pH | Turbidity | $Na^{+}$ | $Ka^{+}$ | $Cl^{-}$ | $Ca^{2+}$ | $Pb^{2+}$ | $Cu^{2+}$ | TP | BOD | TN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 0.836 | | | | | | | | | | | |
| Turbidity | 0.372 | 0.076 | | | | | | | | | | |
| $Na^{+}$ | 0.753 | 0.579 | 0.344 | | | | | | | | | |
| $Ka^{+}$ | 0.251 | -0.129 | 0.400 | 0.333 | | | | | | | | |
| $Cl^{-}$ | 0.356 | 0.345 | 0.397 | 0.570 | 0.236 | | | | | | | |
| $Ca^{2+}$ | -0.576 | -0.291 | -0.476 | -0.221 | -0.300 | -0.067 | | | | | | |
| $Pb^{2+}$ | 0.860 | 0.820 | 0.301 | 0.723 | 0.129 | 0.347 | -0.414 | | | | | |
| $Cu^{2+}$ | -0.146 | -0.355 | -0.069 | -0.119 | 0.011 | -0.397 | -0.113 | -0.185 | | | | |
| TP | 0.222 | -0.102 | 0.316 | 0.285 | 0.309 | 0.032 | -0.376 | 0.137 | 0.622 | | | |
| BOD | 0.132 | -0.253 | 0.600 | 0.233 | 0.372 | 0.042 | -0.354 | 0.045 | 0.568 | 0.647 | | |
| TN | 0.340 | 0.040 | 0.429 | 0.443 | 0.349 | 0.300 | -0.305 | 0.201 | 0.308 | 0.502 | 0.586 | |
| Colour | 0.350 | -0.027 | 0.530 | 0.365 | 0.377 | -0.006 | -0.525 | 0.288 | 0.525 | 0.747 | 0.675 | 0.479 |

R= Correlation Coefficient.

≥ 0.5 indicates existance of a strong correlation between parameters.

< 0.5 indicates existance of a weak correlation between parameters.

The high value of turbidity at Hwan sung fish could be due to the presence of fresh fish remains and blood in the effluents from this industry and that at downstream could be due to effluent containing suspended matter from Oxy-gas that is discharged into the stream (Fig. 4.3).

**4.4 Colour (Apparent)**

Apparent color is the color of the whole water sample, and consists of color from both dissolved and suspended components. The presence of color in water does not necessarily indicate that the water is not potable. Color-causing substances such as tannins may be harmless.

Colour was 72±0.2.11 TCU at site 1 (Upstream), 101 ±4.32 TCU at Kampala Pharmaceutical, 499±51.18 TCU at Britania. 958±86.52 TCU at site 2, 302 ±5.92 TCU at Hwan Sung Fish processing Industry, 123 ±2.74 TCU at Megha Industries, 113 ±2.13 TCU at site 3, 777± 59.86 TCU at Crown Bottlers and 319±5.98 TCU at site 4 (Table 4.1).

Colours in natural waters can originate from decomposition of organic matter and discharge of certain waste. Colours interfere with penetration of light and affects photosynthesis. It may also hamper oxygen absorption from the atmosphere. Colour in most places along the stream was below NEMA (1999) standards for effluent discharge of 300 TCU but was higher in the effluent channel or where the effluent from industry joins the stream. High values of colour exceeding NEMA (1999) standards were recorded at Britania (499±51.18 TCU), sampling site 2 (958±86.52 TCU), Crown Bottlers (777±

59.86 TCU) and downstream (319±5.98 TCU) as shown in Fig 4.3.

The high value of colour at sampling site 2 is probably due to the coloured organic effluents from Britania which are discharged close to this point while that at Crown Bottlers is probably due to the use of coloured cleaning agents which are carried by the effluents from this industry.

There was also a strong correlation coefficient (R= 0.747) observed between colour and Total Phosphorus (Table 4.2) indicating usage of coloured phosphorus in some of the industries in this area. There are several forms of phosphorous, called white, red and black (Mosley *et al*., 2004).

