

ASSESSMENT OF HEAVY METALS IN FISH AND SEDIMENTS FROM RIVER MTAKUJA IN THE VICINITY OF A GOLD MINE IN TANZANIA

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ABSTRACT

Concentrations of heavy metals namely Cr, Fe, Cu, Zn, As, Cd and Pb in African Sharptooth Catfish (*clarias gariepinus*) and sediment from river Mtakuja Tanzania were analyzed using the Energy Dispersive X-ray Fluorescence spectrometry technique. 32 samples from fish and sediment were investigated. The results show that the concentration of heavy metals was higher in upstream areas than in the downstream area. The concentration of Fe of 428.5 mg/kg in catfish from the upstream area was about 2 times 243.8 mg/kg obtained from the same fish in the downstream area. Similar cases observed for sediments with Fe concentration of 127626.9 mg/kg from upstream that was about 6 times higher than that of 21460.3 mg/kg from downstream area. The concentration of 44.8 mg/kg for Cu in the upstream area sediment was also about 2 times higher than 23.2 mg/kg in the downstream area sediment, while for as the concentration of 13.2 mg/kg was measured in the upstream, which is which is more than 5 times 2.5 mg/kg measured in downstream. The concentration of Cr in the catfish was 17.6 mg/kg which is higher than the permissible limit values of 0.8 mg/kg set by the European Commission (EC), 0.2 mg/kg set by the Food and Agricultural Organization (FAO) and 0.15 mg/kg the World Health Organization (WHO) limit. Moreover, the concentration of Cd was 3.0 mg/kg, which is above the permissible level of 0.2 mg/kg recommended by the EC and WHO. A positive correlation exists between the Cu, Pb, Fe and Cd concentration found in sediments and fish samples. The results show that the river Mtakuja is polluted by mining waste, domestic and agrochemical activities. This suggest that, there is a need for regular monitoring of heavy metal in river Mtakuja in order to monitor and protect aquatic organisms and health of benefactors of this river.

Keywords: Heavy metals, Energy Dispersive X-ray Fluorescence, African Sharptooth Catfish, Gold mine.

INTRODUCTION

Heavy metals refer to elements having specific gravity/density greater than 4 or 5 g/cm³ (Jaishankar et al., 2014). Moreover, heavy metals include Cadmium (Cd), Lead (Pb), Copper (Cu), Zinc (Zn), Arsenic (As) and Chromium (Cr) which are mainly dependent on chemical properties rather than specific gravity (Duruibe et al., 2007). Some heavy metals are essential to living organisms while others such as As, Cd and Pb are non-essential and toxic even at a low level of exposure (Wang et al., 2020). These metals can be released into the environment as byproducts of human activities including mining operations, domestic sewage, industrial waste, oil spills, combustion of biomass, and the use of fertilizers, pesticides and disease control agents in plants (Okereafor et al., 2020). The emission of heavy metals leads environmental pollution in air, lands and water such as rivers and lakes which are considered environmental hazards for invertebrates, fishes and humans.

The heavy metal contaminants in aquatic ecosystems being in soluble or suspension form tend to settle down at the bottom and be ingested by plants and animals or absorbed by sediments (Baby et al., 2010; Opaluwa et al., 2012). In the

aquatic ecosystem, 99% of the heavy metal contaminants are stored in the sediments (Shen et al., 2019). Heavy metals in the sediments cause detrimental impacts that can change the aquatic ecosystem and can reach the food chain through plants and aquatic animals (Mataba et al., 2016). Among the inhabitants of the aquatic ecosystem that are largely affected by the detrimental impacts of the heavy metal pollutants are fish (Baby et al., 2010). Generally, fish can be used to assess the environmental health of the aquatic ecosystem and bio-accumulation of heavy metals is known to depend on the nature of the aquatic environment, type of heavy metal, rate of absorption, deposition and excretion (Miri et al., 2017; Mielcarek et al., 2022). As a result, sediments and fish are commonly used as good indicators of contamination levels in aquatic environments (Opaluwa et al., 2012; Mataba et al., 2016).

