The Effects of Industrial Effluents discharged on Surface Water Bodies- Case Study of Kitwe Stream, Zambia

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Abstract

Kitwe stream is the recipient of the effluents from the industrial Plants and flows into the Kafue River, an extremely important river to the Zambian economy. Samples were taken from the stream at 5 different sites. The stream was studied in an effort to determine by chemical means the water quality at various sites and hence the pollution levels of the stream. The water were analyzed for pH, total dissolved solids and total hardness. The results obtained revealed that the values for pH, total dissolved solids and total hardness were outside the recommended limits of WHO water quality standards. It was therefore, concluded at 5% level of significance that the effluents from industrial Plants have an effect on the pollution levels of the stream.

Key Words: Total hardness, Total Dissolved solids, pH, Effluents, Water Pollution

Introduction

The discharge of industrial effluent into water bodies is one of the main causes of environmental pollution and degradation in many cities, especially in developing countries. Many of these industries lack liquid and solid waste regulations and proper disposal facilities, including for harmful waste. Such waste may be infectious, toxic or radioactive (WHO, 2004). In most countries the principal risks to human health associated with the consumption of polluted water are microbiological in nature as well as chemical contamination. (UNCED, 1992) stated that an estimated 80% of all diseases and over one-third of deaths in developing countries are caused by the consumption of contaminated water and on average as much as one-tenth of each person’s productive time is sacrificed to water-related diseases. The Third World Centre for Water Management estimates that at least three billion people worldwide still drink water of dubious quality. They have also estimated that only about 10-12 per cent of domestic and industrial waste water produced in Latin America is properly managed (Asit and Peter, B, 2014). This situation is similar in developing countries in Asia and likely worse in Africa.

Kitwe stream is located around Kitwe town. This stream carries effluents discharged from major industries around Kitwe. Industrial activities in these areas have significantly affected the ecology of this stream. Industrial effluents are discharged into the stream almost exclusively without adequate treatment which results in nutrient enrichment, the accumulation of toxic compounds in biomass and sediments , loss of dissolved oxygen in water and other nuisances (Ntengwe et al., 2006). Downstream, the water is highly coloured, turbid and the vegetation along the streams appears scorched despite the fact that water from this stream 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.

Since water pollution implies reducing the available quantity and quality of water that can be used by both humans and the general environment (Petersson et al, 2001), it is extremely important that the use of water and its management take into account reducing and avoiding water pollution to maintain its quality. It is in the light of the above that a research was undertaken to; evaluate the chemical quality of water in Kitwe stream; assess the level at which effluents discharged from the industrial activities affect the quality of water of Kitwe stream; compare the quantity of pollutants in the water with the acceptable limits of WHO and establish the potential public health threat the water could have. The findings of the research, are important not only to the management of the industries in Kitwe but also to other industries in other towns that might be discharging effluents on water bodies, the policy makers and serves as a check on the work of Zambia Environmental Management Agency (ZEMA).

Therefore, the chief purpose of this paper is to report the findings of the research which was carried out to assess the effects of industrial effluents discharged on the surface water of Kitwe stream.

In order to ensure an orderly discussion, the paper is divided into five chapters. The first chapter is this introduction. The second chapter presents the conceptual and theoretical framework of the effects of industrial effluents discharged on water bodies. The third chapter discusses research methods used to undertake the study. The fourth chapter discusses the analysis and results of the findings. The last chapter is the conclusion which proposes policy recommendation to resolve the problem of the discharge of industrial effluents on surface water bodies.. Figure 1 below shows the location of Kitwe stream passing through industrial area leading to Kafue River

