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ASSESSMENT OF THE IMPACT WASTE WATER DISPOSAL ON CATIONS IN RUWA RIVER, ZIMBABWE

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ABSTRACT

Zimbabwe faces challenges of pollution of rivers in its urban areas just like many developing countries in the world. The above necessitated conducting cationic water quality parameters assessment in April and June 2011 on the Ruwa river which is part of the Lake Chivero catchment where we find Harare the capital city of Zimbabwe. Water samples from fourteen sampling points were analyzed for pH, and electrical conductivity in the field and immediately taken to the laboratory and stored in a refrigerator at 4°C to be analyzed for selected cations using Atomic Absorption Spectrometry. A one way ANOVA, Pearson Correlations, water quality guidelines and standards from WHO and Zimbabwe solid were used to analyze the results. The concentrations of Ca, Mg and K were within the WHO and Zimbabwean guidelines for environmental water quality. Iron reached a maximum concentration of 10.9 mg/L in June at the Chavaroyi tributary which was above the above mentioned guidelines. The heavy metals Cd, Cu, Cr, Mn, Ni and Zn were not found in 80%of the samples.

Keywords: *cations, pollution, guidelines, Ruwa River*

1.0 INTRODUCTION

Wastewater management is increasingly becoming a challenge in developing countries due to rapid industrialization and urbanization, which are not matched by expansion, and upgrading of treatment facilities (Nyamangara *et al.*, 2008 and Mwanga, 1995). Industrial waste is one of the most complex sources of water pollution due to nature of the raw materials, the technology used in the production process, the product mix and the resultant effluent (Mwanga, 1995). Industries like electroplating, chemical, leather, paints, fertilizers, plastic, automobile, auto parts and food, result in trace heavy metal pollution of surface waters and soils (Forstner *et al.,* 1983). In Harare, the capital city of Zimbabwe, most small-scale enterprises and informal sector industries have developed along some of the rivers that drain into the city's water source. Due to the high costs of processing industrial effluent and unavailability of processing facilities, most of these industries illegally discharge effluent into the major rivers and their tributaries. Formal industries also dump effluent into rivers mainly because of inadequate pollution monitoring schemes and the fact that polluting rivers has a much lower penalty than the cost of processing the effluent (Muchena, 1998).

When effluents containing heavy metals are disposed off into rivers most metals attach to suspended particles and ultimately accumulate in sediments at the bottom of water bodies (Nyamangara *et al.*, 2008; Pardo *et al*, 1990). Decrease in pH will result in greater trace metal desorption and dissolving of many of their precipitates. At high pH characteristic of most water bodies, most metals will be precipitated in the form of oxides and hydroxides. There is a strong correlation between the pH, extent of degradation of organic materials and concentration of heavy metals in the water (Mapanda *et al*., 2007). Heavy metals like Fe, Cd, Cu, Ni, Mn, and Zn when accumulated in large amounts are known to cause many undesirable effects in the environment and are a health hazard (Ndlovu, 2008). In Lake Chivero which is the main source of water supply for Harare, Zaranyika *et al.*, (1993) found Copper, Cadmium, Lead and Nickel at higher concentrations above the permissible limits by

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WHO and Zimbabwean standards.

In the 1980s and 1990s, rapid expansion of Harare's population and industry concurrent with poor planning regarding waste water treatment led to treatment plants being overloaded (Muchena, 1998). Current treatment capacity of sewage stemming from the main urban areas is insufficient to maintain water quality standards. Nhapi and Tirivarombo (2002) reported that deterioration of water quality in the major inflow rivers into Lake Chivero greatly affected water treatment, rendering it more sophisticated and expensive. In their study, Marimba river failed to recover sufficiently before discharging into Lake Chivero (Muchena, 1998 and Mathuthu *et al.*, 1997). Due to the close proximity of Lake Chivero to its catchment which has diverse socio-economic activities, sustainable management of the water system is very challenging. Since the city of Harare is found in the Chivero catchment, it therefore pollutes its own water source (Nhapi *et al.*, 2006; Kirchmann *et al.*, 2008)

A study of the water quality of some rivers in Zimbabwe was conducted in 1995 and better water quality was found in Ruwa river compared to other rivers in the study namely Mukuvisi, Marimba, Manyame and Muzururu in respect to COD, total nitrogen and total phosphates (Gumbo *et al.,* 2002). Cations were not aassessed in the above study. The study included the Ruwa River which by then had the safe water by Zimbabwean standards. The quality of water in Ruwa river was suspected to have undergone increased pollution due to the rapid expansion of the Ruwa suburbs, industries and farming activities. The population has increased in the nearby suburbs of Mabvuku and Tafara, without corresponding adjustments in the sewage treatment. This necessitated the assessment of the water quality of Ruwa river with respect to cations, a tributary to the Manyame River which pours its water into Lake Chivero the main source of water for Harare residents