Different analytical techniques can be used for the analysis of heavy metals in materials. The commonly used techniques include Atomic Absorption spectrometry (AAS), Inductively Coupled-Plasma Mass Spectrometry (ICP-MS), Neutron Activation Analysis (NAA), Particle-Induced X-ray Emission (PIXE) and Energy Dispersive Spectroscopy (EDXRF). In comparison to other approaches, quantitative and qualitative analysis of sample with EDXRF are performed without any chemical manipulation, less time-consuming in

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terms of sample preparation and analysis, also uses low cost consumables (Eser et al., 2014). The EDXRF is also a non-destructive technique with high resolution potential for accurate determination of the broad elemental composition of samples from parts per million (ppm) to 100% by weight (Ravisankar et al., 2015; Perring et al., 2017). Furthermore, the EDXRF is a mature technique that is widely applied in many fields including geology, metallurgy, environment, ecology, mining, art sciences, fuel industries, jewelry, medicine, forensic sciences, agriculture, food industry and cosmetics (Perring et al., 2017; Nuchdang et al., 2019).

Mining processes at the Geita Gold Mine (GGM) have posed concerns about the heavy metal pollution to the environment and health (Nyankweli, 2012). The wastes, tailings and effluents from different stages of mineral processing are discharged into the environment resulting to contamination of soil, sediments, air, water and plants (Bitala, 2008; Almås & Manoko, 2012). River Mtakuja is located in downstream area of the GGM and it is the home to different fish species including Nile-Perch (*latesniloticas*), Lungfish (*protopterus aethiopicus*) and African Sharptooth Catfish (*clarias gariepinus*). The catfish is the common fish in river Mtakuja that is also largely consumed by the local community. The Catfish is also known to bio-accumulate heavy metals in a significant amount in the tissue and for a long time (Opaluwa et al., 2012). Furthermore, it has been proposed that the mining operations result to pollution of the aquatic ecosystem of river Mtakuja that is flowing toward Lake Victoria (Bitala, 2008).

Moreover, Mtakuja river is a receptor of leaching contaminants from mining activities (Nyankweli, 2012). However, the reports on heavy metals contamination levels in both fish and sediments from the river Mtakuja are still marginal in literature. This means that consumption of fishes from Mtakuja river might pose environmental and health risks to the population. In an effort to overcome some of these challenges, this paper reports the results from the assessment study of the heavy metals in African Sharptooth Catfish (*clarias gariepinus*) and sediments from the river Mtakuja in the proximity of the gold mine. The results provided are significant towards establishments of control measures and monitoring the pollution levels of heavy metals from the river Mtakuja.

MATERIALS AND METHODS

Description of the study area

River Mtakuja is located between the latitude $02^{\circ} 53' 1.854''$ to $02^{\circ} 47' 0.588''$ S and longitude $32^{\circ} 11' 16.302''$ to $32^{\circ} 4' 0.018''$ E as shown in Fig.(1). It is a shallow river formed by different tributaries from the upper Geita forest. The aquatic ecosystem is bounded by thick forests and seasonal swamps in the upper zone which is only 0.5 km from Geita Town while the permanent swamp is located in the lower zone neighboring Lake Victoria. The river receives effluents from the GGM, municipal, domestic and agricultural runoffs, and pours water into Lake Victoria (Emel et al., 2014).