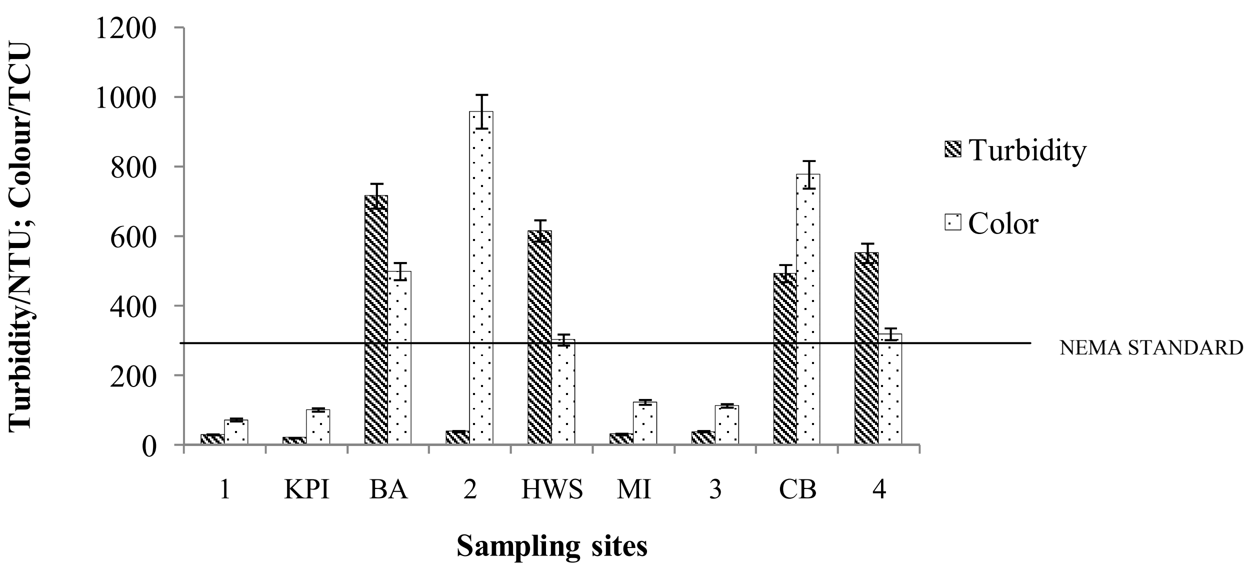


**Fig 4.3:** Turbidity and colour trends along the stream

### 4.5 Biochemical Oxygen Demand (BOD)

BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period

Figure 4.4 shows the trend of Bio-Oxygen Demand (BOD) along sampling sites. BOD was 46.2±2.86 mg/l at site 1 (Upstream), 32.6±7.61 mg/l at Kampala Pharmaceutical, 325.5±40.32 mg/l at Britania, 35.2±1.22 mg/l at site 2, 180.6±24.11 mg/l at Hwan sung Fish processing industry, 16.4±0.45 mg/l at Megha Industry, 17.7±1.84 mg/l at site 3, 35.2±1.39 mg/l at Crown Bottlers, 93.2±5.78 mg/l at site 4 (Table 4.1)

BOD varied significantly along sampling sites (p= 0.002, ANOVA) and ranged from 16.4 to 325.5 mg/l.

The study revealed that the water upstream had BOD levels below NEMA (1999) standards and that downstream had BOD levels (93.2±28.65 mg/l) above the maximum permissible limits. Although a study by LVEMP (2002) established that pollution loading (kg/day) from industry due to BOD accounted for 13% of the total estimated pollution loading due to BOD into lake Victoria after passing through wetlands and other natural purification systems. The continued disposal of biodegradable organic waste into the stream will lead to increased consumption of dissolved oxygen thus affecting the aquatic life.

High values of BOD exceeding NEMA (1999) standards were also observed in effluents from Britania and Hwan Sung Fish. The highest value of BOD was recorded at Britania indicating presence of a high content of biodegradable organic pollutants in the effluent from this industry. The high value of BOD observed at Hwan sung fish industry is probably due to the presence of fresh fish remains that are rich in organic matter in the waste from this industry.

The slightly low levels of BOD at sites 2, and 3 could be due to dilution effect and natural purification systems along the stream while the high value downstream could be due the vegetation cover and presence of decaying plant debris. Also the strong correlation coefficient (R= 0.586) observed between BOD and Total Nitrogen (Table 4.2) indicates the biodegradable organic matter was rich in nitrogenous compounds.