2.0 MATERIALS AND METHODS

Figure 1 shows a sketch of the Manyame catchment which includes the Ruwa river and its tributaries. Figure 2 shows a sketch of the Ruwa river and its tributaries where river water samples were collected for analysis

Water samples were collected using poly ethylene bottles from fourteen sampling points on the Ruwa river and its tributaries which are indicated by codes on the map in fig 2. The samples were taken for laboratory analysis of other water quality parameters. Maps like Zimbabwe Sheet SE-35-5 Harare Edition 2, with details of the area were collected and studied to get a general overview of the area. The Ruwa river was followed from the source until the Epworth dam (R12) reached. The impact of the sewage effluent on the river was evaluated by comparing the levels of the cations upstream and downstream, then evaluated by comparison to the recommended international standards for river water quality by WHO and the effluent and solid disposal regulations of Zimbabwe effective from 2007.

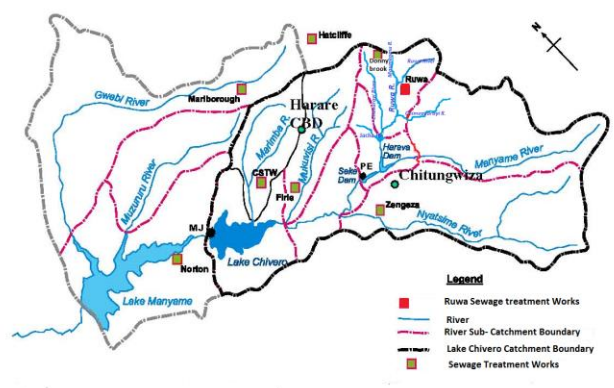

Figure 1 : A sketch of the Manyame catchment which includes the Ruwa (Nyakungu et al, 2013)

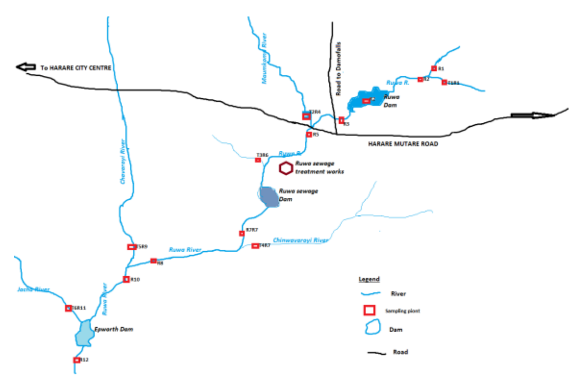

Figure 2 : sketch of the of the sampling points on the Ruwa river and its tributaries (Nyakungu et al, 2013)

The collection of water samples was carried out twice, in April and June 2011 representing summer season and winter season respectively. Water samples were collected in triplicate from each sampling point just below the water surface using 500 ml polyethylene bottles

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which were cleaned by soaking in 10% nitric acid overnight and rinsed with deionised water before the day of sampling. At the sampling site the bottles were rinsed twice with the water to be sampled prior to filing in. Conductivity, and pH were recorded immediately after the samples were collected in the field. All samples were tightly sealed and immediately taken for laboratory analysis. For cation analyses the samples were filtered upon arrival at the laboratory using 0.45μm filter paper mounted on a Pyrex filter holder and 2ml strontium chloride was added per 100ml of filtrate to release the metals into solution. Samples were stored in the dark room at room temperature. Trace heavy metals concentration were analyzed using Shimadzu AES, AAS 6701 of 1993 for the quantitative analysis of heavy metal concentrations (Whiteside and Milner, 1984: Forstener *et al.*, 1983; Kunikane, 1984; Wolverton *et al.*, 1979; Klein *et al.*, 1962)

Genstat 13 was used for analysis of results. The mean, standard deviation, standard error, the least significant difference were determined using one way ANOVA with no blocking at 95% confidence level. Comparison of values of the same water quality parameter in each season was carried out using the LSD test. (Jeffrey *et al.*, 1994). . The standard error of means (SEM) bars, are indicated on the graphs

3.0 RESULTS AND DISCUSSION

Pollution was seen to result from various socioeconomic activities including agriculture, excavation of land, sewage waste disposal and day to day activities in residences close to the Ruwa river (Nyakungu *et al*, 2013). The above no doubt impacted on the concentrations of cations in the Ruwa River.

