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Evaluation of Heavy Metal Concentration in Sediments of Rupingazi River, Kenya

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Abstract:- Heavy metal concentration (Cu, Zn, Fe, Mn, Ni) was evaluated in sediment samples of Rupingazi river during the wet and dry seasons. In this study, the sediment samples were collected from twenty sampling points along the river. The heavy metal levels were evaluated using Atomic Absorption Spectrphotometer.The obtained data was analyzed using one-way analysis of variance. The range of the concentration of copper was found to be 4.68-12.69 mg/kg for the wet season and 0.98-24.10mg/kg for the dry season. The mean values of the concentration of iron was found to be 1422-6145.33 mg/kg for the wet season and 1254-5866.67 mg/kg for the dry season. The range of the concentration of Nickel was found to be 0.72-30.73 mg/kg for the wet season and 2.63-12.48 mg/kg for the dry season. Concentration of manganese was found to be 48.03-411.20 mg/kg for the wet season and 6.15-248.35 mg/kg for the dry season Zinc concentration was found to be 26.29-167.10 mg/kg for the wet season and 4.82-28.39 mg/kg for the dry season. The Zinc, Manganese, Nickel Iron and Copper levels were not beyond the USEPA recommended limits.

Keywords:- *Heavy Metal, Concentration, Sediments, Rupingazi River,*

I. INTRODUCTION

Heavy metals are chemical components with a high density and are detrimental even at very small concentrations (Pafilipaki *et al*.,2008). Heavy metals like manganese, copper and zinc are required for growth and development in the body (WHO\ UNICEF, 2008.However when heavy metals exceed a certain recommended limit, they can become harmful. Heavy metals are naturally part of the ecosystem (Aderinola *et al*.,2009).

With the rapid economic growth, heavy metal pollution has become a key issue in rivers as it is the most common source of drinking water in the world. (Anjum *et al*,.2013). They are undecaying and can get to humans' beings through the food chain as a result of consumptions of food and water which is contaminated with the heavy metals. (Opaluwa *et al*.,2012). Heavy metals concentration in rivers can be kept track of through assessment of water and sediments. Heavy metals which are found in the earth's crust constitute the environmental levels of the heavy metals. The increased levels of heavy metals concentrations in rivers results from anthropogenic sources such as waste from industries and municipalities(Mwamburi,2003). Agricultural activities also act as a source of heavy metals from farms where intensive farming is carried out from farm inputs like fertilizers, pesticides, herbicides and fungicides. Run off from these farms is drained into water bodies. (Marcovecchio *et al.*, 2007) Heavy metals are regarded the most hazardous water pollutant because of bio accumulation and harmful effects. (Naseh *et al*.,2012)

These levels are escalated as a result of their introduction into the environment either through natural sources or anthropogenic sources. Examples of natural sources are weathering of rocks and volcanic eruptions. (Harikumar *et al*., 2009.Bazrafshan *et al*.,2015).

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In aquatic environment as observed by Thomann and muller, (1987) and Zhang *et al* (2015) heavy metals are found to exist either in dissolved or particulate state. The metals in the dissolved state metals are found either in the water column or sediment pore water whereas those that are accumulated on suspended and bed sediments are the ones in particulate state. Constant evaluation of heavy metals concentration in the sediments is necessary, since crucial facts in regard to their distribution and level of contamination is obtained (Asaolo *et al.*, 1997). observed that heavy metals in rivers tend to build more in sediments than in water . The analysis of the metal pollution of a river gives a foundation of the connection linking the metal partitioned into the sediment and there are present in the dissolved state in water. The interchange between sediment and water could also be liable for the deposition of metal in the sediments. (Sing *et al*.,2005, , Silva *et al* .,2014). When sediments are polluted with heavy metals,

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they posse an environmental problem due to the fact that they are toxic, non-degradable and easily accumulate in biota and food chain (Sundaray *et al*., 2014). Sediments are considered major pointers of water pollution since they are principal sources and sinks of the heavy metals (Zhang *et al*.,2015). Suspensions of the river sediments contain the heavy metals that will pollute ground water systems associated with those rivers, and vice versa (Sojka & Jaskuła, 2022) Daily or weekly scanning of heavy metals content in sediments will help in early identification of threats posed to both, aquatic life and people. Some organisms in the benthic environment for instance, benthic invertebrates or bottom-feeder fish have a connecting interface with both the sediments and water and they can get contaminated with heavy metals through direct ingestion or through absorption (Khan *et al*., 2023).

