August 2013. Vol. 4, No. 2 ISSN2305-8269
International Journal of Engineering and Applied Sciences

www.eaas-journal.org

ASSESSMENT OF THE IMPACT OF WASTE DISPOSAL ON THE CONCENTRATION OF ANIONS IN RUWA RIVER, ZIMBABWE

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ABSTRACT

Zimbabwe faces the problem pollution of rivers just as it is with many countries. A study was conducted in 2011 to assess the impact of domestic and industrial waste on the water quality of Ruwa river found in the Lake Chivero catchment where we find Harare the capital city of Zimbabwe. Water samples from fourteen sampling points were immediately taken to the laboratory and stored in a refrigerator at 4°C and analyzed for chemical composition of anions, dissolved oxygen and TDS using standard methods of analysis. A one way ANOVA and standard water quality guidelines from WHO and Zimbabwean were used to assess the river water quality. The concentration of anions increased from sampling points upstream to those downstream. Dissolved Oxygen ranged from 5.7 mg/L to 8.0 mg/L during the two sampling times. TDS reached a maximum of 648.1 mg/L in one of the tributaries. The results obtained indicate that water and waste water management should be taken as a priority by the water authorities in Zimbabwe.

Keywords: Eutrophication; Ruwa River; Water Quality; Waste Disposal; Anions

1. INTRODUCTION

Managing water is a challenge that faces most water management authorities in the world. 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 waste treatment facilities [19] [15]. Pollution of natural waters leads to eutrophication, a problem affecting the quality of river water in developing countries due to rapid changes in socio economic activities that end up generating waste which drain into the rivers [7].

Eutrophication is the natural ageing process of lakes characterized by a geologically slow shift from in-lake biological accumulation of nutrients driven by loading of nutrients from external sources as well as accumulation of nutrients driven by in-lake processes [20]. This slow process can be greatly accelerated by domestic and industrial waste discharges rich in nutrients especially nitrogen (N) and phosphorous (P). When other elements and conditions are optimal, this results in accelerated growth of aquatic flora, fauna, and other physical parameters which lead to degraded water quality [10] [19].

Before the 1960s water pollution in Zimbabwe was not perceived to be a widespread national problem [9]. However, the quality of water in the rivers in the Chivero catchment the most densely populated catchment in Zimbabwe deteriorated with expansion of the city of Harare. Algal blooms in the Lake Chivero that occurred in the 1960s indicated that eutrophication was taking place. The water act of 1927 was then found to be deficient in addressing the existing pollution problems and was then revised using standards from international sources such as USA Environmental protection agency and WHO while taking into consideration local situations [23] [9]. A research done by the University of Zimbabwe and the Harare City Council prompted by invasion of Lake Chivero by the water hyacinth weed in the 1960 showed that eutrophic conditions emanated from nutrient loading of nitrogen and phosphorous from sewage effluent. This led to the change of guidelines for N and P load from sewage

treatment works and measures to reduce their concentration in the environment [9].

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 [14]. Current treatment capacity of sewage treatment from the main urban areas is insufficient to maintain water quality standards [18]. 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 [3]. Since the city of Harare is found in the Chivero catchment, it therefore pollutes its own water source [6] [17].

The development, reassessing and reviewing of the standards for effluent and waste water has continued taking place in Zimbabwe since then. [13] [24]. Zimbabwe is currently using the effluent and waste disposal regulations of 2007 [24]. Adherence to river water quality standards by water management authorities leads good quality of drinking water will be obtained from the lakes which then results in better health for communities [12].

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 [3]. By the year 2010 the quality of water in Ruwa river was suspected to have undergone increased pollution levels due to the rapid expansion of the Tafara, Mabvuku and Ruwa suburbs, industries as well as farming activities. This necessitated the assessment of the water quality of Ruwa river, a tributary to the Manyame River which pours its water into Lake Chivero the main source of water for Harare residents.

2. MATERIALS AND METHODS

Figure 1 shows a sketch of the Manyame catchment which includes the Ruwa river and its tributaries. It was modified from Nhapi and Hoko[16]. Figure 2 is a sketch of the studied Ruwa river its tributaries with sampling points indicated.