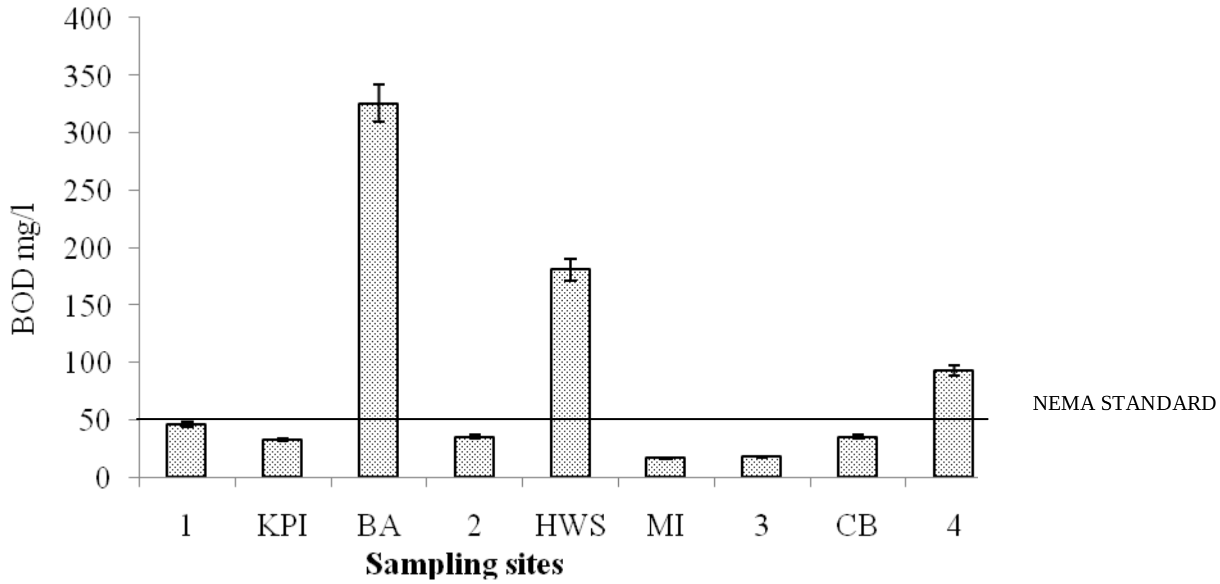


**Fig 4.4:** Trend of BOD along the stream. NEMA Standards = 50 mg/l

### 4.6 Chemical Oxygen Demand (COD)

COD is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite.

COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes

COD was 76±14.19 mg/l at site 1 (Upstream), 71±12.28 mg/l at Kampala Pharmaceutical, 1105±412.76 mg/l at Britania, 2104±218.21 mg/l at site 2, 1351±321.04 mg/l at Hwan Sung Fish processing industry, 39±1.22 mg/l at Megha Industry, 35±7.09 mg/l at site 3, 94±4.31 mg/l at Crown Bottlers, 278±5.19 mg/l at site 4 (Table 4.1)

COD varied significantly along sampling sites (p= 0.006, ANOVA) and ranged from 35±7.09 to 2104±218.21 mg/l (Fig 4.5).

The water upstream had COD below NEMA (1999) standards of 100 mg/l. High concentrations of COD above NEMA standards were recorded at Britania, site 2 and downstream indicating a heavy load of organic and inorganic pollution that require more oxygen to oxidise under increased thermal conditions (Koushik and Saksena, 1999).