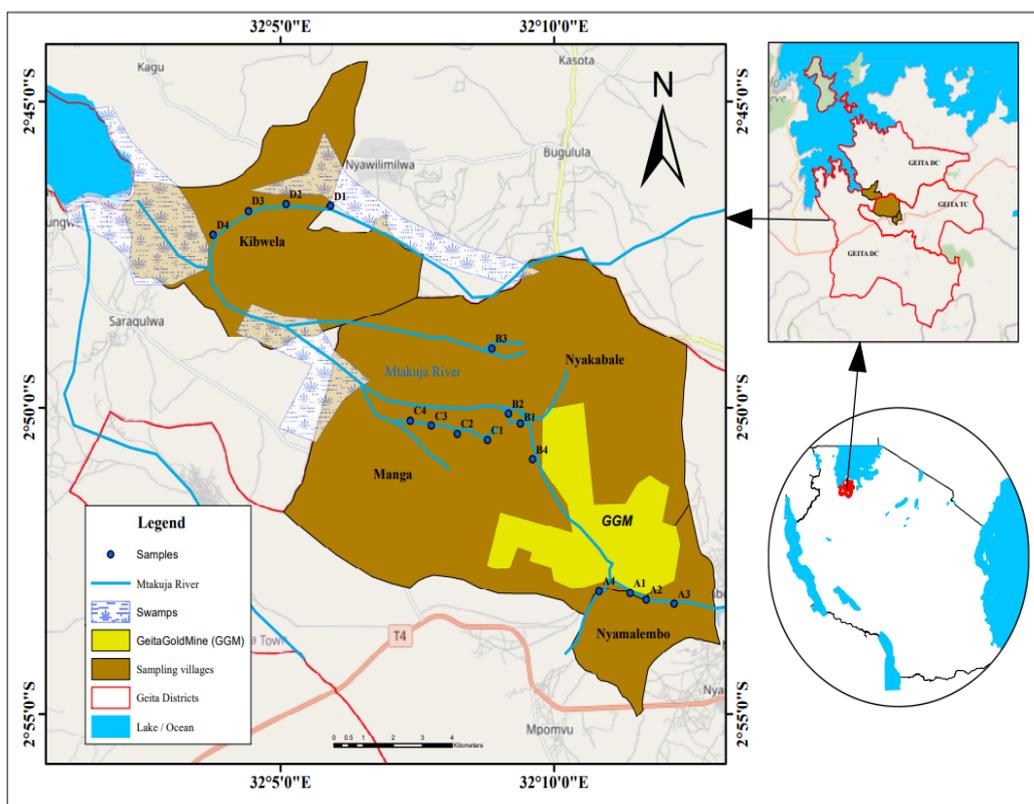


Figure 1. Map of Geita showing sampling areas.

Sampling and sample preparation

The river Mtakuja was divided into two zones, namely, upstream and downstream zones. The upstream zone consists of Nyamalembo, Nyakabale and Manga villages whereas the downstream zone consists of Kibwela village. In this study, 16 sediment and 16 fish samples were collected at different locations along the river Mtakuja as indicated in Fig.(1). At Nyamalembo samples of both sediments and fish were taken at locations marked A1, A2, A3 and A4, while at Nyakabale samples were taken at location marked B1, B2, B3 and B4, at Manga, samples were collected from location marked C1, C2, C3 and C4 and from Kibwela samples were collected at locations marked D1, D2, D3 and D4 (Fig. 1). Samples of catfish (*clarias gariepinus*) were taken directly from the river, then washed with distilled water to remove external dirt. Sediment samples (100 g) were collected from surface sediments at a depth ranging between 2 – 25 cm by scooping with a stainless steel spoon from the location where fish samples were taken. Since the sediments and fish samples were taken from the same locations, the distances from one sampling points to another were not equal.

The samples of fish and sediments were immediately placed in polythene bags, labeled and stored at a temperature ranging between -10 and 0 °C in a cooler box. Both samples were transferred to the University of Dar es Salaam in Dar es Salaam, Physics laboratory for further preparation. In the laboratory fish samples were dissected and bones removed to remain with tissue (gill, liver and muscle). The samples were then placed in a drying oven for 48 hours at a temperature between 45 – 50°C (Mohamed et al., 2016). Thereafter, samples were crushed into small grains using a mortar and pestle for five (5) days and ground using the electric grinder for three (3) days to obtain a fine powder.



Figure 2. Image of pelletized samples ready for analysis.

The powder sample was sieved using an electric shaker to reduce particle size for five (5) days and placed in polythene bags with labeling, this procedure was repeated for all 32 samples. All samples were transferred to the Tanzania Atomic Energy Commission (TAEC) in Arusha for analysis. A wax

binder was used in both samples to ensure homogeneity where 4 g powder was mixed thoroughly with 0.9 g of a binder. The sample was then pulverized until a homogenous mixture was obtained using a vortex mixture machine, then pressed using a hydraulic press at a pressure of 15 bar for one minute to obtain smooth pellets as shown in Fig. (2).

Sample analysis

The collected sample was analyzed for seven heavy metals namely Cr, Fe, Cu, Zn, As, Cd and Pb. The measurements were done using the EDXRF (XEPOS™ bench-top spectrometer) equipped with the X-ray tube and three secondary targets, HOPG crystal, Al₂O₃ and Mo. Pellets were placed in the EDXRF machine and irradiated for 15 minutes, the machine has six active holes where the sample was placed for each analysis. The X-ray tube was operated at a voltage range of 20 to 50 kV and a current varying between 0.1 and 1 mA depending on the target. The resulting spectra were processed using Turbo quant software. The X-lab Pro™ software with turbo quant (Tq 9232) installed in the PC was used to correct the interference noises and background effects of a spectral line using the fundamental parameter-method. Accurate correction of the software was achieved by converting the intensities of the X-ray radiation into the concentration of an element C_i based on Eq. (1) (Mohamed et al., 2016).

$$C_i = K_i \times I_i \times M_\alpha \quad (1)$$

where, K_i is the proportionality constant, I_i is the intensity of fluorescent radiation in counts per second and M_α is the correction factor for the matrix effect.