The graphical plots of cations Ca^{2+}, Mg^{2+} and K^{+} shown in figures 3 to 6 reveals high concentrations at sampling points on the following tributaries: Maumkomu, Chinwavaroyi, Chavaroyi and Jacha. There was a general increase in the cations downstream. The June concentrations of water samples were generally higher than the concentrations found in April. There was an increase in pollutants going down stream and peaks are found on the tributaries before their confluence with Ruwa river. At the last sampling point (R12) calcium recorded the greatest concentration of 33.2 mg/L for the two seasons in April. The standard error of means were very small for all samples making each value significantly different from the rest in the data set. Chavaroyi river had the highest calcium concentration of 25.7 mg/L in June.

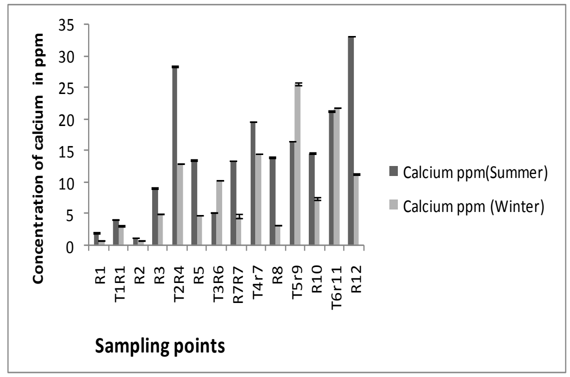

Figure 3: Concentration of Calcium in water samples for June (winter) and April (summer)

Magnesium concentrations flactuated from one point to another but generally increased concentrations on the Ruwa river down stream. A strong correlation was established for magnesium concentrations and electrical conductivity as well as potassium concentrations. The correlation coefficients were 0.90 and 0.84 respectively. In June the tributary Chavaroyi river (T5R9) had the highest magnesium concentration for the two seasons and was recorded at 10.18 mg/L. The April highest concentration was recorded at Maumkomu river (T2R4) as 6.90 mg/L. WHO recommends a concentration of less than 250 mg/L in its guidelines

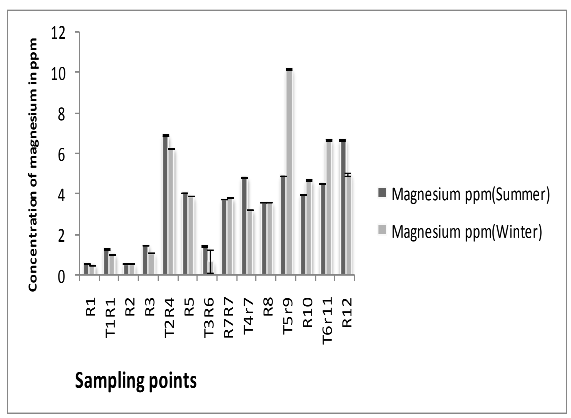

Figure 4: Concentration of magnesium in water samples for June (winter) and April (summer)

Calcium and magnesium in figure 3 and 4 can be released from remains of construction materials such as cement that are dumped from construction since people are still building houses in Ruwa (Msonza, 1993).

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The concentrations of potasium were greater in June than in April at 12 sampling points except for Chinwavaroyi river and the last sampling point after Epworth dam (R12) as shown in Figure 5.

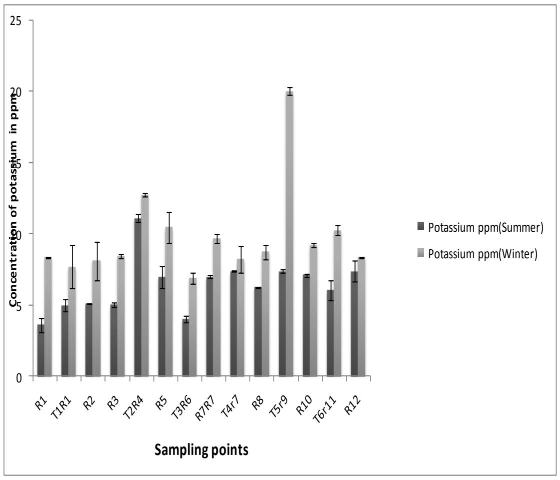

Figure 5: Concentration of Potassium in water samples for June (winter) and April (summer)

The April samples had their highest potasium concentration of 11.1 mg/L at Maumkomu river (T2R4). The highest potasium concentration of 20.05 mg/L in all the water samples was recorded Chavaroyi river in the winter season. Potassium comes from many sources and among them are agricultural fertilizers and domestic waste. Nevertheless the concentrations of the above cations were within the acceptable limits of the water quality guidelines

Heavy metal cations were found to be scarce in the water samples analyzed. The heavy metals Cd, Cu, Cr, Mn, Ni and Zn were not found in 80%of the samples. Cadmium was never detected in any of the samples yet the detection limit for Cd is 0.01 mg/L using the FAAS. The was need for the use of GFAAS since the permissible limits shown in table 1, are way below the detection limits of FAAS. (Whiteside and Milner, 1984). Nickel was only detected in samples collected from the first tributary after the first sampling point (T1R1).