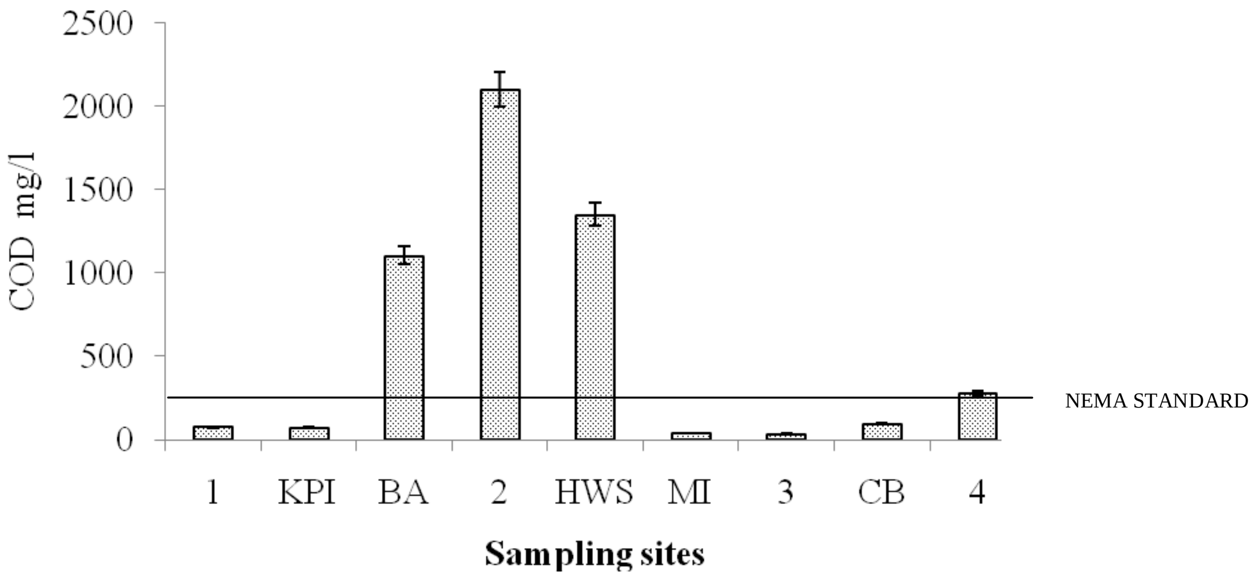


**Fig 4.5:** Trend of COD along the stream. NEMA Standards = 100 mg/l

### 4.7 Total Nitrogen (TN)

Total Nitrogen is a measure of all forms of nitrogen (organic and inorganic). Nitrogen is an essential plant element and is often the limiting nutrient in marine waters.

Total Nitrogen was 0.45±0.18 mg/l at site 1 (Upstream), 1.92±0.24 mg/l at Kampala pharmaceutical, 25.67±1.58 mg/l at Britania, 10.7±1.34 mg/l at site 2, 32.63±4.17 mg/l at Hwan Sung Fish processing industry, 6.52±1.19 mg/l at Megha Industry, 15.7±2.12 mg/l at site 3, 5.13±0.46 mg/l at Crown Bottlers, 13.75±1.64 mg/l at site 4 (Table 4.1)

Total nitrogen varied significantly along the sampling site ($p = 0.001$, ANOVA) and ranged from 0.45±0.18 to 32.63±4.17 mg/l (Fig. 4.6). The water upstream had levels of TN below NEMA (1999) standards and that downstream had total nitrogen content above the permissible limits (13.75±1.64 mg/l).

High values of total nitrogen exceeding NEMA permissible limits were also recorded at Britania (25.67±1.58 mg/l), Hwan Sung Fish (32.63±4.17 mg/l) and sampling site 3 (15.17±2.12 mg/l). The major routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, private sewage disposal systems, decaying plant debris and discharge from car exhausts (USEPA, 1986).

The high value of TN at Britania is probably due to the use of food preservatives containing nitrogenous compound and presence of organic pollutants rich in nitrogen content in the effluents from Britania industry. Effluents from fish processing industry are generally rich in protein content (Meertens *et al*., 1995). This explains the high levels of TN observed in effluent from Hwan sung fish industry.

A study by LVEMP (2002) established that pollution loading (kg/day) from industry due to TN  accounted for 10% of the total estimated pollution loading due to TN into lake Victoria after passing through wetlands and other natural purification systems. Nitrogen, phosphorus, or both may cause aquatic biological productivity to increase, resulting in low dissolved oxygen and eutrophication of lakes, rivers, estuaries, and marine waters (Perry et al, 2007).

Site 3 is close to a garbage collection point which allows seepage of decaying garbage leachate into the stream. This explains the high levels of total nitrogen recorded at site 3. The high concentration of total nitrogen downstream could be due to agricultural runoff containing nitrogen from fertilizers since downstream is heavily cultivated. Presence of dilapidated sewer systems observed close to Oxy-gas (U) Ltd allows seepage of sewage into the stream contributing to concentration of total nitrogen downstream. Also discharges from car exhausts from a nearby petrol station (Con-Corp) end up into the stream (USEPA, 1986) hence high levels of total Nitrogen.