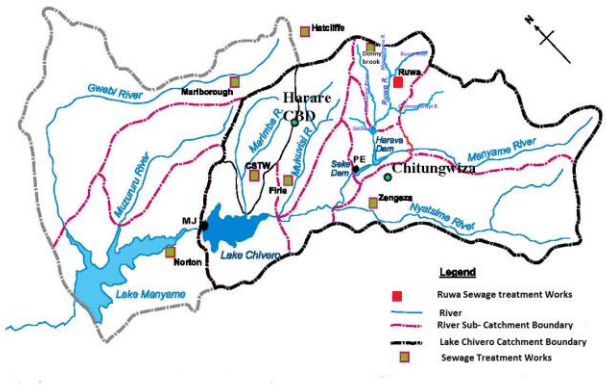

Figure 1: A sketch of the Manyame catchment which includes the Ruwa

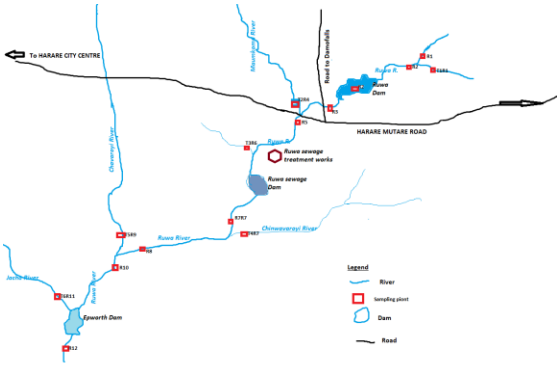

Figure 2: A sketch of the Upper Manyame sub-catchment was Ruwa river and its tributaries are found.

2.1 Sample collection and treatment

The collection of water samples was carried out twice, in April and June 2011 representing summer season and winter season respectively. Triplicate samples were taken from 14 sampling points on the Ruwa river and its tributary designated by codes as shown in Figure 2. Water samples were collected just below the water surface using 500ml polyethylene bottles 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. All samples were tightly sealed and immediately taken for laboratory analysis. Samples were stored in the dark room at room temperature. The remainders of the samples for other analyses were kept in a refrigerator at 4 °C. Deionised water was used as the control sample. The anions: phosphates, nitrates and sulphates are a measure of the amount of anions present in the water individually. They show the degree of eutrophication and were quantified using Shimadzu UV-310PC for the quantitative calorimetric analysis of anions [4] [8] [7]. Chlorides determined using the Mohr titration, show levels of pollution [21].

2.2 Statistical analysis of results

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 [5]. The standard error of means (SEM) bars, are indicated on the graphs

3. RESULTS AND DISCUSSION

3.1 Types and Sources of Pollution

Pollution was seen to result from various socioeconomic activities including sewage disposal, agriculture, excavation of land and day to day activities in residences close to the Ruwa river. Some point pollution sources were identified and among them where three places where vehicles are washed. Solid waste was seen deposited on the river bed or on the islands in the river which included items such as pumpers, condoms, cans and used cotton wool. Squatter shacks were seen at specific points along the Ruwa river. The squatters reside close to Ruwa river farm using inorganic fertilizers sometimes for their grain and vegetable. Churned raw sewage from Ruwa Town Council is discharged into the Ruwa river to be naturally digested about 2km downstream in a dam from discharge piont. This dam does not appear on the map (Zimbabwe Sheet SE-35-5 Harare Edition 2) used in the study. The dam is covered by the water hyacinth weed for most of the top surface showing evidence of high levels of eutrophication. Rivers from Tafara and Mabvuku, Maumkomu and Chavaroyi respectively carry sewage from these areas and add to the pollution and eutrophication of the Ruwa river. The informal settlement Epworth has extended towards the banks of Ruwa river such that in some places houses are found less than 500 metres from the river. Epworth uses blair toilets or bush system of sewage waste disposal. There is no waste collection system in Epworth suggesting that refuse may end up thrown in the Ruwa river.

3.2 Total Dissolved Solids

The greatest concentration of total dissolved solids in 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 3 presents the trends obtained in the two seasons.

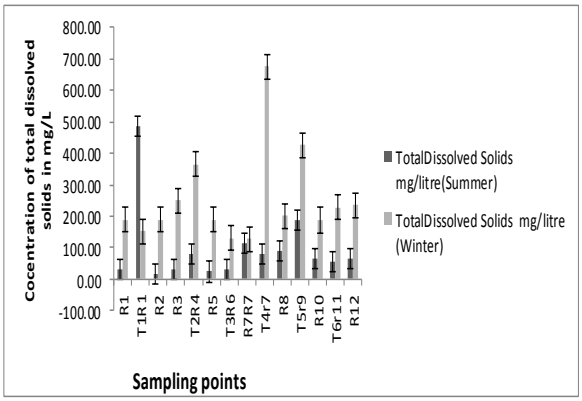

Figure 3: Concentration of dissolved solids in water samples for June (winter) and April (summer)

In june Chinwavaroyi (T4R7) river had the highest value of dissolved solids of 648.1 mg/L. This could be as a result of dissolved fertilizer components since the river comes from farms. All the water samples taken can still be classified as fresh water since the TDS values were less than 1500 mg/L [22].

