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Human Health Risks from Exposure to Heavy Metals in Water from Great Ruaha River Serving Domestic Purpose in Pawaga Division

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Abstract

River water and banks could be very busy with varied activities ranging from farming to small industrial activities and other domestic household activities. The present study aimed at investigating the potential human health risks from selected heavy metal contaminants in Ruaha River water at the Kilolo division. To assess potential human health risks the concentration data for six heavy metals (Fe, Mn, Cu, Pb, Zn, and Cd) during the wet and dry seasons from four (4) villages were analyzed using Atomic Absorption Spectrophotometer. The observed mean concentration of heavy metals during the wet season is in the following order: Fe > Zn > Cu > Mn > Pb > Cd > Al. During dry season is in the following order: Fe > Cu > Zn > Mn > Al > Cd= Pb. The HQ_{ing} *of Cd ranges from 0.000 – 9.000 while Pb ranges from 2.143 – 32.143. The maximum carcinogenic risk (CR) from ingestion of Cd was* 9.429×10^{-4} *and Pb was* 4.714×10^{-3}*. According to risk assessment standard these values are in grade five and six respectively. About 54.2% of the analyzed samples are at grade seven which is extremely high-risk position, while the rest are at high-risk side. Though most levels did not exceed critical values for human health risk from heavy metals, there is still a potential human health risk from chronic exposure to low heavy metal concentrations due to long-term exposure and potential metal interactions. Results of this study inform water pollution remediation and management efforts designed to protect public health in polluted urban area waterways common in rapidly developing regions.*

Keywords: *Heavy metals, Kilolo, Carcinogenic risk, Permissible limits, Great Ruaha*

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INTRODUCTION

Water is absolutely essential not only for the survival of all living things also in development of industries and agriculture (Razo *et al.,* 2004; Su *et al.,* 2004). River water pollution by toxic heavy metals is one of the important environmental concerns due to rigorous anthropogenic pressure on the aquatic environment. The anthropogenic activities along riverbanks lead to rapid population growth, urbanization and rapid industrial development, hence accelerated water pollution. Most significant anthropogenic sources such as domestic, hospital and industrial wastewater effluents are poorly treated or not treated at all and sometimes discharge directly to the open space or rivers (Assubaie, 2015).

Heavy metals released into the aquatic environment can enter food chains; persist in the environment, bioconcentrate, and bio magnify (Li *et al.,* 2017; Li *et al.,* 2018). However, some metals, such as copper, zinc, iron, and cobalt are essential elements play an important role in the metabolic processes of living organisms. These elements are only considered dangerous when they reach higher concentrations than required. Toxic heavy metals may be released into water bodies through anthropogenic activities such as mining and smelting operations, industrial production and use, domestic and agricultural use of metals and metals containing compounds (He *et al.,* 2005). Industrial sources include metal processing in refineries, coal burning in power plants, petroleum combustion, nuclear power stations and high-tension lines, plastics, textiles, microelectronics, wood preservation and paper processing plants (Goyer, 2001). Environmental contamination can also occur through atmospheric deposition, metal corrosion, soil erosion of metal ions and leaching of heavy metals, sediment re-suspension and metal evaporation from water resources to soil and ground water (Herawati *et al.,* 2002).

Other heavy metals are non-essential, and they are not required by living systems (Honest *et al.,* 2020). They can be toxic even in trace amounts, these include: cadmium, antimony lead, titanium, arsenic, bismuth, and mercury (Tchounwou *et al.,* 2012). However, whether essential or non-essential, all heavy metals are toxic at higher concentrations with their toxicity linked to chronic diseases such as renal failure, liver cirrhosis, brain syndrome, *itai-itai* and many others (Kobayashi *et al.,* 2009). These heavy metals continue to pile into higher levels especially when they are discharged into natural waters from agricultural, industrial, and domestic wastes, pesticides, or mining operations. As a result, they end up having severe toxicological effects on humans and the aquatic ecosystem (Underwood, 2002).