Heavy metals are released from sediments through the process of resuspension of particulates at the sediment-water interface. When pollution of river water is being considered in any study, sediments should also be considered as have been extensively regarded environmental pointers for the evaluation of environmental pollution in the water course.

II. MATERIALS AND METHODS

➢ *Study Area*

River Tana is one of the major rivers in Kenya. One of its tributaries is Rupingazi river which is found in Embu county. It passes through Manyatta region, Embu town to Mbeere constituencies. Rupingazi river goes through three key areas; Upper, middle and lower regions. Large scale agricultural activities dominate the upper and middle regions. In this area, the main source of pollution is agrochemicals that are applied in the farms. The lower region gets its pollutant from light industries.

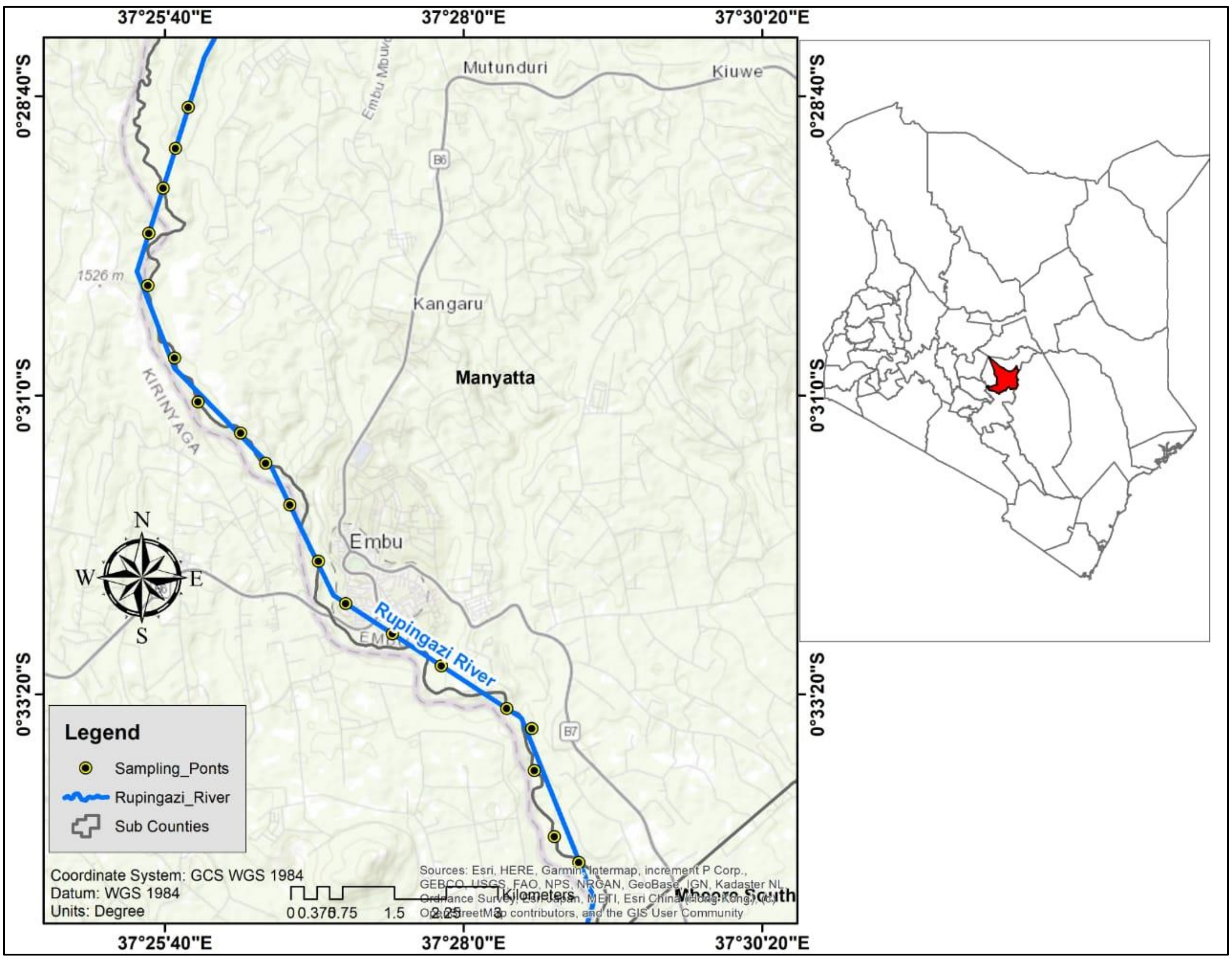

Fig 1: Map Showing the Section of Rupingazi River Covered by the study

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➢ *Sediment Sampling and Sample Preparation*