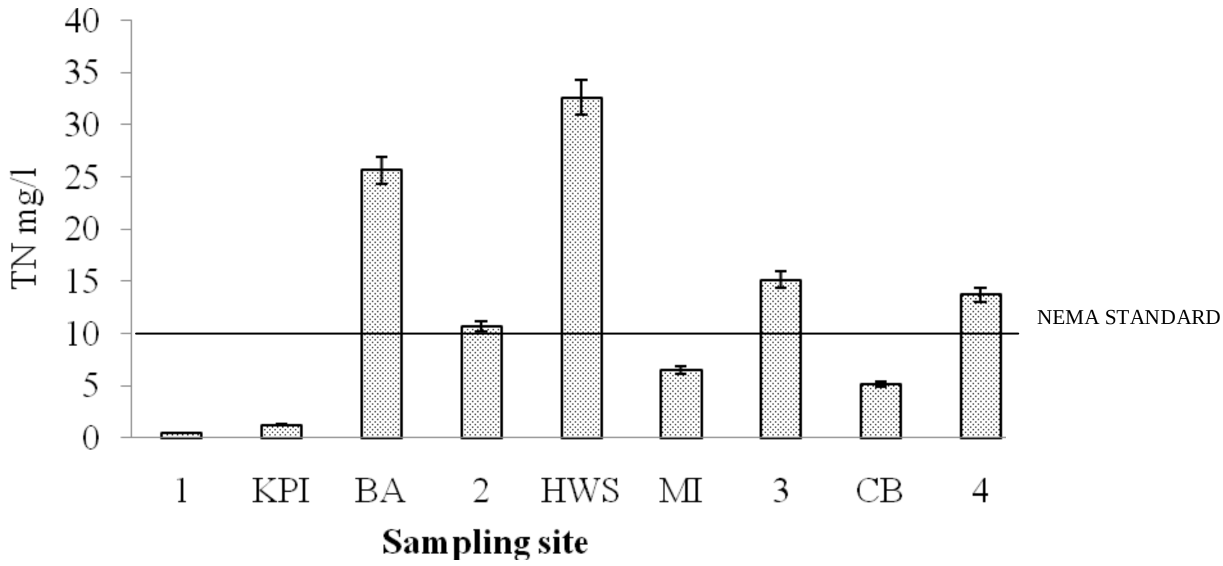


**Fig 4.6**: Total Nitrogen trend along the stream. NEMA Standard= 10 mg/l

## 4.8 Total Phosphorus

Total Phosphorus is a measure of both inorganic and organic forms of phosphorus. Phosphorus can be present as dissolved or particulate matter. It is an essential plant nutrient and is often the most limiting nutrient to plant growth in fresh water.

Total phosphorus was 0.078±0.01 mg/l at site 1 (Upstream), 0.144±0.17 mg/l at Kampala Pharmaceutical, 1.674±0.22 mg/l at Britania, 1.293±0.27 mg/l at site 2, 0.394±0.14 mg/l at Hwan Sung Fish processing industry, 0.345±0.19 mg/l at Megha Industry, 0.424±0.22 mg/l at site 3, 1.629±1.28 mg/l at Crown Bottlers, 0.251±1.71 mg/l at site 4 (Table 4.1).

Total phosphorus varied significantly ($p = 0.003$, ANOVA) and ranged from 0.078±0.01 to 1.629±1.28 mg/l (Fig 4.7). Total phosphorus levels were generally below the NEMA (1999) permissible limits (10 mg/l) at all sampling sites, however they were higher than (≤ 0.05 mg/l) for streams discharging into reservoirs, and (≤ 0.025 mg/l) for reservoirs recommended by the US Environmental Protection Agency (USEPA, 1986)

Phosphates enter waterways from human and animal waste, phosphate rich bedrock, wastes from laundry cleaning and industrial processes, and fertilizer runoff (Mosley, 2004). If too much phosphate is present, algae and water weeds grow wildly, choke the water way and use up large amount of oxygen resulting into death of aquatic organisms.

The slightly high levels of total phosphorus observed in effluents from Britania and Hwan Sung Fish industries could be due to use of laundry detergents during cleaning processes in both industries. According to Perry and Green (2007), it is not possible to find a high phosphate reading if the algae are already blooming, as the phosphates will already be in the algae but not in water. This explains the low levels of total phosphorus observed along the stream because algae was observed at some sections along the stream.