Lead interferes with functions performed by essential mineral elements such as calcium, iron, copper and zinc. It also inhibits red blood cell enzyme systems (Vasudevan and Streekumari, 2000). Similarly, lead can displace calcium in the bone to form softer denser spots and can inactivate the cysteine-containing enzymes, allowing more internal toxicity from free radicals, chemicals, and other heavy metals (Underwood, 2002). Moreover, hyperactivity and learning disorders have been correlated with lead intoxication in children. A relationship between lead levels and learning defects (like daydreaming as well as being easily frustrated or distracted) was found to exist. Other defects include a decrease ability to follow instructions and poor learning focus in children (Underwood, 2002).

Heavy metals are known to cause carcinogenic and non-carcinogenic effects in the human body (Mohod and Dhote, 2013). The term carcinogenic risk means the probability that an individual will develop cancer over a lifetime of exposure, whereas the term non-carcinogenic risk means the body can sometimes be able to cope with or recover from the exposure (EPA, 1999).

Iron is an essential trace element used for hemoglobin formation and has a role in oxygen and electron transfer in human body (Kaya and Incekara, 2000). Also, it plays an important role in the normal functioning of the central nervous system and in the oxidation of carbohydrates, proteins, and fats (Odhav *et al.,* 2007). The element cadmium is known to be carcinogenic and considered to be a non-essential element in foods and natural waters and it accumulates principally in the kidneys and liver (Divrikli *et al.,* 2003). A high concentration of cadmium than the maximum permissible limit is known to cause severe diseases such as kidney damage, tubular growth, cancer, diarrhea, and incurable vomiting (Divrikli *et al.,* 2003).

Manganese occurs naturally in many surface and groundwater sources as well as in the soils. Anthropogenic activities are also responsible for manganese contamination in river water. Basically, manganese is used in the manufacture of iron and steel alloys and manganese compounds can be an ingredient in various products such as fertilizers and pottery glazes (Venugopal and Luckey, 1978). Manganese dioxide and other manganese compounds are used in products such as dry-cell batteries, glass, and fireworks. Manganese neurotoxicity is associated with motor and cognitive disturbances known as Manganism (Cortez-Lugo *et al.,* 2015).

Zinc is one of the most important elements for normal growth and development in human beings. It is an essential element for the normal functioning of various enzyme systems of human beings and its deficiency, particularly in children, can lead to loss of appetite, growth retardation, weakness, and even stagnation of sexual growth (Saracoglu *et al.,* 2009).

The main objective of this study was to analyze the concentration of heavy metals in Ruaha river water from four different sampling sites at Pawaga division. Based on the concentrations of heavy metals detected, the human risk in terms of carcinogenic and non-carcinogenic was then evaluated.

MATERIALS AND METHODS

Study Area

This study will cover the Pawaga division, the area graphically situated downstream of Great Ruaha Rivers, and is one of the six divisions in the Iringa District Council in the Iringa region (Figure 1). Pawaga division has the smallest land area, just 684.3 km (3.3%) of the total district land area. It has a total of 12 villages and 60 hamlets. The main economic activities in this division are agriculture and pastoralism.