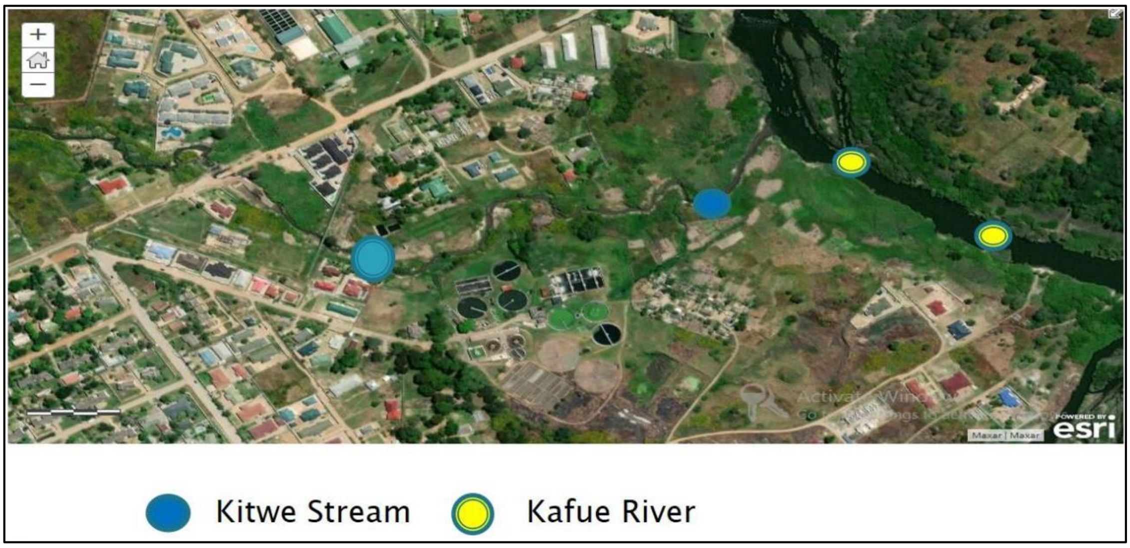

Figure1: Location of Kitwe Stream

Literature Review

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).

Waste water from industries and sewage spillages from burst pipes in urban centers in
Zambia are released into streams and wetlands which finally discharge into Kafue River.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. Industrialization is expanding rapidly in Zambia particularly in Kitwe District. Industry is growing in this area because the Zambian Government has reinforced the policy of industrialization to help recovery of the economic status lost in the 1990s. 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 (Samerendra and Mirriam,2014) indicated that most factories in Zambia particularly on the Copperbelt 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 Pollution from KCM's tailing dam number 2 (known as TD2) has contaminated the water supplies as well as mushishima streams which runs nearby Helen and Shimulala communities in Chingola. Local resident reported that KCM drilled them a borehole after the stream became contaminated but when they took samples it was also polluted with copper sulphate. They alleged that a water tank subsequently delivered by the company also contained contaminated water. With no clean water source in their village residents now walk to a shallow well they have dug in marsh to fetch dirty water. They fear this may also be polluted.

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). 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

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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).(Samerendra and Mirriam,2014), stated that in 2006 KCM released raw effluent from their pollution control dam into mushishima stream, which runs directly into the Kafue River, the water source for 40 percent of Zambia's population (Sinkala et al., 2002). The result was some of the worst contamination Zambia has ever seen, with chemical concentration 10x acceptable levels of copper, 770 x acceptable manganese and 100x cobalt in the Kafue River, turning it into a strange blue green colour. Water companies in Kitwe and Chingola sued KCM for their negligence, which had damaged their water processing plants, and Vedanta compensated them out of court. But they refused to settle any compensation with the thousands of people affected by drinking the water. Following the failure of Environmental Council of Zambia (ECZ now ZEMA) to prosecute the company, a Lusaka private lawyer took a public interest litigation against KCM on behalf of 2000 affected people. However, Vedanta challenged the case claiming that they were not responsible for the contamination. Until now the case has not been heard and the residents are yet to be compensated. The long term effects being experienced by the local people are miscarriage, and premature and deformed birth.The likely long term impact of the spill may include lung and heart problems, respiratory diseases and liver and kidney damage. Brain damage effects in the local population may only show up in future generation(Mwase et al., 2002) . In 2010 KCM again contaminated the river again, in another major incident which left thousands poisoned once again. They were found guilty by Zambian courts on four counts, including willfully failing to report an act or incident of pollution of the environment.