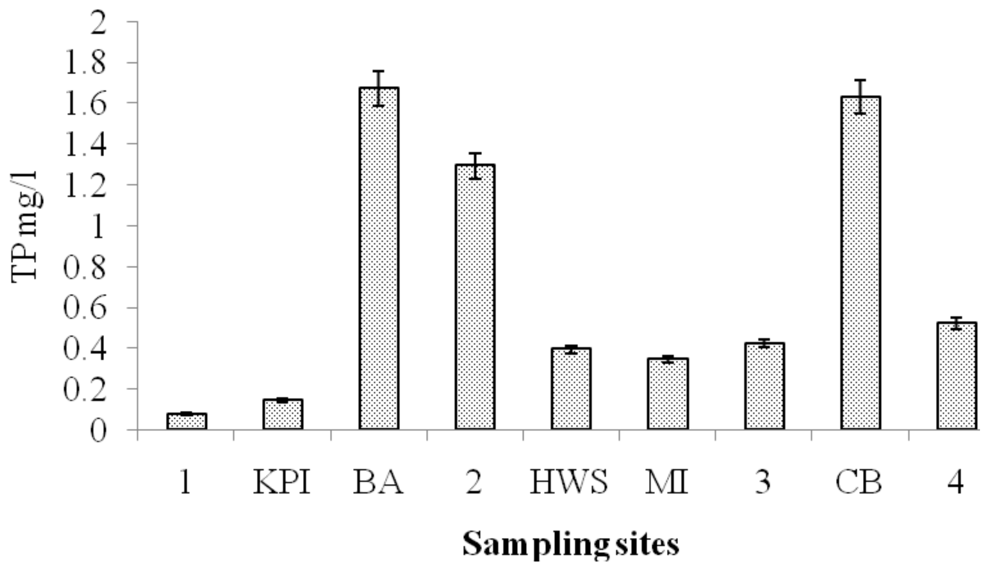


**Fig 4.7:** Total Phosphorus trend along the stream. NEMA Standards = 10 mg/l

**4.9 Calcium, Sodium and Chloride**

Figure 4.8 shows trends of calcium, sodium and chloride concentrations along the stream.

Calcium ranged from 17.49±1.86 to 38.75±7.41 mg/l, sodium ranged from 0.59±0.27 to 53.04±1.74 mg/l and chloride ranged from 11.68±0.14 to 31.08±1.48 mg/l.

When an ionic salt like NaCl is added to water, the ions from the salt introduced will attract the water molecules in an effort to "solvate" the ions. This has the tendency to decrease the weak affinity of non-polar oxygen molecules to water and drive the dissolved oxygen out of the polar water (USEPA, 1986).

Calcium, sodium and chloride varied significantly (p= 0.001, ANOVA) along sampling sites and the levels obtained were within the maximum NEMA (1999) permissible limits.

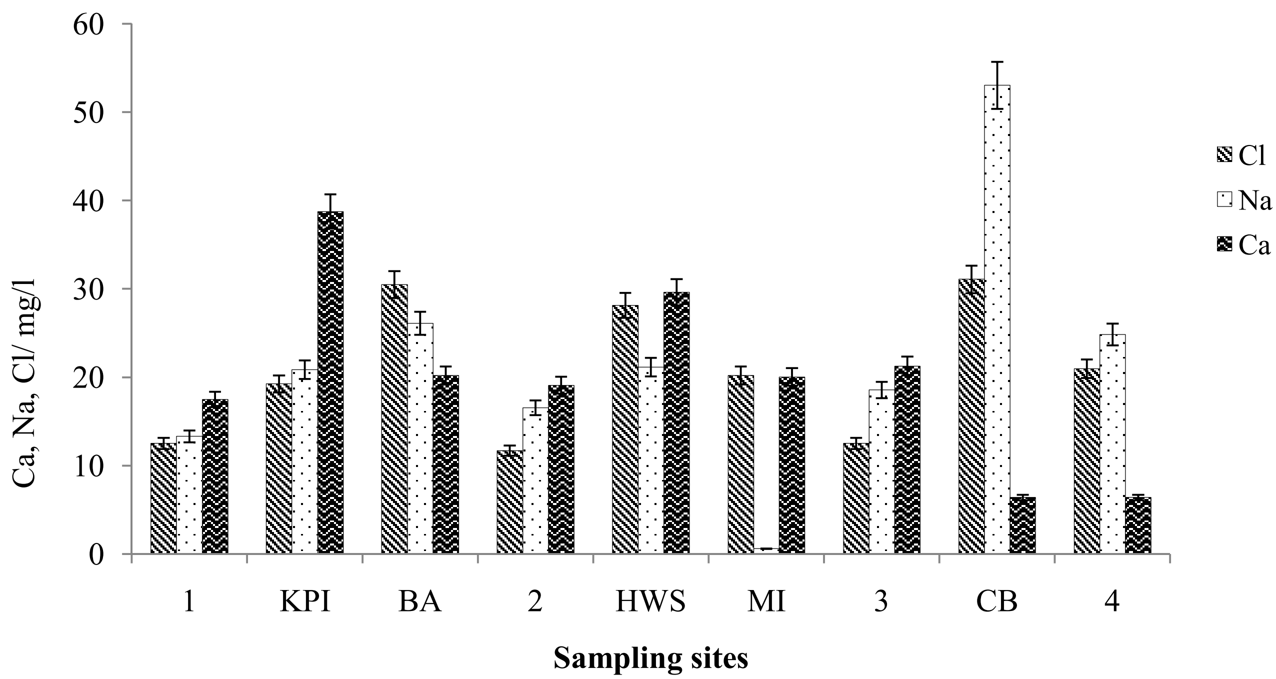


**Fig 4.8:** Calcium, sodium and chloride trends along the stream. NEMA Standard for Ca= 100 mg/l, Cl= 500 mg/l.

### 4.10 Heavy metals (Lead, Copper and Cadmium)

**Lead**

Lead is a toxic element that accumulates in the skeletal structures. The toxic effects of lead to fish decreases with increasing water hardness and dissolved oxygen.