A PVC pipe was used in the collection of the sediment samples. The pipe was pushed through the water to collect the samples from a layer of about 15cm.The sediments, since they contained water and particles like sand and soil were put in a container so that the sand and soil settled down and water was poured from the container. The sediment samples were put in plastic containers. They were then taken to a laboratory for storage awaiting analysis. The samples were dried-up in an oven at a temperature 105°c for 24 hours until there was no change in weight in order to remove water. A mortar and pestle was used to crash the sediment samples which were then sieved using a 2-mm mesh sieve in order to get rid of the large debris. The samples were then stored in large containers awaiting digestion and analysis. The sediments were wet dried and 2g of it added to 18ml of concentrated nitric acid. The mixture was heated and hydrogen peroxide added to it until the brown fumes disappear and the volume reduced to about 5ml.Filtration was done and the sample diluted with distilled water. The samples were then labeled and stored for analysis. The resulting concentrate then diluted to the 25ml mark with distilled water.

Fig 2 A Batch of Sediment Samples

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III. RESULTS AND DISCUSSIONS

Table 1 Heavy Metals in Sediments(mg/Kg) during the Dry Season

Site	Cu	Fe	Ni	Mn	Zn	Exceeding Limit
1	0.98±0.24^{a}	1722.13±11.78^{c}	9.55±0.16^{cd}	84.17±1.59^{cd}	28.39±1.44^{i}	
2	<LoD	2077.60±89.62^{e}	10.92±0.18^{d}	104.59±4.05^{cd}	22.90±0.25^{g}	
3	2.63±0.62^{ab}	1515.73±5.37^{b}	12.48±0.11^{d}	210.41±2.32^{f}	18.43±0.09^{e}	
4	24.10±1.8^{g}	5866.67±26.57^{i}	8.80±2.10^{cd}	167.22±1.86^{e}	13.71±0.20^{d}	
5	10.76±0.3^{d}	1254.47±7.64^{a}	5.32±0.21^{abc}	101.67±1.43^{cd}	9.37±0.10^{b}	
6	6.12±0.09^{c}	1474.87±6.15^{b}	12.27±2.15^{d}	215.49±1.62^{f}	26.30±1.10^{h}	
7	<LoD	1518.87±6.24^{b}	7.98±0.04^{bcd}	79.02±1.11^{c}	20.58±0.26^{f}	
8	14.94±0.2^{e}	1260.60±0.83^{a}	<LoD	248.35±2.89^{g}	6.07±0.05^{a}	
9	19.36±0.15^{f}	2239.33±56.00^{f}	6.10±0.14^{abc}	176.92±2.44^{e}	4.82±0.11^{a}	
10	4.34±0.15^{bc}	1833.93±13.53^{d}	<LoD	52.60±1.20^{b}	13.88±0.11^{d}	
11	4.96±0.15^{bc}	4844.67±4.81^{h}	<LoD	14.23±0.48^{a}	8.18±0.25^{b}	
12	<LoD	1711.00±8.09^{c}	4.10±0.09^{ab}	109.04±1.65^{d}	5.31±0.04^{a}	
13	0.76a±0.0^{a}	1641.33±11.27^{c}	2.63±0.03^{a}	6.15±0.14^{a}	18.85±0.15^{ef}	
14	<LoD	2632.67±9.61^{g}	<LoD	81.13±26.65^{c}	11.13±0.40^{c}	
15	0.98±0.24^{a}	1722.13±11.78^{c}	9.55±0.16^{cd}	84.17±1.59^{cd}	28.39±1.44^{i}	
16	24.10±1.8^{g}	5866.67±26.57^{i}	8.80±2.10^{cd}	167.22±1.86^{e}	13.71±0.20^{d}	
17	10.76±0.3^{d}	1254.47±7.64^{a}	5.32±0.21^{abc}	101.67±1.43^{cd}	9.37±0.10^{bc}	
18	<LoD	1518.87±6.24^{b}	7.98±0.04^{bcd}	79.02±1.11^{c}	20.58±0.26^{f}	
19	14.94±0.2^{e}	1260.60±0.83^{a}	<LoD	248.35±2.89^{g}	6.07±0.05^{a}	
20	19.36±0.15^{f}	2239.33±56.00^{f}	6.10±0.14^{abc}	176.92±2.44^{e}	4.82±0.11^{a}	
Average	7.416±0.22	2170.66±65.1	5.895±0.18	120.717±3.62	14.543±0.44	
Limits	32	20,000	23	460	123	

