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ASSESSMENT OF HEAVY METAL CONTAMINATION OF DZINDI RIVER, IN LIMPOPO PROVINCE, SOUTH AFRICA

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ABSTRACT

This study was carried out to evaluate the current water quality of Dzindi River in Limpopo Province, South Africa. pH, electrical conductivity (EC), total dissolved solids (TDS) and turbidity were measured using a pH meter, EC and TDS multimeter and a turbidimeter respectively. The water samples were collected from four different sampling points along the river and digested with concentrated nitric acid in a fume cupboard. The concentrations of the selected heavy metals (Al, Cr, Cu, Fe, Mn, Pb, and Zn) were determined in triplicate using a Perkin Elmer Flame Atomic Absorption Spectrophotometer. The pH values (7.47-7.53) from the sampling sites were lower than what is recommended by the Department of Water and Forestry (DWAF) guidelines of South Africa. The EC and TDS values obtained (30-133 mS/cm and 20.10-89.11 mg/l) were within the recommended guideline of DWAF. Turbidity values (4.61-25.82 NTU) exceeded the recommended level of ≤1NTU for domestic water use. The average concentrations of all the metals investigated were higher than the recommended levels of DWAF for the protection of aquatic life and domestic water use except copper. The order of heavy metal contamination followed the trend: Fe (1.33 mg/l) >Al (0.3 mg/l)>Mn (0.15 mg/l) >Zn (0.10 mg/l) >Cr (0.06 mg/l)>Cu (0.05 mg/l)> Pb (0.03 mg/l). Results from this investigation reveals that Dzindi River is contaminated with heavy metals and should not be used for domestic purposes without treatment due to the probable health effects it may have on the user, but it is suitable for irrigation purposes.

Keywords: Aquatic life, Domestic use, Dzindi river, Heavy metals, Irrigation, Pollution.

Contribution/ Originality

This study is one of very few studies which have investigated heavy metal concentrations in Dzindi River and gives a broader baseline information on the physicochemical parameters investigated.

1. INTRODUCTION

Water is essential for industrial and economic development and the creation of livelihoods for the poor. A clean and safe water supply also helps poor households augment their income through several productive activities like subsistence agriculture. Water is a medium through which climate change exhibits its environmental, economic and social impacts [1]. Many regions particularly poorer communities, are vulnerable to droughts and similar water-related disasters which can destroy lives, assets and incomes [1].

Water is an important natural resource for the sustainability of life. The unavailability of sufficient clean and safe water is a global problem which is more intense in developing countries of the world [1-3]. Over 40% of people without improved drinking water live in sub-Saharan Africa [2].One of the Millennium Development Goals (Goal 7c) is targeted to reduce by half the population of people without access to clean and safe water by 2015.The supply of potable water to rural areas in South Africa is erratic and this makes people living in those areas resort to the use of river water for domestic purposes. Contamination of fresh water sources can be caused by natural and anthropogenic activities but the later far outweighs the former. Sources of water pollution in South Africa include: mining operations, industrial and domestic effluents, runoff of biocides, nutrients and pathogens from agricultural lands, urban areas and informal settlements [4]. Their wastes are discharged into water bodies which can affect human health and interfere with industrial and agricultural water use [5].

Pollution combined with high human demand for water affects biodiversity, ecosystem functioning and the natural services of aquatic systems upon which the society depends. Pollutants, among which are heavy metals and organic chemicals, decrease the supply of useable water, increase the cost of purification, contaminate aquatic resources and affect food supplies [6-8]. This problem cannot be solved by the construction of more dams but by the maintenance and conservation of natural water resources already in place.

Intake of toxic metals can cause several harm to the body ranging from acute to chronic diseases such as allergies, asthma, hypertension, anemia and immune system dysfunction. Aluminium, mercury and lead are known to attack the nerves and brain causing hyperactivity in children, liver and kidney dysfunction, Alzheimer's and other diseases in adults [9, 10].

2. STUDY AREA

Dzindi River which is a tributary of Luvuvhu River (Figure 1) is used by the residents of several communities along its course for domestic and agricultural purposes. Major land use around Dzindi River includes subsistence and commercial farming, brick industries, formal and informal settlements, garages and wastewater treatment plant. Abstraction of water and use without prior treatment is a common practice by people living around Dzindi River [11]. This could have several negative health impacts on them. This study is aimed at assessing the current level of some physicochemical parameters including heavy metal concentrations in Dzindi River so as to mitigate any adverse condition.