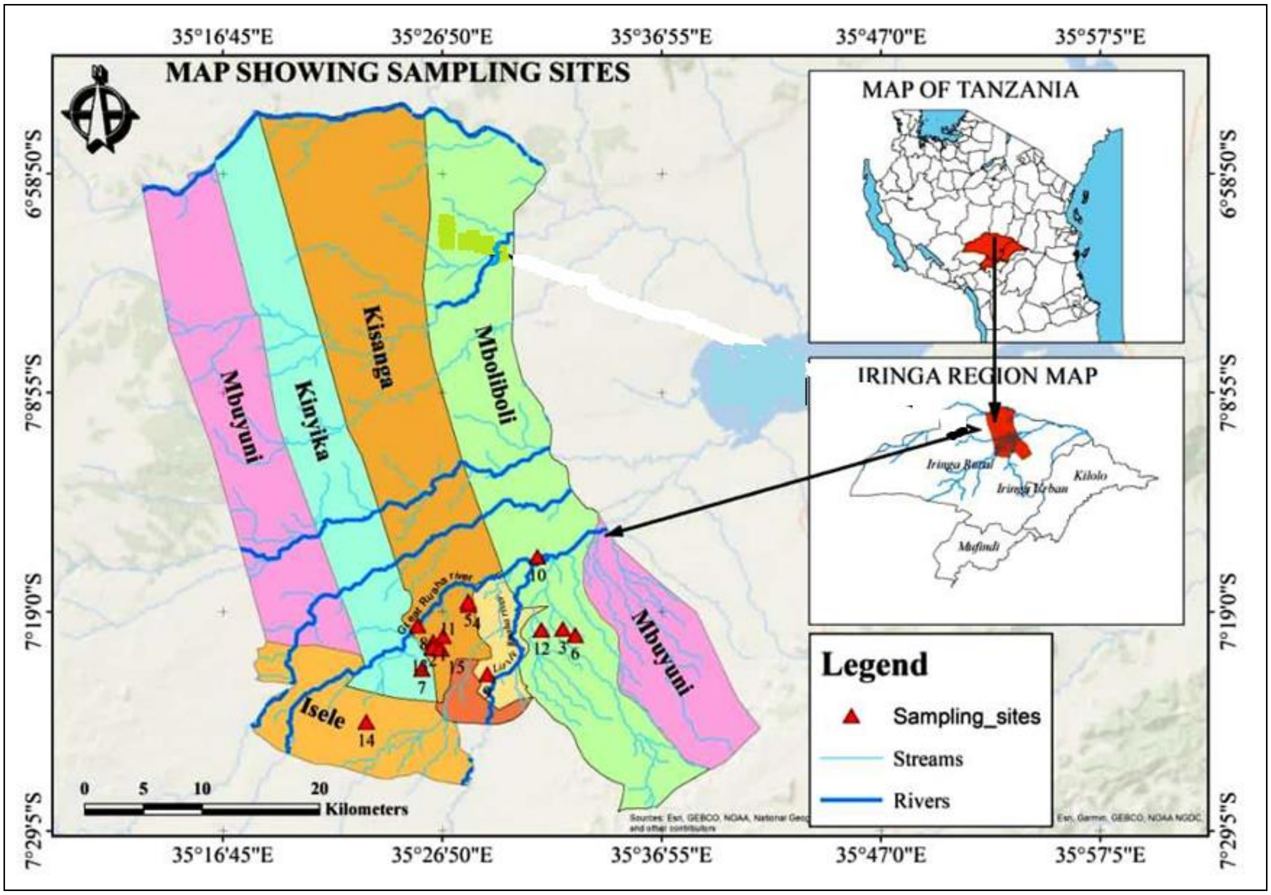

Figure 1: Map of Pawaga Division Showing Sampling Sites

The climate of the Pawaga division is semi-arid with low mean rainfall ranging from 500 – 600 mm, with temperatures over 25ºC. Water demands at the Pawaga division are extremely high due to agricultural activities being dominant and accounting for 85% of the region's gross domestic product (GDP) (Lufingo, 2019). Water scarcity in this region with many water resources has attracted research studies on water quality consumed by the communities around the Pawaga division.

Sampling, Analytical Determination, and Quality Control

Water samples from four different villages were obtained four sites in the Great Ruaha river. Samples were taken four (4) times during the wet season and three (3) times during the dry season (from July 2018 to April 2019) for every 2 months. At each sampling site, the polyethylene sampling bottles were rinsed at least three times before sampling was done. River water samples were collected at a depth of 30 cm in the center of the river (Meng *et al.*, 2022). Four mL of Conc.HNO_3 was added to all water samples to stabilize the samples until pH < 2 and then sealed with parafilm to prevent water evaporation (Meng *et al.*, 2022).