Situation of worldwide urban river pollution

Chinese, Japanese and Indians are among the major investors that are bringing direct foreign investments to Zambia. Therefore, we thought it wise to review the literature about the state of the rivers in their countries in term of pollution and what we found is as follows:

From the years 1932 through to 1968, the Chisso Corporation located in Kumamoto in Japan dumped an estimated 27 tons of mercury compounds into the Minamata Bay. Kumamoto is a small town which consists mostly of farmers and fishermen (Nakamura et al., 2006). After the mercury was dumped into the bay, thousands of people whose normal diet included fish from the bay developed symptoms of methyl mercury poisoning. The poisoning resulted from years of environmental destruction and neglect from the corporation. A disease was noticed in the region in the 1950s. The mercury poisoning affected humans' limbs, speech, vision, and mental capacity. Animals were affected as well. A river flows into other areas in Japan from the bay, causing the disease to be spread to these areas as well. The corporation began to make deals with the victims which absolved the corporation of any further liability. Victims were still being compensated as of 1993, (Asit and Peter, B,2014)

In 2011, more than half of china's largest lakes and rivers were deemed unfit for human consumption. To this effect particularly since 2012, Ecological Civilization has been included in the plan to promote coordinated economic, political, cultural, social and ecological advancement. In this respect, the Chinese government actively promotes rehabilitation of heavily polluted water bodies in urban areas (Hailong, 2019).In 2013, China's Ministry of Environmental Protection admitted that "toxic and hazardous chemical pollution has caused many environmental disasters, cutting off drinking water supplies and even leading to severe health and social problems."

India's situation is not much better, with the state run Central Pollution Control Board reporting in 2013, that nearly half of the country's 445 rivers are too polluted in terms of biochemical oxygen demand and coliform bacterial to be safely consumed. If other pollutants such as nitrates, fluorides, pesticides and heavy metals were considered the figure would be significantly higher, (Asit and Peter, 2014).The urban stream syndrome(Meyer et al., 2005) that is characterized by high peak flows, owing to dramatic increases in storm water runoff, as a result of increasing impervious surface covers (ISC) in urban catchments (Booth and Jackson, 1997), causes significant physical and biological changes in urban rivers.

Methodology

Data Collection

The data collection process included both secondary and primary sources. The primary sources where the data was collected during the research process included; direct observation and collection of samples from the water bodies, consultations from Environmental Department of some industries, Kitwe city council and from interviews with the local people of 'Zambia Compound'. A secondary source was only from reviewing relevant literature and studies.

Research Design

A reconnaissance survey of the stream was first undertaken and systematic sampling was then used to establish 5 sites along the stream. Since rivers are dynamic systems and are subjected to too much variation, only a few stations with sufficient samples were required to define the results in terms of statistical significance. The first station was located sufficiently downstream from the point of pollution entrance to ensure dispersion through the cross section, and also to afford an opportunity for adequate mixing but not far enough for biological chemical degradation. The other 4 stations followed at equal intervals of 150m. These distances were measured using time factor and were designed to give the complete contamination picture of the stream. Two samples were collected from each station at the middle of the cross section of the stream. One sample was taken at the depth of 60% and the other sample from the surface. Since 5 sites were established, in total 10 samples were collected and taken to the laboratory for analysis.