Table 1 shows the maximum permissible concentrations of some heavy metals in parts per billion for drinking water as set out in the Zimbabwean and WHO guidelines..

Metal	Pb	Mn	Cu	Ni	Cr	Cd	Zn	Fe
WHO	50	100	1000	200	50	5	5000	300
Zimbabwe	50	100	50	300	50	10	1000	300

Table 1: Acceptable limits for water quality standards in ug/l for drinking water (WHO, 1989; Zimbabwe Government, 2007)

The highest iron concentration of 10.93 mg/L for iron was recorded at Chavaroyi River in june, as shown in Figure 6. This was past pemmissible standards in the Zimbabwean guidelines for effluent. The same sampling point recorded a relatively lower iron concentration of 2.56 mg/L which was the maximum for April though and above the acceptable standards.

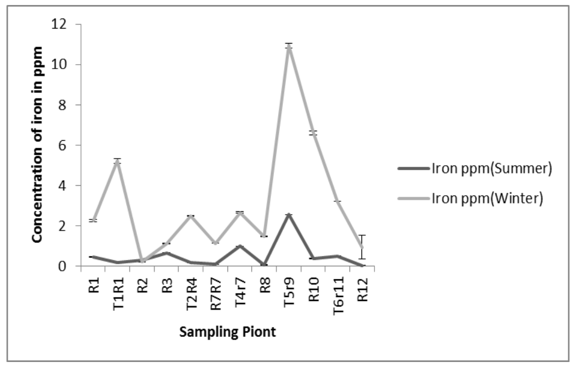

Figure 6: Changes in Iron concentrations for June (winter) and April (summer)

All concentrations of iron in water samples were higher in June than in April except for water samples from the Ruwa dam. The above could be a result of the rusting of the metal objects that are washed into the river from the waste dumps. The above values shows that, the causes for such high concentrations needs to be studied but most likely is related to sewage effluent discharge since june concentrations were higher than those of April. Iron concentrations above the maximum allowed concentrations in the effluent guidelines becomes toxic to animals and human beings (Tchobanoglous and Schroeder, 1985).

Zn was only detected at the Ruwa dam with a concentration of 0.36 mg/L and from the water collected after the Ruwa sewage dam (R7R7) at 0.72 mg/L. The value of 0.72 mg/L was in the second category of effluent waste guidelines of Zimbabwe.

. There was a general increase downstream showing that the concentrations were accumulating. The fact that lower concentrations or none at all of manganese and other metals were detected, shows that the concentrations present in the water could be very low. Some of the metal ions could have been precipitated as hydroxide when the water falls

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presented by the rocks on the river bed are effective in mixing oxygen with water (Dara, 1994). The detection of the other heavy metals whose concentration was below the detection limit of FAAS could have been possible if a graphite furnace atomic absorption spectrometer (GFAAS) was used (Skoog *et al.*, 2004).

EC values in figure 7 increased from upstream going down stream yet values in the tributaries Maumkomu (T2R4) and Chavaroyi (T5R9) were above those from the rest of the tributaries sampled. The highest electrical conductivity in April was obtained in Maumkomu river valued at 27 mS/m yet in June it was the Chavaroyi river with a value of 53.4 mS/m. The EC values obtained showed strong correlation with the concentrations of potassium and magnesium

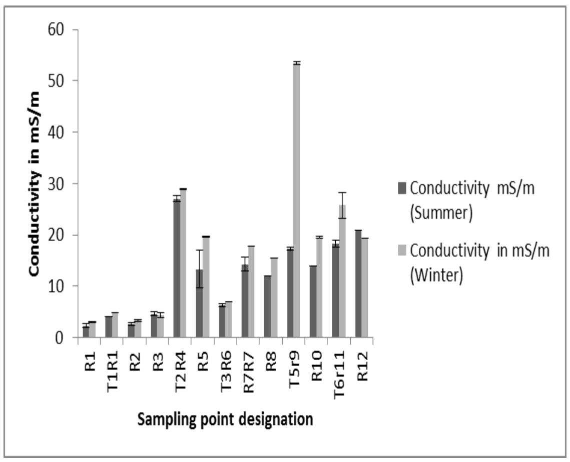

Figure 7: Electrical conductivity values of water samples collected in June (winter) and April (summer) 2011.