Statistical analysis software

Statistical analysis of data was accomplished using the origin software (version: 2019b 9.65). P values less than 0.05 were considered statistically significant. Correlation between the investigated element in sediment and fish was performed by using the Pearson correlation coefficient. In addition, the MS excel spreadsheet 2013 was also used to store and process statistical data.

RESULTS AND DISCUSSIONS

Minimum detection limit

The minimum detection limit (MDL) is the smallest amount of the analyte that can be detected by the machine in a specified context for a given matrix with a 95 % confidence level (Kadachi & Al-Eshaikh, 2012). MDL is the quantity of the analyte that provides a net line intensity equal to three times the standard counting error of the background intensity (Rousseau, 2001). Detection limits are lower when the measuring time is higher and with increasing tube voltage and

anode current (Kadachi & Al-Eshaikh, 2012). The MDL was determined automatically by using X-Lab Pro Software based on Eq. (2) (Rousseau, 2001).

$$MDL = \frac{3 \times C_i}{I_p - I_b} \sqrt{\frac{I_b}{T_b}} \quad (2)$$

where, C_i is the concentration of the analyte i in % or ppm, I_p is the peak intensity, I_b is the background intensity and T_b is the background counting time. The minimum detection limits of the analyzed elements by using the EDXRF in this study as presented in (Table 1).

Table 1. MDL (mg/kg) of the analyzed elements from fish and sediment samples.

Chemical symbol	Atomic number	Fish	Sediment
Cr	24	5.6	18.8
Fe	26	2.4	5.0
Cu	29	0.9	2.0
Zn	30	1.0	0.9
As	33	0.3	1.4
Cd	48	4.1	5.6
Pb	82	0.7	1.6

Mean concentration of heavy metals in catfish (Clarias gariepinus)

The mean concentration of heavy metals in African Sharptooth Catfish (*Clarias gariepinus*) from upstream and downstream areas of river Mtakuja are presented in (Table 2).

Table 2. Measured mean concentration levels of heavy metals in catfish from the upstream and downstream areas of Mtakuja river.

Element	Concentration \pm Standard Deviation (SD) (mg/kg)	
	Polluted areas (Upstream) (n = 60)	Clean area (Downstream) (n = 20)
Cr	17.6 \pm 2.1	16.9 \pm 1.8
Fe	428.5 \pm 3.9	243.8 \pm 3.4
Cu	2.7 \pm 0.1	14.6 \pm 0.5
Zn	38.3 \pm 1.2	32.5 \pm 0.9
As	0.2 \pm 0.01	0.2 \pm 0.01
Cd	3.0 \pm 0.05	2.9 \pm 0.05
Pb	0.3 \pm 0.02	0.3 \pm 0.02

The results show that the highest concentration is recorded for Fe and the lowest concentration is recorded for As. The mean concentration of the heavy metals in catfish from upstream area follows the order, Fe > Zn > Cr > Cd > Cu > Pb > As. Meanwhile, the downstream concentration levels are in the following order, Fe > Zn > Cr > Cu > Cd > Pb > As.

The results show that the average concentration levels of Cr, Fe, Zn and Cd in catfish are slightly higher in the samples collected from upstream areas than those from the downstream areas (Table 2). This implies that the upstream areas of river Mtakuja are more polluted by the mining activities than the areas in the downstream of the river. The concentration of Fe in the upstream area is about 2 times more than that of the downstream area. However, the concentration of Cr, Zn and Cd from the upstream area show significant deviation to that of the downstream. Results of the non-essential elements As and Pb did not show any difference in upstream and downstream concentration levels, while Cu recorded a concentration of more than 5 times in the downstream area compared to the upstream area.

Iron is the 4th most abundant element in the earth's crust, it naturally occurs in rocks in form of sulphides such as pyrite (FeS₂) (Nkuli, 2008). Despite the natural phenomenology of iron that increase its concentration in water bodies and sediments, a higher concentration of iron recorded in this study can be linked to anthropogenic activities including mining and the presence of human settlements along the river Mtakuja that discharge domestic and industrial wastes into the river. The elevated mean concentration of Zn recorded is associated to the fact that most of the Zn compounds are largely soluble in water, therefore easily absorbed by aquatic organisms such as fish. Moreover, Zn occurring naturally in rocks such as sphalerite (ZnS) are easily exposed to the rock surfaces by anthropogenic activities such as mining activities. Moreover, weathering and abrasion of rocks, zinc galvanized objects, domestic and industrial discharge might also cause an increase in concentration levels of Zn in sediments and fish.