The standard solution of metals was supplied by Merck (Germany) with the highest purity level (99.98%). The commercial analytical grade 1000 ppm stock solutions of Fe, Mn, Cu, Pb, Zn, and Cd were diluted in a 25 mL standard flask and made up to the mark with deionized water to obtain the working standard solutions of 2.0 ppm, 3.0 ppm, and 4.0 ppm of each metal ion.

About 200 mL of each collected water sample was first concentrated on a sandy oven at 80 ºC until the volume reached 50 mL. Then 4 mL of Conc. HNO_3 was added to each sample and digested for 3 minutes. Then 10 mL Conc. H_2O_2 (Merck, 30%) was then added and heated at at 80ºC in the fume hood until oxidation was completed. After cooling, each sample filtered by filter (Whatman filter Merck, 0.45 μm). The filtrate was diluted by deionized water to a final volume of 50 mL (Meng *et al.*, 2022).

Instrument Calibration

Appropriate working standards were prepared for each of these metal solutions using a dilution of the intermediate solutions using distilled water in 2M HNO_3. Using the instrument operation manual (Perkin-Elmer, 1996), to attain its better sensitivity, the working standards were aspirated one after the other into the flame atomic absorption spectrometry (FAAS) and their absorbance was recorded. Calibration curves were plotted with different points for each of these metal standards using absorbance against concentration (mg/L). Immediately after calibration, the sample solutions were aspirated into the AAS instrument, and a direct reading of the metal concentrations was made (Table 1).

Table 1: Calibration Curve A vis Conc. of Heavy Metals (mg/L)

Metal	Model for Absorbance vis Conc.	R^2
Fe	y = 0.0172×	0.9976
Mn	y = 0.0691×	0.9952
Cu	y = 0.0814×	0.9948
Pb	y = 0.0185×	0.9967
Zn	y = 0.0204×	0.9983
Cd	y = 0.0168×	0.9952

Human Health Risk Assessment

Risks of individual heavy metals

Risk assessment is defined as the method of evaluating the probability of occurrence of any given probable amount of harmful health impacts over a determined time period (Wongsasuluk *et al.*, 2014). The health risk assessment of each contaminant is normally based on the estimation of the risk level and is classified as carcinogenic or non-carcinogenic health hazards (Custodio *et al.,* 2020). To estimate the heavy metal contamination and potential carcinogenic and non-cancer health risk caused via ingestion and dermal absorption of heavy metals in the great Ruaha river water; Hazard Quotients (HQ) and Hazard Index (HI) to adults were used (Wang, et al., 2005).

According to EPA (2005), the human health risk assessment estimates the human health effects that could arise from the combined exposure to carcinogenic and non-carcinogenic chemicals. The risk assessment was performed on the basis of exposure doses (D) to heavy metals in river water by ingestion and dermal pathways using Equations (i) and (ii).

$$D_{ingestion} = \frac{C_{ingested} xIRxEFxED}{BWxAT} \qquad (1)$$

$$D_{der} = \frac{C_{derm} xSAxKPxETxEFxEDxCF}{BWxAT} \qquad (2)$$

where, $D_{ingestion}$ is the exposure dose through water ingestion (µg/kg/day), D_{der} is the exposure dose through dermal absorption (µg/kg/day), $C_{ingested}$ is the measured metal concentration in water (µg/L). IR is the ingestion rate per unit time (L/day) estimated to be 2.2 L/day for adults, 1.8 L/day for children; EF is the exposure frequency (350 days/year); ED is the exposure duration (70 years for adults, 6 years for children); BW is the average body weight (70 kg for adults, 15 kg for children). AT is the average life expectancy of people, which is 66×365 = 25,550 for child and for the adult the average exposure time is 24,090 days. SA is the exposed skin area (18,000 cm^2); ET is the exposure time (0.58 h/ day); CF is the unit conversion factor (0.001 L/cm^3), and Kp is the dermal permeability coefficient (cm/h).