3. MATERIALS AND METHOD

3.1. Water Sampling

Water samples were collected upstream and downstream of the river. Four samples were collected in 2L bottles, the sample bottles were rinsed with the sample prior to collection. pH was measured using a pH meter while the EC and TDS were measured using 340i multimeter. Orion AQ2010 AQUAFast II turbidimeter was used for turbidity measurements. The equipment were calibrated following the manufacturers' guidelines before use. The samples were acidified with 3 ml concentrated nitric acid so as to retain the integrity of the trace metals. The samples were transported and stored in a refrigerator in Hydrology and Water Resources Laboratory of the University of Venda at 4°C before further analysis.

3.2. Sample Pre-Treatment

The samples were digested using concentrated nitric acid in a fume cupboard following the procedure stated in Ogola, et al. [12]. The digestate was filtered and stored in the refrigerator and were analysed within one week of digestion.

3.3. Sample Analysis

The Perkin Elmer Flame Atomic Absorption Spectrophotometer was used to measure the concentration of heavy metals in the samples. Calibration standards were prepared from a stock solution of 1000 ppm of each of the target metal. Serial dilutions were made into 0.5 ppm, 1 ppm, 2 ppm, 5 ppm and 10 ppm respectively for each of the metals. Distilled water was used to zero the instrument before analysis. Duplicate analysis method which is an effective method for determining the precision of an analysis was used in this study [13]. One of the field samples collected was divided into two, digested and ran by the instrument. All the samples showed a relative difference of ≤10% which is a precision of high level duplicates [13]. Also prepared known concentration of each metal was ran by the instrument and the results showed consistency. Calibration curve was prepared for each metal to be tested and the correlation coefficient was also checked. The curve was linear and the correlation coefficient varied between 0.98-1.00 for all the metals investigated. Each sample was analysed in triplicate.

3.4. Data Analysis

The data were analysed using IBM SPSS Statistics 20 and MS excel 2013 for calculating average, drawing of graphs and performing t-test.

4. RESULTS AND DISCUSSION

4.1. Some Physicochemical Parameters

pH of the samples varied from 7.47-7.53 (Figure 2). These values were within the set guideline by DWAF (6-8.5) for domestic and agricultural water use [14].This parameter is important because the acidity (or alkalinity) of water can affect plant growth, benthic organisms, soil and crops when used for irrigation and the bioavailability of heavy metals. Alkaline pH can contribute to accumulation of algal bloom.

The EC values of the samples were in the range of 30-133 mS/cm and were within the set guideline of DWAF (7000 mS/cm) for domestic water use (Figure 3).The electrical conductivity values usually give an estimate of the presence of certain ions in water such as carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium, all of which carry an electrical charge [14]. The presence of these chemical constituents gives water the ability to conduct electricity. The electrical conductivity of water is an indirect measure of its dissolved constituents. It is therefore another measure of dissolved material which is often used as a surrogate for TDS since the EC of water is a function of the number of charged ions in solution.

TDS values were in the range of 20.10-89.11 mg/l and were within the recommended limit of DWAF for domestic water use (450 mg/l) but was higher than the guideline value of 0.4 mg/l for use in irrigation [15].The turbidity of the water varied from 4.61-25.82 NTU (Figure 4). High turbidity values indicate the possible presence of silt, clay, fine organic matter and microscopic organisms that are suspended in the water. This reduces light transmission, photosynthesis and fall in the oxygen level of the water [15]. The turbidity values are above the maximum limit of 1 NTU recommended by DWAF for domestic water use. This could be as a result of high sediment runoff to the river during high incidences of rainfall. This can pose a health risk to children and the elderly when the water is used to wash vegetables to be eaten raw and some insignificant effect when used for other domestic purposes [15].

4.2. Heavy Metal Concentration

The results of heavy metal concentrations are shown in figure 5 and 6. The concentrations of Aluminum (Al) were in the range 0.2-0.4 mg/l with a mean value of 0.3 mg/l which is above the guidelines set by DWAF for the protection of aquatic organisms and domestic water use (0.15 mg/l) but is within the guideline for use in irrigation (5mg/l) [14]. There was significant difference in the mean concentration of Al between all sites except between site 3 and site 4 at 95% confidence level.