Copper and lead are released into the aquatic ecosystems due to runoffs from agricultural activities and the use of agrochemicals containing heavy metals. Cu and Pb are also found naturally in the sulphide rocks in form of chalcopyrite (CuFeS₂) and galena (PbS), respectively, which are released into the marine environments by weathering of rocks and mining operations. The concentration levels of Pb measured was below the detection limit of the EDXRF machine for fish samples (Table 1) and the presence of Cu can be attributed to the activities of GGM and agricultural activities along the river Mtakuja. A high concentration of Cu in the downstream area is associated to a large agricultural field at Kibwela village where runoffs during the rainy season increase the concentration of Cu in this river. Cadmium originates from large cadmium-based batteries commonly used in mining industries and

agricultural run-offs where phosphate fertilizers are used (Opaluwa et al., 2012). The presence of Cd in any aquatic ecosystem indicates intolerable contamination level. Cadmium concentration levels were however below the detection limit of the EDXRF for both fish and sediment samples.

Arsenic is naturally found in sulphide ores containing gold minerals commonly in the form of arsenopyrite (FeAsS) and realgar (As₄S₄) (Almås & Manoko, 2012). In this study, the concentration of arsenic was below the detection limit for fish samples. However, its presence in sediments originates from the leaching of the tailing waste due to the activities of the GGM. Dissolved arsenic is transported in the leachate ending in the aquatic environment where it is absorbed by the fish species. Chromium naturally occurs in rainwater, seawater, surface water and ground water, and in minerals where manmade activities such as mining become the major source of Cr in aquatic environments (Vaiopoulou & Gikas, 2020). Figure 3 presents the variation of the concentration levels of heavy metal in fish from the upstream and the downstream areas of Mtakuja river.

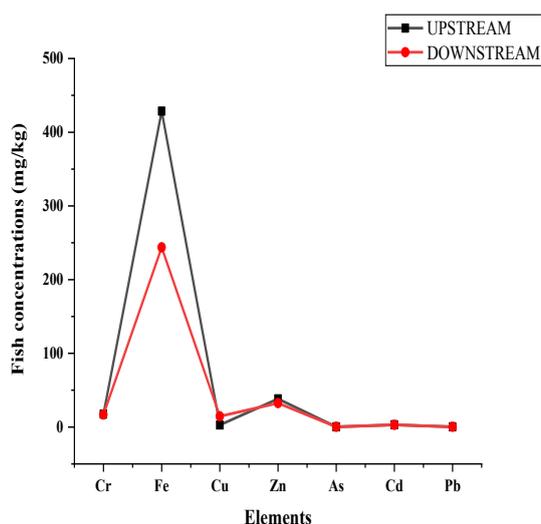


Figure 3. Variation of concentration of heavy metals in fish from upstream and downstream areas.

Mean concentration of heavy metals in sediments

The mean concentration levels of heavy metals in sediments collected from upstream and downstream areas of river Mtakuja are shown in (Table 3). The highest concentration level in the sediment samples from the upstream area was recorded for Fe and the least concentration recorded for Cd. Higher levels of Fe, Cu, Cr, Zn and As were obtained in sediment samples collected from upstream than those from downstream areas (Table 3). The concentration of Fe in the upstream area is about 6 times higher than the concentration of the elements in the downstream area. The concentration of Cu in the upstream area is about 2 times that of the downstream area, and that of As is more than 5 times higher in the

upstream than in the downstream. The concentration of Cr and Zn are slightly higher in the upstream area than the concentration levels in the downstream area. Notably, the concentration levels for Cd and Pb are also significant in upstream and downstream areas. Variation of heavy metal concentration levels between the upstream and downstream areas can be associated to the proximity distance from the source of contamination. The separation between the contaminated area and contamination source is known to influence the concentration of heavy metals (Bitala, 2008). Furthermore, dissolved elemental concentration levels are expected to be low in the downstream area which is far from the mine due to the absorption of the sediment that reduces the elements from the water column (Mataba et al., 2016). The variation in the concentration of heavy metals in sediments in the upstream and downstream areas of the river Mtakuja is shown in Fig. (4).

Table 3. Concentration of heavy metals obtained in sediments from the upstream and downstream areas.