Two samples from each station were mixed to have one homogeneous sample for each station. Therefore we only had 5 samples to analyze

Experiments for pH

Material used

- 5 beakers, 1 funnel, pH meter model 630, Thermometer (range -10 to 110 0 C), Buffer solutions of pH = 7 and pH=4 with the temperature of 25 o C

Procedure

- The pH meter was calibrated using the pH buffer 7 and 4
- Samples were put into 5 separate beakers and tested for pH

Experiments for Total Hardness

Material used

- Burette, Pipette, 5 conic flask, 1 funnel, Clamp stand and Volumetric flask

Reagents

- EBT, EDTA, NH 3 OH and Indicator

Procedure

- 5ml was pipette from each sample and dilute with 20ml of distilled water
- 2cm 3 of NO 3 OH buffer and 3-4 drops of EBT were added
- Then titrate with EDTA and record the volume of EDTA used to reach the end point

Equation (1) was used to calculate the total hardness

$$ppm = ml \times dil \times conc \times \frac{1000}{v} \qquad (1)$$

where,

ppm= Total hardness in mg/l
ml = Volume of the sample in mg/l
dil = Dilution factor
conc= Concentration of EDTA in mg/l
v = Volume of EDTA used in litre(l)

Experiments for Total Dissolved Solids

Material used

- Pipette, 5 small heating dishes, Weighing scale and Heater

Procedure

Firstly the weight of each dish was measured and recorded. Then 10ml of each water sample was put on 5 separate dishes and heat to dry. After heating to dry the weight of each dish was measured and recorded. The weights of the dissolved solids were calculated by subtracting the initial weight from the final weight of the dishes. Equation (2) was used to convert the weight into ppm.

$$ppm = \frac{(w \times 1000)}{10}$$

where, ppm = concentration of dissolved solids in mg/l
W = weight of the dissolved solids in mg

Assumptions

The study was carried out under the following assumption:
1. There was steady flow of the stream during the time of sample collection.
2. The stream has a uniform depth
3. The samples were collected at constant temperature.
4. The concentrations of the pollutants were as result of effluents from industrial plants and nothing else.

Scope and Limitations

The study was only focused on the assessment of the effects of effluents discharged into Kitwe stream. The main variables that were measured in the samples from the site are pH, Total Dissolved Solids and Total Hardness. Statistical analysis and conclusions were made based on the results that were obtained. The following are some of the limitations that were faced:

- Lack of enough resources to analyze adequate number of samples and the concentration of heavy metals in the samples.
- Lack of adequate information from Environmental departments of most industries.

Statistical Analysis

The results of all three variables were analyzed using student t- distribution at 5% level of significance. This test was chosen because the sample size in the entire three variables was less than 30 and the results are assumed to be normally distributed. The sample means were analyzed with respect to WHO maximum standard values which are as follows:

- Dissolved solids = 1000mg/l
- Hardness = 500 mg/l
- PH = 6.5 – 8.5

Research Findings And Discussion

The research findings after carrying out all the procedures were as follows:

According to data from the finding of our research, pH varied significantly along sampling sites and ranged between 4.5 and 6.7 (Figure 2). Low pH values outside WHO permissible limits were observed at sites A, B, C and D. The low pH levels in water could be due to the raw materials such enzymes, lactic acid, benzoic acid and yeast that is mainly used by food industry (Chennakrishnan, 2008). pH values within WHO permissible limits (range, 6.5-8.5) were observed at site 3 (6.7)). The high value of pH at site 3 is attributed to the basic effluent from a nearby industry that is discharged close to this point. The high value observed in the water downstream is probably due to the use of alkaline sodium hydroxide (NaOH) as a cleaning agent in these industries