Al concentration is strongly influenced by pH and its solubility and toxicity are strongly pH-dependent. At alkaline pH, it is present as soluble but biologically unavailable hydroxide complexes, while under acidic conditions, it occurs as a soluble, available and toxic species to various invertebrates and plants and can interfere with calcium ion metabolism [16]. High aluminum concentration in domestic water can cause Alzheimer's disease and renal failure among others. The concentrations of Fe ranged from 0.79-1.72 mg/l. There was significant difference in the mean concentration of Fe in all the sites at p=0.05. The DWAF guideline value of 0.1 mg/l for domestic water use was exceeded but was within the limit for agricultural use (5-10 mg/l). This could result in objectionable taste and appearance of the water; when used for laundry purposes it causes slight staining of white clothes [15]. This presence could be due to leaching of iron from the sewer pipes from other non-point sources such as storm runoff.

The concentration of Mn varied between 0.08-0.20 mg/l with a mean value of 0.15 mg/l which is higher than the recommended standards set by DWAF for domestic water use(0.05mg/l) [14]. There was significant difference in the mean of the concentration of Mn in all the sites at p=0.05. This level of Mn observed in the water could lead to the staining of clothes and fixtures when used for laundry purposes and an increased taste and colour to the water [14, 15]. The high levels of Fe and Mn is a cause for concern as their combined effect can significantly add to the taste of the water and affect its use for laundry purposes.

The concentration of Pb varied between 0.01-0.05 mg/l with an average value of 0.03 mg/l and was above the recommended guideline of 0.01 mg/l. There was significant difference in the mean concentration of lead between site 3 and the other sites as the p-values obtained (0.06, 0.04, and 0.02) was lower than the critical value (0.05); but there was no significant difference between other sites as the p-values obtained were greater than the critical value at the same confidence level.

Lead is a non-essential and toxic metal which is usually associated with various diseases like memory lapses, anemia, anorexia, constipation, etc. The concentration observed could be due to leaching of Pb containing materials and run off from garages and roads around the river. High concentrations of lead are known to cause death or permanent damage to the central nervous system, the brain and kidneys when absorbed in humans [17]. This damage commonly results in behavior and learning problems such as hyperactivity, memory loss, slowed growth, reproductive problems in men and women [15].

Chromium (Cr) concentrations were in the range of 0.03-0.11 mg/l and the average Cr concentration was 0.06 mg/l which was in excess of the DWAF guideline for total maximum chromium in domestic water use (0.05 mg/l) and the protection of aquatic life (0.0007 mg/l) but was lower than the guideline for agricultural use (0.1 mg/l) [14].There was significant difference in the mean concentration of chromium between site 1 and sites 2 and 4 at p=0.05. Similarly, there was significant difference in the mean concentration between site 4 and the other sites at the same confidence level but there was no significant difference between site 1 and 3.

These results are different from a similar study conducted by Ogola, et al. [18] around Ebenezer Dam in Limpopo Province where a concentration lower than 0.01 mg/l was observed for Pb and Cr [18]. Chromium is not known to accumulate in the bodies of aquatic organisms, but a high concentration of chromium due to disposal of metal products containing it in surface water can damage the gills of fish that swim near the point of disposal [19].

The concentrations of zinc (Zn) were in the range 0.05-0.21 mg/l with an average concentration of 0.10 mg/l. This concentration was higher than the recommended guideline of DWAF for the protection of aquatic life but was lower than the guidelines for use in irrigation [14].There was significant difference in the mean concentration of zinc between all sites except between site 2 and site 3 at p=0.05.

Zinc is usually present in tap water at concentrations less than 0.2 mg/l, although drinking water in galvanized pipes can contain up to 2 to 5 mg/l. Zn is an essential trace element for bacteria, plants and animals including human beings. It has many biochemical functions catalytic, regulatory and structural. The catalytic role of zinc is understood in terms of the fact that it forms part of the specialized enzymes and proteins [14]. A very high concentration of zinc is known to be harmful to the body. It causes phytotoxicity and affects many functions of the body such as reproduction, skin health, senses of smell and taste, brain functions and growth [20].

The concentrations of copper (Cu) was 0.03 mg/l in site 1 and 0.05 mg/l for the other sites this could be due to more industrial activities in the other three sites when compared to site one. The result from all the sites were above the DWAF guideline value of 0.00003 mg/l for the protection of aquatic life and water use in aquaculture (0.005 mg/l) but was lower than the guideline for domestic use (≤ 1 mg/l), livestock watering (≤ 0.5 mg/l) and irrigation (≤ 0.2 mg/l) [14, 15]. There was significant difference in the mean concentration of copper only between site 1 and the other sites at p=0.05.