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Table 2 Heavy Metals in Sediments (mg/kg) during the Wet Season

Site	Cu	Zn	Fe	Ni	Mn
1	11.10±0.12^{j}	53.76±0.62^{g}	5818.00±16.77^{j}	12.45±0.04^{ef}	195.73±3.01^{e}
2	6.05±0.04^{b}	32.44±0.15^{c}	6026.67±26.57^{k}	10.82±0.02^{d}	144.70±1.72^{c}
3	4.68±0.05^{a}	30.15±0.11^{b}	1422.73±9.63^{a}	9.95±0.04^{c}	< LOD
4	6.92±0.03^{d}	26.29±0.10^{a}	2243.33±20.67^{f}	12.08±0.06^{e}	48.03±0.71^{a}
5	8.80±0.01^{f}	60.74±1.58^{h}	4969.33±16.01^{i}	14.17±0.04^{h}	61.76±0.76^{b}
6	7.94±0.08^{e}	48.42±0.19^{f}	1857.93±5.62^{d}	18.83±0.03^{j}	<LOD
7	10.09±0.12^{h}	34.20±0.09^{c}	6145.33±78.95^{l}	23.54±0.07^{l}	217.60±1.29^{f}
8	12.69±0.06^{i}	60.07±0.11^{h}	1824.93±2.90^{cd}	<LOD	174.70±0.70^{d}
9	6.56±0.12^{c}	28.50±0.17^{b}	2426.67±21.18^{g}	0.72±0.02^{a}	139.21±0.83^{c}
10	11.73±0.04^{k}	81.75±0.62^{j}	2436.00±16.04^{g}	22.60±0.01^{k}	307.60±5.63^{i}
11	12.52±0.15^{l}	77.81±0.88^{i}	1744.73±2.51^{bc}	<LOD	222.07±1.00^{f}
12	12.03±0.02^{k}	51.71±0.23^{g}	1852.47±4.03^{d}	8.70±0.06^{b}	<LOD
13	12.37±0.05^{i}	40.49±1.21^{e}	1742.20±1.22^{bc}	15.39±0.01^{i}	366.27±1.33^{k}
14	10.93±0.04^{j}	37.55±0.17^{d}	2138.67±58.56^{e}	12.72±0.03^{g}	289.53±1.05^{h}
15	9.83±0.02^{gh}	34.28±0.20^{c}	1723.53±1.92^{b}	10.15±0.08^{c}	258.93±0.90^{g}
16	12.65±0.11^{i}	114.35±0.82^{k}	2491.33±2.40^{gh}	23.34±0.38^{l}	307.87±1.62^{i}
17	10.58±0.18^{i}	128.88±1.07^{i}	2409.33±3.71^{g}	14.31±0.05^{h}	294.53±3.14^{h}
18	9.76±0.12^{g}	141.56±0.67^{m}	2448.67±4.37^{g}	27.16±0.43^{n}	326.60±0.31^{j}
19	10.55±0.17^{i}	167.10±1.02^{o}	2535.33±1.76^{h}	26.26±0.14^{m}	377.00±1.86^{l}
20	11.73±0.04^{k}	157.60±1.09^{n}	2620.67±1.76^{h}	30.73±0.49^{o}	411.20±2.43^{m}
Average	9.9755	70.3825	2170.66	14.669	207.17
Limit	**32**	**123**	**20,000**	**23**	**460**

The range of the concentration of copper was found to be 4.68-12.69 mg/kg for the wet season and 0.98-24.10mg/kg for the dry season. Concentration of copper in the sampling stations was observed to vary significantly. Sampling station 8 recorded significantly high level during the wet season and Sampling station 4 recorded significantly high level during the dry season. The concentration of copper in sediments found in this research was not beyond the recommended limit of 32mg/kg for copper levels in sediments (USEPA,2011). Copper can be introduced into water bodies from copper compounds that are used in fungicides and insecticides (Akan *et al.*, 2010). There are also copper compounds that are components in fertilizers and some animal feeds. The high copper concentration in some sampling points could be as a result of farming practices which result in the excess use of fungicides, fertilizers and insecticides. Over the wet season, the copper compounds are introduced into Rupingazi river via run-off water.