Lead was 0.05±0.01 mg/l at site 1, 0.256±0.14 mg/l at Kampala Pharmaceutical industries, 0.039±0.01 mg/l at Britania, 0.051±0.01 mg/l at site 2, 0.048±0.01 mg/l at Hwan Sung Fish processing industry, 0.074±0.01 mg/l at Megha Industries, 0.112±0.02 mg/l at site 3, 0.082±0.01 mg/l at Crown bottlers, 0.154±0.02 mg/l at site 4 (Fig. 4.9).

Lead was generally below the maximum permissible limits for NEMA (1999) standard of 0.1 mg/l at most sampling sites. High levels of lead exceeding NEMA limits were recorded at Kampala Pharmaceutical, site 3 and downstream. The highest value of lead was recorded at Kampala Pharmaceutical (0.256±0.14 mg/l) which is attributed to the chemicals that are used in manufacture of drugs that may contain lead- organo compounds and this in agreement with the findings of Muwanga and Barifaijo (2006). High value of lead observed at sampling site 3 (0.112±0.02 mg/l) is probably due to the presence of dilapidated lead sewage pipes in this area.

The high value downstream (0.154±0.02 mg/l) could be ascribed to lead originating from the use of leaded fuel by Oxy-gas industry given the fact that downstream is about 50 meter from Oxy-gas industry. The results show that the waste waters released by some industries into the streams have heavy metal concentrations above those recommended and this poses a risk to the environment.

Although lead is expected to have low phytotoxicity because of its strong affinity to organic matter, under certain environmental conditions eg, change in pH, it may become mobile (Muwanga and Barifaijo, 2006). Pb may go into food chain given the fact that the area downstream is cultivated.

**Copper**

Copper is essential for all plant and animal nutrition. Increased quantities of copper make water distasteful to drink. Very large prolonged doses may result liver damage. Copper is acutely toxic to most forms of aquatic life at relatively low concentrations.

Copper was below maximum permissible limits (MPL) for NEMA (1999) standards at most sampling sites. Copper ranged from 0.015 mg/l at upstream to 0.52 mg/l at Megha Industries (Table 4.1) and varied significantly ($p< 0.05$, ANOVA) along sampling sites. High levels of copper above NEMA limits was recorded at Megha industries (Fig 4.8) and this could be due to the effluent containing copper metal chips from metal fabricating operations involving Cu scrap. Although copper toxicity in humans is rare, aquatic organisms are potentially at risk from Cu exposures (Adriano, 2001).

A remedy must be sought for Cu levels in the effluent of industry where the metal is high in effluent. Low levels of copper observed along the stream are attributed to the natural purification processes within the stream and this is in agreement with the findings of Muwanga and Barifaijo (2006).

**Cadmium**

Cadmium has cumulative and highly toxic effects in all chemical forms. It accumulates in plant cells and is has been known to have extremely toxic effects on trout and zooplankton.

Cadmium was not detected at all sampling sites. The minimum detectable limit was (0.01 mg/l) for Atomic Absorption Spectrophotometer (AAS) used in this analysis. NEMA (1999) recommended a maximum concentration of 0.1 mg/l for discharge of effluents into water or land. The US Environmental Protection Agency set a maximum contaminant level goal for cadmium at 5 parts per billion (ppb).

A similar study by Muwanga and Barifaijo (2006) entitled 'Impact of industrial activities on heavy metal loading and their physico- chemical effects on wetlands of Lake Victoria Basin', recorded very low levels of Cadmium in Kinawata streams.

Cadmium is a non-essential element and it is both bioavailable and toxic. It interferes with metabolic processes in plants and can bioaccumulate in aquatic organisms and enters the food chain (Adriano, 2001).