Copper is an essential substance to human life, but chronic exposure of drinking water to copper can result in the development of anemia, liver and kidney damage [21]. Copper can travel great distances in surface water either suspended on sediment particles or as free ions.

5. CONCLUSION

The results show that Dzindi River is contaminated with heavy metals as all the metals investigated except copper were present in concentrations higher than the recommended values by DWAF for the protection of aquatic life and domestic use. However, all the metals were present in concentration lower than the guideline values for water use in irrigation. The reason for this could be due to high sediment inflow to the river during rainfall, poor agricultural practices, uncontrolled deforestation, poorly planned informal settlements and effluents from wastewater treatment plant. Heavy metals can be carried along with sediments into the river, also leaching of soils from agricultural soils usually have heavy metals and nutrients contained in fertilizers into the river. Runoff from road sides and bricks industries around the river is possible sources of heavy metal contamination. It is recommended that the river water be treated prior to use for domestic purposes in order to prevent any adverse health effect.

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Figure-1. Map of the study area [11]

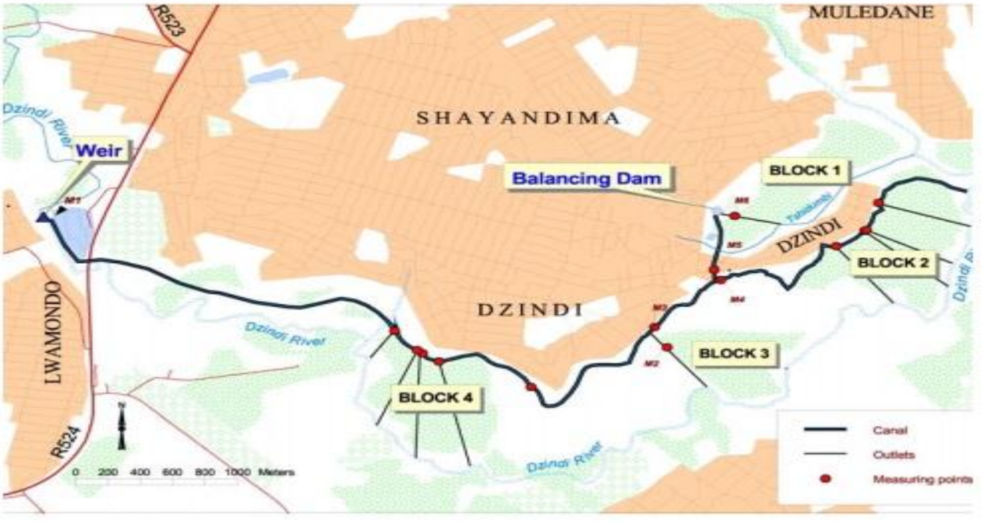

Figure-2. pH values for different sites in the river

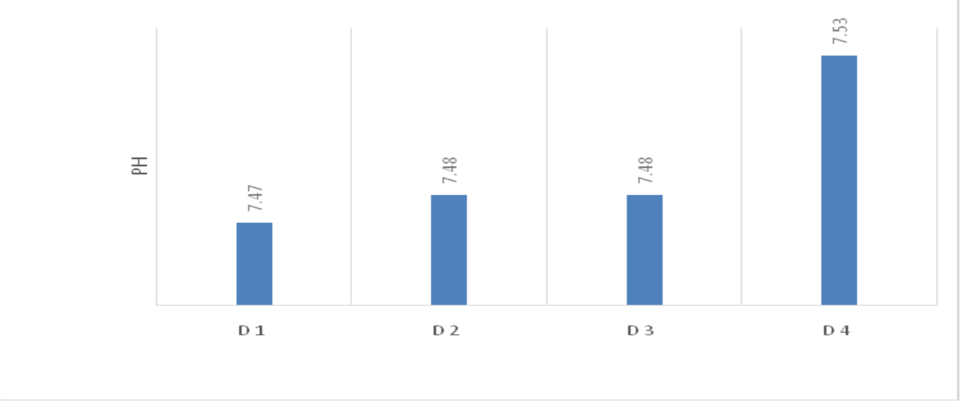

Figure-3. Electrical conductivity values for different sites in the river

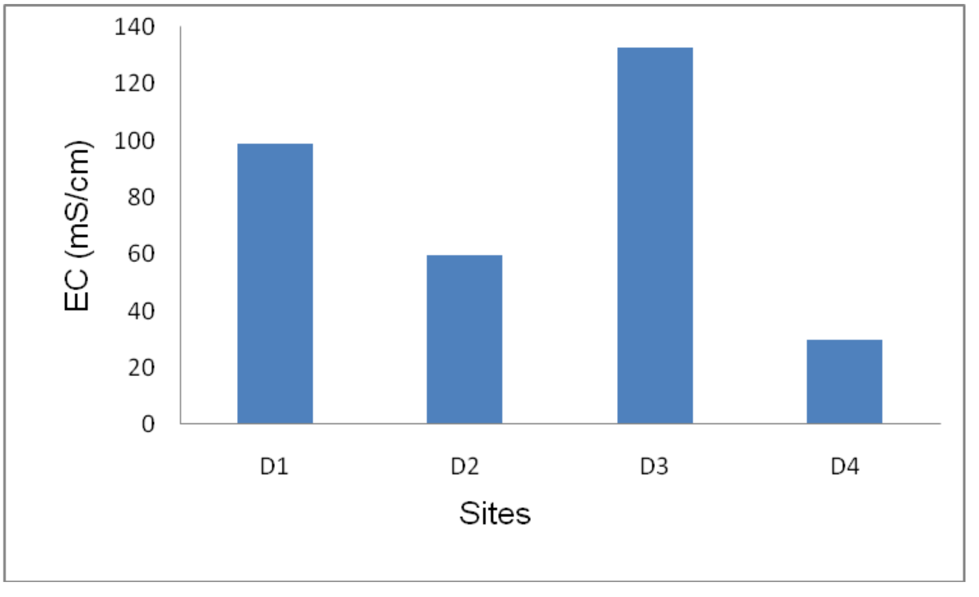

Figure-4. Turbidity values for different sites in the river

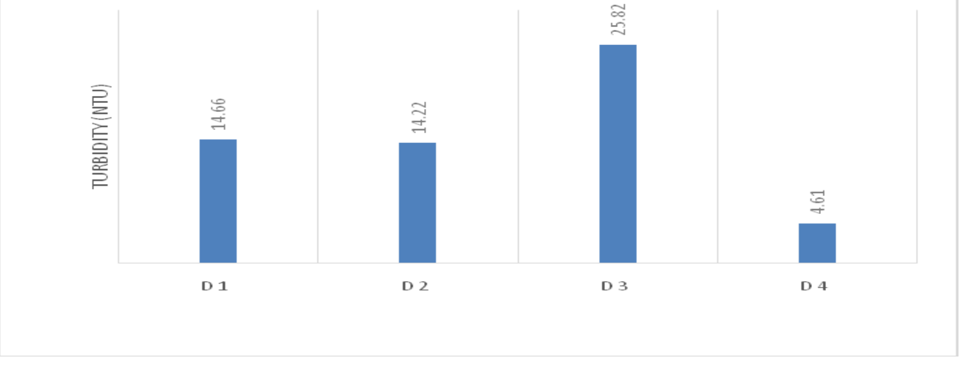

Figure-5. Concentration of Fe, Mn and Al in the study sites

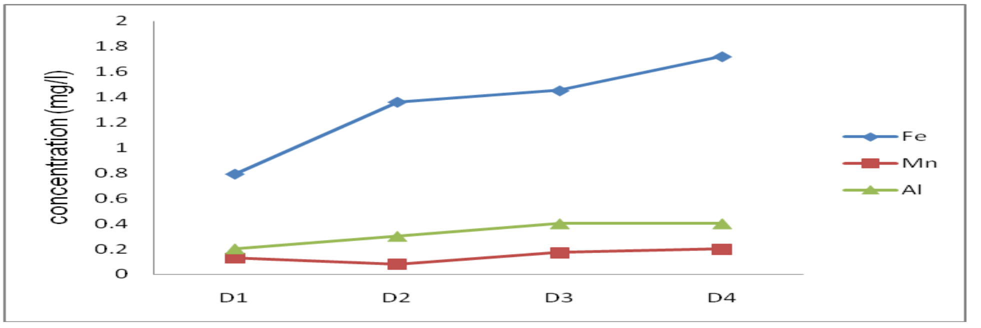

Figure-6. Concentration of Pb, Zn, Cu and Cr in the study sites