3.3 Anions

Anions were found to be within the acceptable limits of WHO and Zimbawe guidelines yet the highest and second highest anions concentration were recorded in Maumkomu river (T2R4) and Chavaroyi(T6R9) river as shown in figures 4 to 7. The presence of the anions in high concentrations in the above

mentioned tributaries shows that their major source could be sewage effluent. This is further supported by the presence of high values for these anions at R7R7 a sampling point on the Ruwa river just after Ruwa's sewage discharge point into the river [2].

Chlorides and sulphates for both seasons were within the limits of less or equal to 250 mg/L stipulated by Zimbabwean guidelines for waste water [24]. From the sampling point after the Ruwa dam downstream all chloride concentration values were higher in April samples than in June samples yet at the last sampling point there was no significant difference for the two seasons. In the two seasons the LSD test showed 5 sampling points to have significantly higher chloride concentrations than the rest as shown in figure 4.

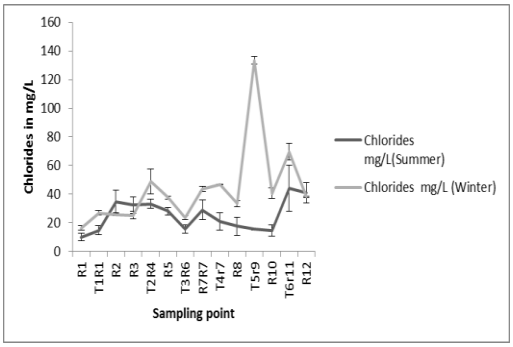

Figure 4: Concentration of Chlorides in water samples for June and April

Nitrates shown in figure 5 were within the limits of less or equal to 50 mg/L specified by WHO guidelines for drinking water [23]. They are not stipulated in the Zimbabweean guidelines [24]. A peak value of 117.87 mg/L for nitrates was recorded at Chavaroyi river (T5R9) in April. The nitrates shown in figure 5, had peak concentrations on the following tributaries Maumkomu (T2R4), Chavaroyi (T5R9) both which carry sewage effluent and Chinwavaroyi (T4R7) which comes from the farms suggesting high N loads.

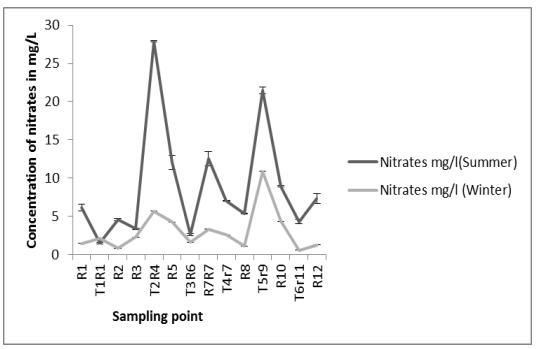

Figure 5: Concentration of nitrates in water samples for June (winter) and April (summer

The concentrations of phosphates in all sampling points is presented in Figure 6 showed 4 sampling points to have significantly higher concentrations than the rest in April. Two of the points are tributaries which carry sewage effluent Maumkomu river (T2R4) and Chavaroyi(T6R9) river, another one is R7R7 a sampling point after Ruwa Sewage Dam and the last sampling point (R12) with an accumulated phosphates load.

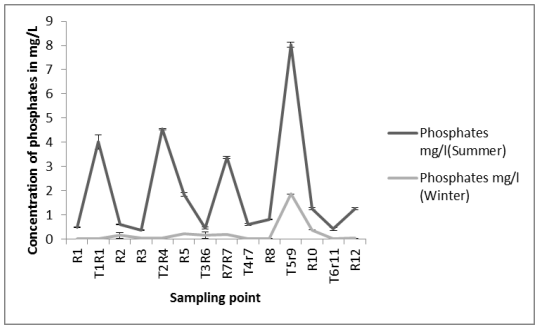

Figure 6: Concentration of phosphates in water samples for June (winter) and April (summer)

In June only Chavaroyi river (T5R9) river had significantly higher phosphate concentration above the rest yet all concentrations recorded were within the acceptable limits of environmentally safe water of less or equal 0.5 mg/L of phosphates [24]). In April water at Chavaroyi tributary (T5R9) was the most phosphate polluted water with a concentration of 8.03 mg/L which is past the red category with a maximum of 5 mg/L for the most environmentally hazadous waste. [24] April results indicate that phosphates originates from agricultural activities.