Element	Concentration ± Standard Deviation (SD) (mg/kg)	
	Polluted areas (Upstream) (n = 60)	Clean area (Downstream) (n=20)
Cr	39.4 ± 2.3	30.0 ± 2.1
Fe	127626.9 ± 221.4	21460.3 ± 51.2
Cu	44.8 ± 3.2	23.2 ± 1.8
Zn	32.0 ± 1.5	28.3 ± 0.9
As	13.2 ± 1.0	2.5 ± 0.2
Cd	4.4 ± 0.3	4.7 ± 0.3
Pb	21.8 ± 1.1	27.8 ± 1.0

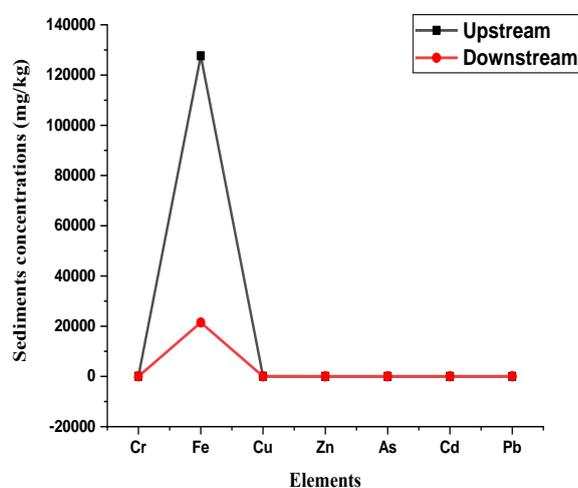


Figure 4. Variation of concentration of heavy metals in sediments from upstream and downstream areas.

The trends of the results show that the concentration levels of heavy metals in fish and sediments are higher in upstream areas than downstream areas of river Mtakuja (Figs. 3 and 4). For evaluation, the pictures of acid mine drainage and tailing rocks and other mining wastes along the river Mtakuja are shown in Figure 5. These pictures reveal compelling reason due to the indication of the Acid Mine Drainage (AMD) from the upstream area of the river Mtakuja especially in slow-moving waters as shown in Fig. 5. (a). The AMD is formed from sulphide oxidation products after it has been accumulated on rock surface by the mining process (Casiot et al., 2009). The acidic water dissolves heavy metals and transports them into water bodies. Sediments absorb heavy metals when pollutants are dissolved and discharged into water surfaces (Candeias et al., 2018). Moreover, the presence of tailing rocks and other mining waste observed along the river Mtakuja in the upstream area as shown in Fig. 5. (b) is a clear indication that the activities of a gold mine are major sources of heavy metals in river Mtakuja.



a)



b)

Figure 5. (a) Acid mine drainage and (b) Tailing rocks with other mining wastes along the river Mtakuja.

Comparison of the concentration of heavy metals in fish from river Mtakuja and other rivers

The mean concentration levels of heavy metals in fish obtained from the present study from upstream areas of river Mtakuja were compared with the concentration in fish obtained from river Mara in Tanzania, Buriganga in Bangladesh and Yangtze in China. Results of the concentration levels in this work were obtained on a dry mass basis. The mean concentrations of Fe of about 429 mg/kg from this study is higher than the concentration value of 53.5 reported from river Mara in Tanzania (Mohamed et al., 2016). Meanwhile, the concentration of Cr of about 18 mg/kg was higher than the concentration of 0.956 mg/kg reported from river Yangtze (Yi & Zhang, 2012), 0.3 mg/kg from river Mara and 6.33 mg/kg from Buriganga river (Ahmad et al., 2010). In addition, the concentration of Zn of about 38 mg/kg from the present work is higher than the concentration levels of 30 and 28 mg/kg reported from Yangtze and Mara rivers, respectively (Mohamed et al., 2016; Yi & Zhang, 2012). However, the concentration of Cd of 3.0 mg/kg is also higher than the Cd concentration values of about 0.5 and 1.0 mg/kg reported from Yangtze and Buriganga rivers, respectively (Yi & Zhang, 2012, Ahmad et al., 2010). In comparison, the concentration levels of Cr, Fe, Zn and Cd heavy metals in catfishes collected from river Mtakuja are significantly higher than those reported for rivers Mara, Buriganga and Yangtze. Since, fishes are good indicators of contamination in the aquatic environment (Mataba et al., 2016), the elevated concentration levels of heavy metals in fish from the river Mtakuja indicates that river Mtakuja is polluted by heavy metals.