Figure 8 presents the pH which varied between acceptable values of 6 and 7 for almost all the samples in both seasons.

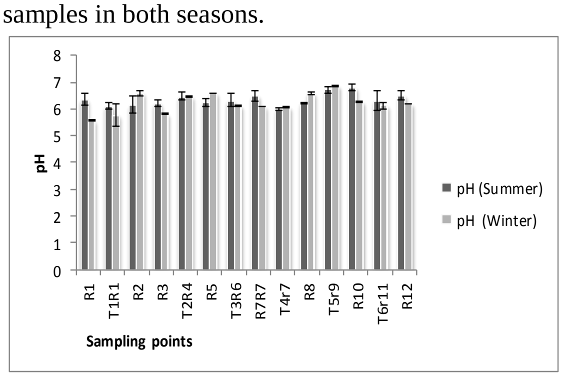

Figure 8: The pH of water samples collected in April (summer) and June (winter)

The greatest concentration of total dissolved solids (TDS) shown in figure 9 for the two seasons was obtained in June were obtained at Chinwavaroyi river (T4R7). The June TDS values were generally greater than the April values except for the first tributary after the Ruwa river source (T1R1).

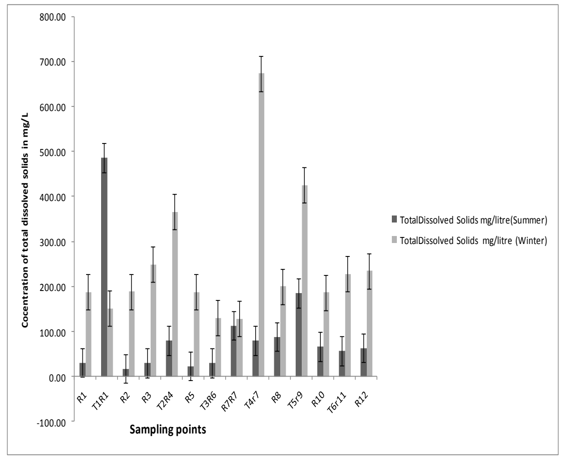

Figure 9: Concentration of dissolved solids in water samples for June (winter) and April (summer)

In this study it was evident that tributaries added dissolved solids to the Ruwa river. In june Chinwavaroyi river had the highest value of total solids dissolved solids which was found to be 648.1 mg/L which was within the confines of fresh water expected to be less than 1500 mg/L (Tchobanoglous and Schroeder, 1985). This could be as a result of dissolved fertilizer components since the river comes from farms and the presence of potassium, magnesium and calcium in the water sampled from this river.

3.2 Conclusion

The main focus of this study was to assess the impact of sewage and domestic waste on the cationic water quality parameters of the Ruwa river and its tributaries as well as determining point pollution sources of solid waste and effluent in the river. Assessing the levels of pollutants against WHO and Zimbabwean waste water standards as well as to show the trend, distribution and correlations of the water quality parameters of Ruwa river became essential tools.

The pH which impacts on cation sorption and desorption was between 6 and 7 for 90% of the samples in April 2011 and all the samples were in that range in June 2011. This research furnished information on metals to augment the research of COD, phosphates and total nitrogen by Gumbo *et al.*, in 1995 published in 2002 as well as anions by Nyakungu *et al* 2013.

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Ruwa river also contributes a lot to the concentrations of calcium, magnesium, potassium and iron that ends up in Lake Chivero. The concentrations of Ca, Mg and K were within the WHO and Zimbabwean guidelines for environmental water quality. The heavy metals Cd, Cu, Cr, Mn, Ni and Zn were not detected in over 90% of the samples. Iron reached a maximum concentrationof 10.9 mg/L in June at the Chavaroyi tributary and became a cause for concern. Sediments need to be studied so as to determine the fixed forms of metals which can dissolve when conditions such as pH and redox potential change.

Ruwa river is polluted by sewage from Tafara, Mabvuku and Ruwa town through the tributaries Maumkomu and Chavaroyi as well as directly from Ruwa town sewage discharge point into the river and from Chinwavaroyi a tributary from the farming area. Results of this study showed that most pollution parameters measured were higher in the two tributaries compared to sampling points on the Ruwa river points.

3.3 Acknowledgements

I acknowledge the help rendered by Admire Mafurauswa, Reginald Nhenderere, Kudzanayi Chipiso and Rumbidzai Musonza in sample collection as well as Mrs Kufazvineyi and her team in the Upper Manyame Subcatchment for supporting the project.

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