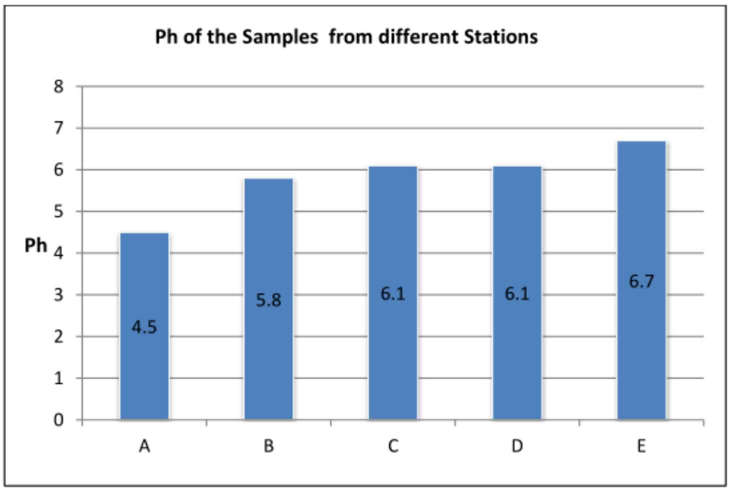

Figure 2: pH. Trends

However after subjecting this data to statistical analysis using student t-distribution at 5% level of significance, it was concluded that the effluents from the industrial plants have an effect on the pollution levels of the stream in terms of the 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,18 1996). As reported by 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.

Total Dissolved Solids (TDS)

TDS, which stands for Total Dissolved Solids, refers to the amount of organic and inorganic dissolved substances that may be found in your water, such as minerals, metals and salts. Essentially, it is everything present in water other than pure H2O and suspended solids. Total Dissolved Solids are measured as parts per million (ppm), and it is worth noting that WHO water standards recommend a limit of 1000 ppm. The concept of parts per million may be difficult to visualize, but the same measurement can be stated as "milligrams per litre" when you discuss mineral content. The TDS varied along sampling sites, flactuating between 81,000 mg/l to 199,000mg/l (Figure 3). High values of TDS were observed at all the fives sites which were far much above the WHO permissible limit of 1000mg/l.The high levels of TDs could be due to the effluents coming from mining activities which involve the washing of the rocks. The increasing trend in TDS along the stream can also be attributed to the fact that water is naturally slightly acidic, hence as it flows there is a continuous dissolving of the rock particles carried with it into a liquid form. These dissolved minerals include calcium, magnesium, chlorides and silica. However a sharp decrease in the TDS was observed at site E and serves as evidence that the stream is naturally trying to dilute, disperse, degrade, absorb or otherwise reduce the impact of unwanted residue. TDS affects the taste of water and beverages, and can mean that sodium, calcium, chloride, and magnesium may all be detectable in your final product. Depending on the quantities and combinations of the dissolved materials, water can taste alkaline (bitter), salty or metallic.

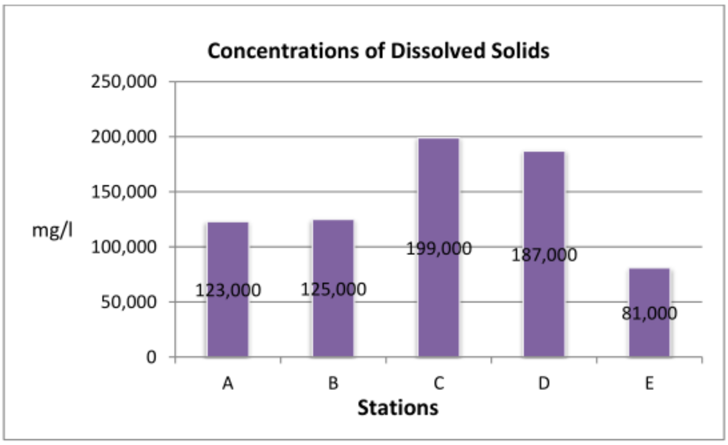

Figure 3: Concentrations of Dissolved Solids

However after subjecting this data to statistical analysis using student t-distribution at 5% level of significance, it was concluded that the effluents from the industrial plants have an effect on the pollution levels of the stream in terms of TDS. The calculated average TDS value of 142 000mg/l together with the results of statistical analysis indicated that the self- purifying capacity of the stream has been overloaded.