The standard parameters and input assumptions for exposure assessment of metals through ingestion and dermal pathways are given on Table 2 (Zakir *et al.*, 2020; Custodio *et al.*, 2020).

Table 2: Standard Constant Parameters (USEPA, 1991; USEPA, 2005).

Parameter		Fe	Mn	Cu	Pb	Zn	Cd
Kp (cm/h)		0.001	1.03×10^{-7}	0.001	0.004	0.006	0.001
Rfd	Ing.	0.7	0.01	0.04	0.0014	0.3	0.001
(mg/kg.day)	Derm.	0.3	0.0008	0.012	0.00042	0.06	0.000025

Parameter	**Unit**	**Ingestion**	**Dermal adsorption**
Daily average intake (IR)	L/day	2.2	-
Skin-surface area (SA)	cm^3	-	18000
Exposure time (ET)	h/event	-	0.58
Exposure frequency (EF)	day/year	365	350
Exposure duration (EP)	year	70	30
Conversion factor (CF)	L/cm^3	-	001
Body weight (BW)	kg	70	70
ABS	All	001	001
Average time (AT)	days	25550	25550

Non-carcinogenic Risk Assessment

The non-carcinogenic risk was evaluated using the hazard quotient (HQ), which was calculated by dividing the exposure value by the reference dose (Custodio *et al.,* 2020).

$$HQ_{ing(derm)} = \frac{D_{ing(derm)}}{RfD_{ing(derm)}} \qquad (3)$$

Where $HQ_{ing(derm)}$ is the hazard quotient for ingestion or skin contact, $D_{ing(derm)}$ is daily intake ingestion or contact. The R_fD are standard values for ingestion or skin contact (Custodio *et al.,* 2020). A value of HQ ≤ 1 indicates that adverse health effects are unlikely. When HQ > 1 reveals probable adverse health effects, while when HQ > 10 indicates high chronic risk. The general potential for non-carcinogenic effects has been assessed by integrating the HQs calculated for each element and expressed as a hazard index.

$$HI = \sum_{i=1}^{n} HQ_{ing(derm)} = HQ_{Pb} + HQ_{Cd} + HQ_{Zn} + HQ_{Cu} + HQ_{Fe} + HQ_{Mn} \qquad (4)$$

where $HI_{ing/der}$ is the hazard index for ingestion or dermal contact, n is the total number of chemical elements considered. If HI < 1, the non-carcinogenic adverse effect due to a particular route of exposure or chemical is assumed to be insignificant.

Carcinogenic Risk Assessment

According to Li and Zhang, (2010), the chronic daily intake (CDI) was calculated using the formula:

$$CDI = \frac{C_{water} xDI}{BW} \qquad (5)$$

C_{water}, DI, and BW represent the concentration of metal trace in the water (mg/kg), mean daily water intake and body weight, respectively.

The cancer risk (CR) was calculated using the formula:

$$CR = \frac{CDI}{SF} \qquad (6)$$

Where SF is the slope factor of cancer where for Pb = 8.5, Cd = 6.1 both in µg/kg/day (Li and Zhang, 2010).

RESULTS AND DISCUSSION

Concentration of Selected Heavy Metals

The statistical concentrations of heavy metals in the Great Ruaha River during wet season and dry season are given in Table 3 and 4 respectively.