The high concentrations of phosphates and nitrates in the water samples as well as their increase downstream explains the existence of water weeds which increased in water surface coverage on the Ruwa river starting from its confluence with the Maumkomu river in Ruwa till Epworth dam is reached. This increase in eutrophication must be remediated since a lake normally retains 30-60% of nutrients, indicated by a sudden drop in concentrations of the anions at R12, the last sampling point [1].

The case of sulphates is given in Figure 7. The tributaries Maumkomu (T2R4)

and Chavaroyi (T5R9) from Tafara and Mabvuku sewage works respectively had the highest levels of sulphates in June. Chavaroyi river was 124.7 mg/L sulphates above Maumkomu river. June concentrations of sulphates were generally higher than the April concentrations

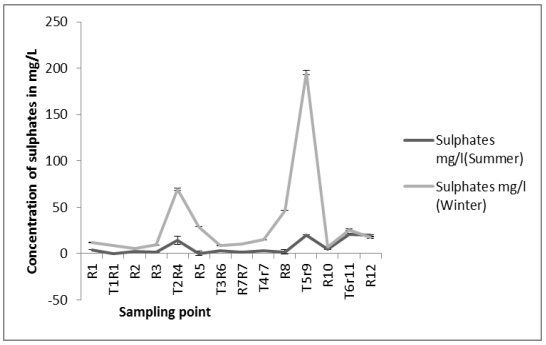

Figure 7: Concentration of Sulphates in water samples for June (winter) and April (summer)
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3.4 Dissolved oxygen

The dissolved oxygen levels shown in figure 8, were within the permissible limits set in the WHO guidelines for the two seasons.

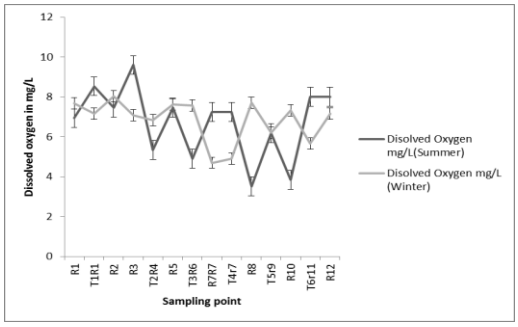

Figure 8: Concentration of dissolved Oxygen for June (winter) and April (summer)

The dissolved oxygen levels were within the permissible limits qouted at an optimum of 4 to 6 mg/L yet maximum is 9 mg/l [2]. All the points had a acceptable DO values in the optimum range and above the optimum range. The rocks along the Ruwa river allow water to fall over and form bubbles facilitating the disolution of oxygen. The presence of fish also shows that the DO values were still within the range that allows fish to survive. Most fish species tolerate a DO concentration in the range of 5-8 mg/L [11].

\3.5 Conclusion

The main focus of this study was to assess the impact of sewage and domestic waste on the anions concentration in the Ruwa river and assessing these levels against WHO and Zimbabwean waste water standards. In 1995 phosphates in the Ruwa river were estimated at 4.75 mg/L yet in this study they averaged 2.01 mg/L. The dry season concentration of phosphates in the Ruwa river was estimated at 1.88 mg/L yet in this study, an average of 0.66 mg/L was recorded for the June season. It will be easy to conclude that environmental management with respect to phosphates has improved but this has to be approached with caution since the 1995 figures are recorded as estimates. No details were given as to how the estimates were made [3]

The same can be said of the nitrogen concentration quoted in the 1995 study [3]. Total nitrogen was estimated at 21.00 mg/L in the wet season and 4.75 mg/L in the dry season. Though total nitrogen was not measured in this study due to financial constraints, the nitrate form of nitrogen measured was found to be 5.04 mg/L in April and 0.68 mg/L in June. No conclusion can be reached regarding the changes in nitrogen content in the Ruwa river.

Ruwa river contributes to the eutrophication of the Manyame river and consequently Lake Chivero as shown by the existence of extensive coverage of the water surface by the water hyacinth weed. Dissolved Oxygen ranged from 5.7 mg/L to 8.0 mg/L during the two sampling times acceptable by Zimbabwean standards. Ruwa river is polluted by sewage from Tafara, Mabvuku and Ruwa town through the tributaries Maumkomu and Chavaroyi as well as directly from Ruwa.

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