Total Hardness

Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce lather. Hard water often produces a noticeable deposit of precipitate (e.g. insoluble metals, soaps or salts) in containers, including "bathtub ring". It is not caused by a single substance but by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations, although other cations (e.g. aluminium, barium, iron, manganese, strontium and zinc) also contribute. Hardness is most commonly expressed as milligrams of calcium carbonate equivalent per litre. Water containing calcium carbonate at concentrations below 60 mg/l is generally considered as soft; 60–120 mg/l, moderately hard; 120–180 mg/l, hard; and more than 180 mg/l, very hard (McGowan, 2000). However in our study we considered the concentration of both calcium and magnesium ions hence the term total hardness. Total hardness showed a downward trend along the stream from 657.5mg/l to 540mg/l (Figure 4). However, at every site the total concentration of magnesium and calcium ions were beyond the WHO permissible limit of 500mg/l. These high figures of total hardness could be attributed to the effluents coming from the mining industries in the area and other industries involved in the use of sedimentary rocks like stone crushing. The average total hardness was found to be 604.5mg/l and after statistical analysis of the data it was discovered that the stream purifying capacity has been overloaded. It was therefore concluded that the stream has been polluted by the effluents discharged on it from the industries.

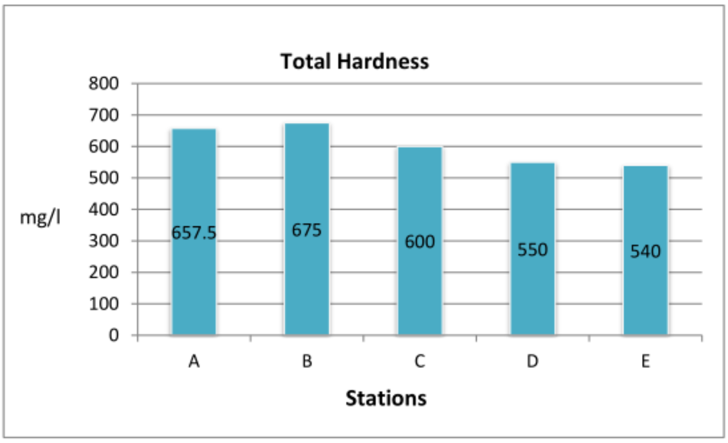

Figure 4: Total Hardness

These figures are very alarming as hard water can also have corrosion tendencies. It contributes to corrosion of metal surfaces and pipes, resulting in the presence of certain heavy metals, such as cadmium, copper, lead and zinc, in drinking-water. Corrosion can be associated with health risks (from leachates such as lead, copper and other metals) and reduced lifespan of the distribution network and appliances (e.g. water heaters) using water. In addition to that, exposure to hard water has been suggested to be a risk factor that could exacerbate eczema. A suggested explanation relative to hard water is that increased soap usage in hard water results in metal or soap salt residues on the skin (or on clothes) that are not easily rinsed off and that lead to contact irritation (Thomas & Sach, 2000).

Conclusion

Overall, the study has shown that the effluents from industries have a big impact on the water quality of Kitwe streams. This is depicted by the fact that there is higher concentration of the parameters analysed along the stream as compared to the WHO permissible limits. Although the values in some cases were lower than the maximum allowable limits by WHO, the continued discharge of un-treated effluents in the stream may result in severe accumulation of the contaminants. With the present primitive processing technology, in both extractive and manufacturing Industries on the Copperbelt, their activities will continue to enrich Kitwe stream with key nutrients and easily degradable carbon compounds, leading to further oxygen depletion in streams. In addition to degradable carbon compounds, these Industry discharges high loads of inorganic compounds; these substance are likely to accumulate in the streams and pollute the Kafue River if it not treated at the source. This is a situation that should alert the Zambia Environmental Management Agency.

Recommendations

The following are the recommendations that were made:

1. The industries should make use of emerging technologies, of waster water treatment before discharging into the stream;

2. The Government should ensure that there is an adequate system of environmental policies, laws and their enforcement.

3. Institutions like Engineering Institute of Zambia (EIZ) in collaboration with other stakeholders to mobilize technocrats with innovate ideas in order to find new ways of managing industrial effluents

4. Further research should be carried out to find out the concentration of heavy metals in the stream.

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