Table 3: Heavy Metal Concentration during Wet Season (mg/L)

Name of Village		**Fe**	**Mn**	**Cu**	**Pb**	**Zn**	**Cd**
Kinyika	Min	0.02	0.10	0.03	0.02	0.23	0.01
	Max	0.87	0.22	0.40	0.42	6.78	0.06
	Mean	0.82	0.14	0.17	0.15	2.07	0.03
	Std	0.70	0.08	0.17	0.19	3.16	0.02
Mboliboli	Min	0.04	0.01	0.00	0.00	0.01	0.00
	Max	1.34	0.13	0.07	0.02	1.20	0.01
	Mean	0.57	0.06	0.02	0.01	0.36	0.01
	Std	0.58	0.06	0.04	0.01	0.56	0.01
Kisanga	Min	0.01	0.11	0.00	0.01	0.01	0.00
	Max	1.09	0.12	0.02	0.01	0.29	0.00
	Mean	0.58	0.08	0.01	0.01	0.12	0.00
	Std	0.52	0.05	0.01	0.01	0.11	0.00
Isele	Min	0.11	0.03	0.01	0.00	0.04	0.01
	Max	0.99	0.10	0.23	0.02	0.69	0.00
	Mean	0.44	0.06	0.07	0.01	0.26	0.00
	Std	0.43	0.03	0.10	0.01	0.29	0.00

Table 4: Heavy Metal Concentration during Dry Season (mg/L)

Name of Village		Fe	Mn	Cu	Pb	Zn	Cd
Kinyika	Min	0.12	0.01	0.02	0.01	0.03	0.01
	Max	0.32	0.04	0.08	0.05	0.08	0.06
	Mean	0.20	0.03	0.05	0.03	0.05	0.03
	STD	0.11	0.02	0.03	0.02	0.02	0.03
Mboliboli	Min	0.04	0.02	0.01	0.01	0.01	0.00
	Max	0.25	0.07	0.08	0.02	0.13	0.03
	Mean	0.14	0.04	0.03	0.01	0.07	0.01
	STD	0.11	0.03	0.04	0.01	0.06	0.01
Kisanga	Min	0.05	0.02	0.02	0.01	0.02	0.00
	Max	0.18	0.02	0.03	0.01	0.10	0.04
	Mean	0.14	0.01	0.02	0.01	0.05	0.01
	STD	0.08	0.02	0.01	0.01	0.04	0.02
Isele	Min	0.03	0.01	0.04	0.01	0.01	0.01
	Max	0.44	0.02	0.07	0.02	0.12	0.04
	Mean	0.19	0.01	0.06	0.01	0.01	0.02
	STD	0.22	0.001	0.02	0.001	0.001	0.01

The observed mean concentration was high during wet season than during dry season. Kilolo division area is semi-arid land, during wet season agricultural activities are at peak where farmers apply more chemicals to their farm as well as migration of animals towards Usangu area. During wet season river water at Kinyika is more contaminated followed by river water at Kisanga village than at Mboliboli and the last at Iseke. During dry season river water at Kinyika is more contaminated and the last is at Mboliboli village. The observed mean concentration of heavy metals during wet season is in the following order: Fe > Zn > Cu > Mn > Pb > Cd > Al. During dry season is in the following order: Fe > Cu > Zn > Mn > Al > Cd= Pb.

Iron is used in industries added to brass to enhance its mechanical strength and produce hard and tough alloy. People at Kilolo are engaged in small industries like garage and industrial waste directed to Ruaha river which has led to iron contamination in the river. The average concentration of Fe during the wet season was in the range of 0.44 – 0.82 mg/L, while during dry season it ranges from 0.14 – 0.20 mg/L. These values correspond to values detected earlier (Bala *et al.,* 2008) ranging from 0.08 – 0.217 mg/L. However, the concentration is higher than the WHO permissible limit of 0.01 mg/L (WHO, 2011).