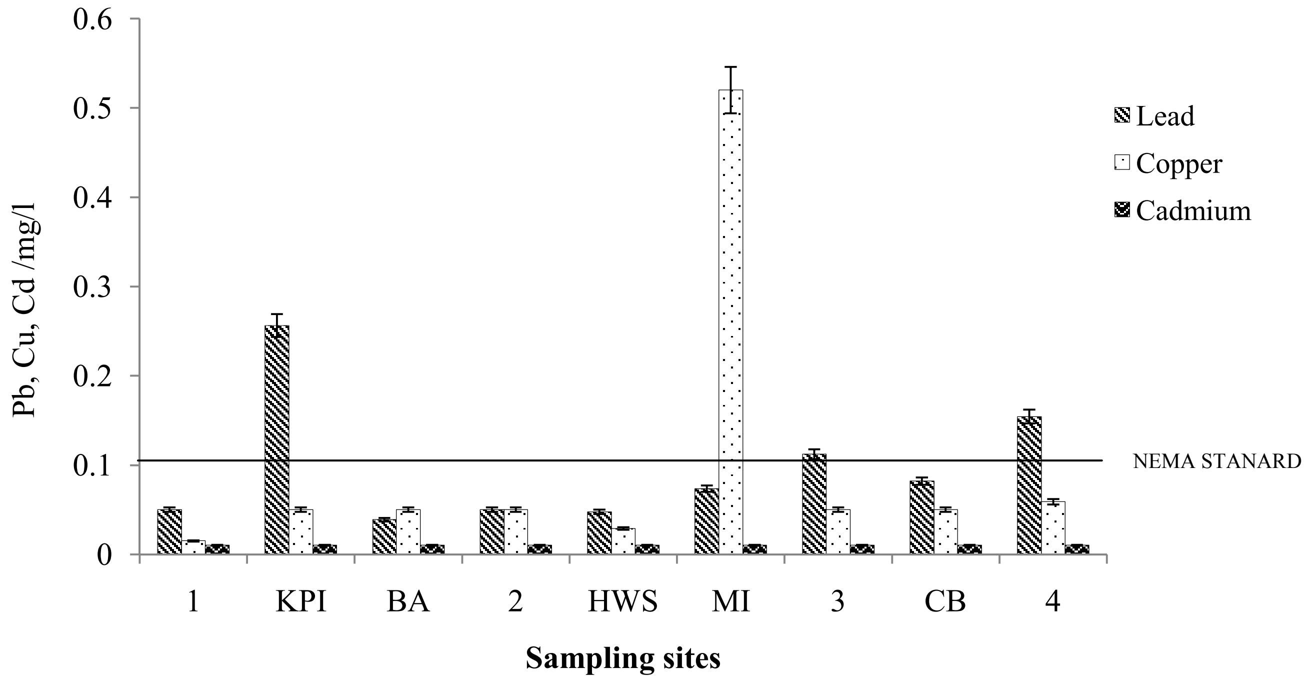


**Fig 4.9:** Pb, Cu and Cd trends along the stream. NEMA Standards = 0.1mg/l

# CHAPTER FIVE

## 5.0 CONCLUSION

Overall, the study has shown that the effluents from industries have a big impact on the water quality of the receiving streams. This is depicted by the fact that there is a general increase in concentration of the parameters analysed downstream as opposed to up stream. Although the values in some cases were lower than the maximum allowable limits by NEMA (1999), ` the continued discharge of un-treated effluents in the stream may result in severe accumulation of the contaminants.

With the present primitive processing technology, fish filleting at Hwan Sung Industries and food processing activities at Britania will continue to enrich the receiving streams with key nutrients and easily degradable carbon compounds, leading to further oxygen depletion in streams.

Kampala Pharmaceutical Industry discharges high loads of toxic lead; this substance is likely to accumulate in the streams and pollute Lake Victoria if it is not treated at the source. This is a situation that should alert the Uganda National Environment Management Authority to continuously monitor industrial effluents and enforce Uganda's National Environment Statute (NEMA, 1995).

## 5.1 RECOMENDATIONS

The results suggest that the effluents being discharged into the streams have considerable negative effects on the water quality in the receiving streams. With increased industrial activities in Nakawa-Ntinda, the load of nutrients and pollutants entering the receiving streams will continue to increase and further diminish the quality of water. Introduction of cost-effective cleaner production technologies must be enforced, such as on-site waste separation and reduction, and effluent recycling.

It is therefore recommended that careless disposal of the wastes should be discouraged and there is need for each industry to install a waste treatment plant with a view to treat wastes before being discharged into the streams.

There is need for NEMA to closely monitor the effluents from industries. It has been noted that wetlands contribute greatly to the purification of waste water therefore measures should be taken to protect Kinawataka wetland which drains Nakawa-Ntinda streams.

**APPENDIX 1**
**Plates showing some of the selected sampling sites**

**Plate 1:** Effluent from Crown bottlers

**Plate 2:** Effluent from Britania

**Plate 3**: Used Polyethene bags being washed from the stream

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