The mean values of the concentration of iron was found to be 1422-6145.33 mg/kg for the wet season and 1254-5866.67 mg/kg for the dry season. Concentration of Iron in the sampling stations was observed to vary significantly. Sampling station 7 recorded significantly high level during the wet season and Sampling station 16 recorded significantly high level during the dry season. The iron levels were generally high which could have resulted from weathering and anthropogenic sources around the municipality. Other likely sources of iron are agricultural activities and the building and construction sector. (Jitendra and Rachna 2015) The concentration of iron in sediments found in this research was not beyond the recommended limit of 20,000mg/kg for copper levels in sediments (USEPA,2011)

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The range of the concentration of Nickel was found to be 0.72-30.73 mg/kg for the wet season and 2.63-12.48 mg/kg for the dry season. Concentration of copper in the sampling stations was observed to vary significantly. Sampling station 20 recorded significantly high level during the wet season and Sampling station 19 recorded significantly high level during the dry season. The likely sources of nickel in surface water that leads to accumulation in sediments are anthropogenic activities like burning of fossil fuels, wastes from old batteries and nickel alloys The concentration of nickel in sediments found in this research was not beyond the recommended limit of 23mg/kg for nickel levels in sediments (USEPA,2011)

Concentration of manganese was found to be 48.03-411.20 mg/kg for the wet season and 6.15-248.35 mg/kg for the dry season. Concentration of manganese in the sampling stations was observed to vary significantly. Sampling station 20 recorded significantly high level during the wet season and Sampling station 19 recorded significantly high level during the dry season. The concentration of manganese in sediments found in this research was not beyond the recommended limit of 460 mg/kg for manganese levels in sediments (USEPA,2011). There are many agricultural activities that take place in the catchment of Rupingazi river. Manganese found in the sediments could be as a result of use of fertilizers and activities in the building and construction sector.

Zinc concentration was found to be 26.29-167.10 mg/kg for the wet season and 4.82-28.39 mg/kg for the dry season. Concentration of zinc in the sampling stations was observed to vary significantly. Sampling station 19 recorded significantly high level during the wet season and Sampling station 15 recorded significantly high level during the dry season. The high levels of zinc could be from zinc carbonates that are utilized as pesticides (Anglin-Brown *et al*., 1995) The concentration of zinc in sediments found in this research was not beyond the recommended limit of 123 mg/kg for zinc levels in sediments (USEPA,2011)

Table 3 Correlation matrix of the heavy metals during the wet season in sediments

	Cu	**Fe**	**Zn**	**Mn**	**Ni**
Cu	1	-0.165	0.425	0.586	0.162
Fe		1	-0.161	0.056	0.168
Zn			1	0.646	0.625
Mn				1	0.654
Ni					1

The correlation matrix table showed that there was a moderate relationship between Zn versus Cu (0.425), Mn versus Cu (0.586), Mn versus Zn (0.646), Ni versus (0.654) and Ni versus Zn (0.625) in sediments during the wet season. Cu versus Fe (-0.165), Zn versus (-0.161), Mn versus Fe (0.056), Ni versus Cu (0.162) and Ni versus Fe (0.168) did not show any relationship for the same season in sediments.

Table 4 Correlation matrix of the heavy metals during the dry season in sediments

	Cu	**Fe**	**Zn**	**Mn**	**Ni**
Cu	1	0.517	-0.622	0.589	-0.099
Fe		1	-0.137	-0.053	0.118
Zn			1	-0.256	0.751
Mn				1	0.481
Ni					1

The correlation matrix table showed during the dry season in sediments Fe versus Cu (0.517), Mn versus Cu (0.481), Zn versus Ni (0.517) and Ni versus Mn (0.481) indicated a moderate correlation and no correlation between Zn versus Fe (-0.137), Mn versus Fe (-0.053), Mn versus Zn (-0.256), Ni versus Cu (-0.099) and Ni versus Fe (0.118).

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