Manganese occurs naturally in many surface water and groundwater sources (from the dissolution of manganese oxides, carbonates, and silicates in soil and rock). Anthropogenic sources (from industrial discharges, mining activities, and landfill leaching) can also be a source of manganese contamination in water (Adhikari and Mal, 2021) and is often considered as one of the least toxic metals. The mean concentration level fluctuated between 0.06 – 0.14 mg/L which is higher than maximum permissible limits in drinking specified to be 0.05 mg/L (WHO, 2020). The mean concentration during the wet season ranges from 0.06 – 0.14 mg/L and 0.01 – 0.04 mg/L during dry season. These values are lower than maximum acceptable limit WHO (2020). The lower level of manganese tends to be lower in flowing rivers and streams due to presence of dissolved oxygen in water, which limits the amount of manganese that is dissolved (WHO, 2020).

The maximum mean values of Cu from both seasons are 0.17 mg/L (wet season) and 0.06 mg/L (dry season). These values are higher than those detected earlier (Mahugija, 2018) which was 0.04 mg/L. Similarly, the highest mean value of Pb during wet season was 0.15 mg/L and during dry season was 0.03 mg/L. These values are higher than those detected in Dar es Salaam ranges from 0.012 – 0.08 mg/L (Mahugija, 2018). Also, values are higher than WHO maximum permissible limit in drinking water 0.01 mg/L (WHO 2011).

During dry season, the highest mean concentration of Pb was detected at Kinyika village (0.002 mg/l). The same village detected highest concentration during wet season (0.15 mg/L). The high level of Pb in water samples indicate disposal in the effluents in the study areas, which may be attributed to the large number of tanning industries found in along the river. Lead is normally found in dyes and pigments used in industries (Idrees *et al.,* 2018).

The highest mean concentration of Zn was detected during wet season (2.07 mg/L), which is below the WHO maximum permissible limit of 5 mg/L (WHO, 2011). These values were below the values detected earlier (Idrees *et al.,* 2018) which ranges between 0.04 – 0.07 mg/L. These results may be because these areas at Kilolo are densely populated, having small, developed hubs of electronic industries. The illegal dismantling of E-wastes materials is high within these areas. The dispose or recycling of E-wastes is either by open-air burning, dissolving by acid, or other methods to get valuable parts from the waste and hence find their way into the river.

Human Health Risks Assessment

The non-carcinogenic health risk owing to ingestion and dermal exposure to the studied heavy metals are shown in Table 5. Average levels of non-carcinogenic risk (HQ) via ingestion of river water were observed in the descending order wet season > dry season. For the heavy metals the trend for HQ via ingestion, were observed in the ascending order Fe < Zn <Cu < Mn < Pb < Cd.

Table 5 Non-carcinogenic Risk by Ingestion (HQ_{ing}) of Heavy metals in River Water

Village name	Season	Fe	Mn	Cu	Pb	Zn	Cd	HI
Kinyika	Wet	0.037	0.447	0.136	32.143	0.221	9.000	51.984
	Dry	0.009	0.096	0.040	6.249	0.005	9.000	15.399
Mboliboli	Wet	0.026	0.192	0.016	2.143	0.038	3.000	21.399
	Dry	0.006	0.128	0.024	2.143	0.007	3.000	5.308
Kisanga	Wet	0.026	0.256	0.075	2.143	0.013	0.000	2.513
	Dry	0.006	0.032	0.150	2.143	0.005	3.000	5.623
Iseke	Wet	0.020	0.192	0.056	2.143	0.028	0.00	2.439
	Dry	0.009	0.300	0.048	2.143	0.001	0.639	3.140

There is little exception at Kinyika and Kisanga villages, where the HQ_{ing} for Pb is higher than HQ_{ing} for Cd. According to Liang *et al.,* (2011) the heavy metal pollutant can pose potential adverse health effects when the HQ_{ing} value of a metal is higher than 1. The HQ_{ing} of Cd ranges from 0.000 – 9.000, while Pb ranges from 2.143 – 32.143. Other metals in the present study have the HQ_{ing} values lower than 1 via ingestion of water.