Comparison of concentration in toxic metals in fish with Maximum Tolerable Limits (MTLs)

The concentrations of toxic metals in catfish (*clarias gariepinus*) from Mtakuja river were compared with the permissible limits recommended by Food and Agricultural Organization (FAO), World Health Organization (WHO) and European Commission (EC). The toxic metals detected in catfish include Cr, As, Cd and Pb having concentrations of 17.6, 0.2, 3.0 and 0.3 mg/kg respectively. The concentration of Cr was significant beyond the respective EC, FAO and WHO permissible limits of 0.8 mg/kg (EC 2005), 0.2 mg/kg (Joint & World Health, 2007) and 0.15 mg/kg (WHO, 2015). African Catfish feed near the bottom of the river from decaying organic matter and sediments, implying that it can certainly accumulate Cr in their tissue since Cr is known to be largely absorbed by the soil and organic matter. The concentration levels of Pb obtained from the present work were below the permissible limits of 0.5 mg/kg set by FAO/WHO (Joint & World Health, 2007). However, Pb can accumulate in sediments and other aquatic substances where catfish lives and feeds.

The concentration level measured for Cd was above the permissible level of 0.2 mg/kg as recommended by EC (EC, 2005) and 0.05 mg/kg by the WHO (2015). The high concentration values of Cr and Cd measured suggest that river Mtakuja is contaminated by heavy metals. Furthermore, high concentration levels of heavy metals in catfish (*clarias*

gariepinus) can be attributed to the concentration of heavy metals that were absorbed in the sediments that were collected from the same location, since polluted sediments are known to be source of chemicals that contaminate the food chain by feeding the benthic fauna and benthopelagic feeders (Mataba et al., 2016).

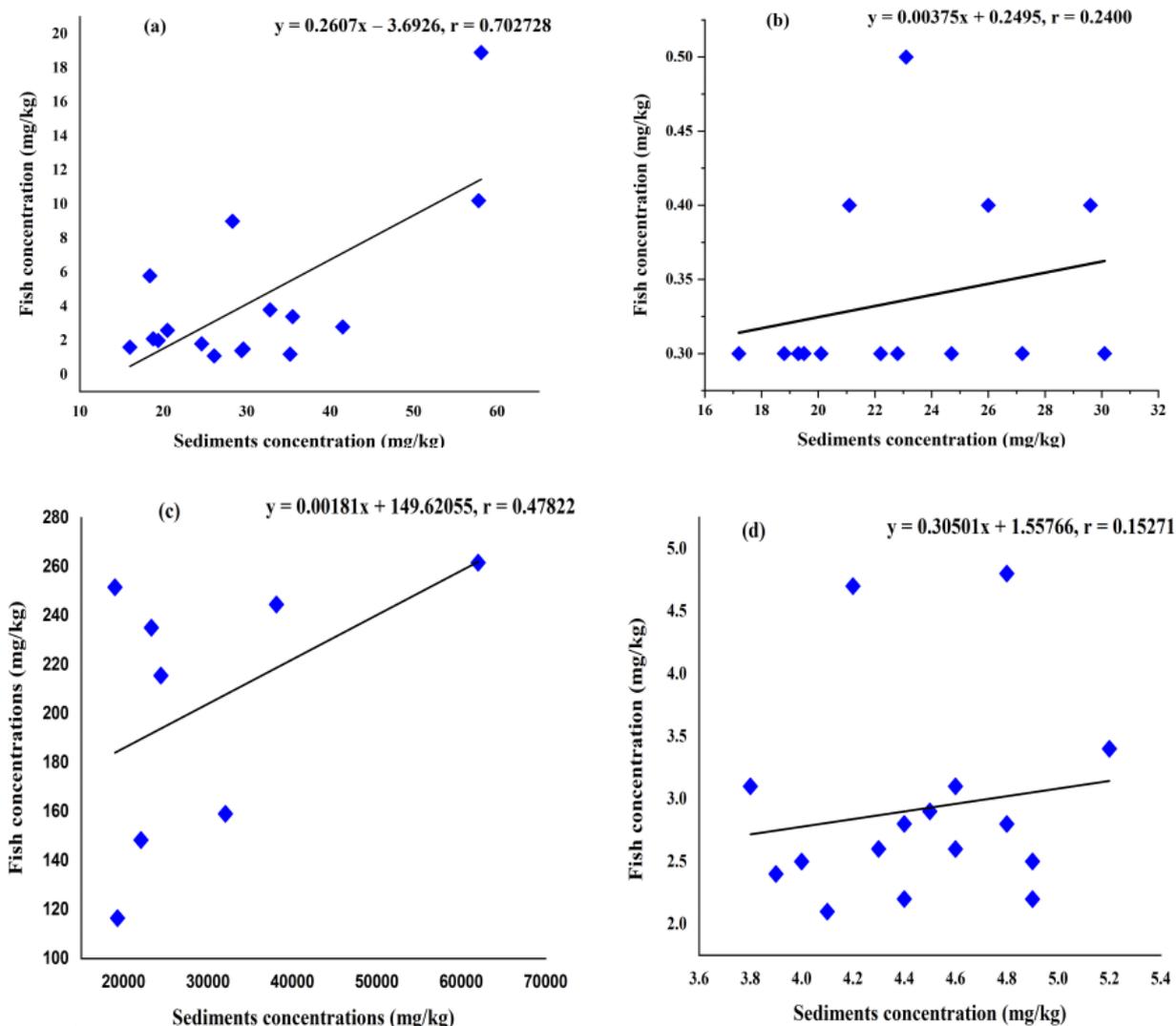


Figure 6.Correlation between concentration of heavy metals in sediments and fish for (a) Cu, (b) Pb, (c) Fe and (d) Cd.

Comparison of the concentrations of heavy metals in sediments from river Mtakuja and other rivers

The mean concentration levels of heavy metals in the sediments from river Mtakuja were compared with heavy metal concentration levels in sediments reported for rivers Tighithe and Mara in Tanzania, Buriganga in Bangladesh and Shurriver in Iran. The Concentration level of Fe of about 127627 mg/kg in river Mtakuja sediments was higher than the concentration of 10300 mg/kg from river Shur (Karbassi et al., 2008). Similar case for Cu with concentration level of about 45 mg/kg, which is higher than concentration levels of 27 mg/kg and 25 mg/kg reported for sediments from rivers Buriganga

and Tighithe, respectively (Ahmad et al., 2010; Almås & Manoko, 2012). The concentration level of Cd of about 5 mg/kg was above the concentration reported in sediments from river Buriganga with concentration value of 3.31 mg/kg and river Mara of 1.53 mg/kg(Nkinda et al., 2020, Ahmad et al., 2010). Moreover, the concentration of Pb of about 22 mg/kg obtained in this study was beyond the concentration level reported in sediments from river Tighithe of 18 mg/kg (Almås & Manoko, 2012). The concentration levels of Cr of about 39 mg/kg from the present work was higher than the concentration level of 1.5 mg/kg reported in sediments of river Mara(Nkinda et al., 2020). Additionally, the concentration levels of Fe and Pb of about 127627 and 22 mg/kg obtained

from this study are significantly higher than the recommended mean world sediment concentration levels of 41000 and 19 mg/kg, respectively (Karbassi et al., 2008). Therefore, the sediment collected from river Mtakuja have Cr, Fe, Cu, Cd and Pb concentration levels that are significantly higher than recommended concentration limits.

Correlation analysis

The correlation between the concentration of the heavy metals in fish and sediments found showed the strong to weak trend given by, Cu ($r = 0.70273$) > Fe ($r = 0.47822$) > Pb ($r = 0.24003$) > Cd ($r = 0.15271$) > Cr ($r = -0.17445$) > Zn ($r = -0.35394$) > As ($r = -0.42635$). A positive correlation for Cu, Fe, Pb and Cd suggests possibilities of transfer for these toxic metals moving from sediment to the fish via different pathways in river Mtakuja. The negative correlation of Cr, Zn and As indicates that the sediment is not the only reason for the presence of heavy metals in fish. Therefore, the concentration levels in fish samples might also be caused by other factors that may include the presence of heavy metals in water and water hyacinth. Regression lines of the concentration of four heavy metals namely Cu, Pb, Fe and Cd for sediment and fish samples are shown in Fig.6. (a - d).

CONCLUSION

The paper reports the concentrations of heavy metals in catfish and sediments that were collected along the river Mtakuja. The results show that the river Mtakuja is polluted by heavy metals associated to both mining and domestic activities that cause discharging of wastes into Mtakuja river. In addition, runoff from agricultural lands with fertilizers, pesticides and other farming chemicals can influence the toxicity and heavy metal concentration levels in the river Mtakuja. The results also showed a positive correlation for Cu, Pb, Fe and Cd and a negative correlation for Cr, Zn and As. In conclusion, the polluted sediments can significantly increase the concentration levels of heavy metals in African Sharptooth Catfish (*clarias gariiepinus*). However, the concentration levels in fish can also be influenced by the contaminated water and water hyacinth. This suggests that, there is a need for further work to refine the influences of contaminated water and water hyacinth on the heavy metals content in catfish at the river Mtakuja to discover all possible transfer mechanisms of heavy metals absorption from aquatic environment into fish.

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