Therefore, the studied metals were capable individually to pose adverse health effect through ingestion in the water of Ruaha River. During wet season, river water at Kinyika village indicates high chronic risk as the value of HQ_{ing} of Pb > 10, while other villages has revealed probable adverse health effects as 1< HQ_{ing} > 10. The heavy metal HQ_{ing} values studied were below the permitted limit and indicated that adverse health effects are unlikely.

The HQ_{ing} values of Zn, Cu, Mn and Fe obtained in this study indicate that adverse health effects on the inhabitants who consume water from the rivers evaluated are unlikely. Stelmashook, et al., (2014), indicated attention must pay to Zn levels due to possible consequences of excessive Zn intake. It is well indicated *(*Kuo *et al.*, 2013) that Zn can affect the gastrointestinal tract, before it is distributed throughout the body. Another study also reported that, metal ions imbalance such as Zn and Cu play an important role in the pathogenesis of many neurodegenerative diseases (Yang and Wang, 2018). Intake of high concentrations of Fe may cause a variety of disorders that can lead to pathological conditions, including diabetes mellitus (Huang, 2003), liver disease, and cardiovascular disease, as well as neurodegenerative disorders (Kuo *et al.,* 2013).

However, the combined hazard index for ingestion registered HI > 1 values in all the rivers sites evaluated, indicating that the adult population is at risk of suffering non-carcinogenic effects due to the combined effects of heavy metals analyzed. The HI > 10 values were recorded in Kinyika village during the wet and dry season and at Mboliboli during the wet season. People at these two who consume river water are at very high-risk to their health.

Table 6 shows the non-carcinogenic skin contact risk of heavy metals in water for adults. The results reveal a risk considerably below the permitted limit (HQ_{derm} and HI less than 1), indicating that there is no evident risk to the population in the study area via the dermal pathway. The trend of HQ via dermal contact was in the order Mn < Fe < Cu < Zn < Cd < Pb.

Table 6 Non-carcinogenic Risk by Contact (HQ_{derm}) of Heavy metals in River Water

Location	Season	Fe	Mn	Cu	Pb	Zn	Cd	HI
Kinyika	Wet	3.909 x 10^{-4}	2.578 x10^{-6}	2.026 x10^{-3}	0.204	2.960 x10^{-2}	0.172	0.408
	Dry	9.534 x 10^{-5}	5.524 x10^{-7}	5.959 x10^{-4}	0.041	7.151 x10^{-4}	0.172	0.221
Mboliboli	Wet	2.717 x 10^{-4}	1.105 x10^{-6}	2.384 x10^{-4}	0.014	5.148 x10^{-3}	0.057	0.0767
	Dry	6.674 x 10^{-5}	7.365 x10^{-7}	3.575 x10^{-4}	0.014	1.001x10^{-3}	0.057	0.0724
Kisanga	Wet	2.765 x 10^{-4}	1.473 x10^{-6}	1.19 x10^{-4}	0.014	1.716 x10^{-3}	0.000	0.016
	Dry	6.674 x 10^{-5}	1.841 x10^{-7}	2.384 x10^{-4}	0.014	7.151 x10^{-4}	0.057	0.072
Iseke	Wet	2.097 x 10^{-4}	1.105 x10^{-6}	7.151 x10^{-4}	0.014	3.718x10^{-3}	0.000	0.019
	Dry	9.058 x 10^{-5}	1.841 x10^{-7}	7.151 x10^{-4}	0.014	1.430 x10^{-4}	0.114	0.129

Overall, the results reveal that adults are not vulnerable to acute and chronic effects of heavy metal intake. This was consistent with the previous study (Alidadi *et al.,* 2019) they reported that non-carcinogenic risk (HI) of heavy metals for adults' dermal contact with heavy metals ranges from 0 016 – 0.244. Although the results in this study indicated that there was no obvious non-carcinogenic risk observed at the Kilolo division among selected trace elements analyzed, routine monitoring must be done.

Carcinogenic Risk Assessment of Trace Elements

Carcinogenic risk is the product of daily exposure dose and cancer slope factor, which is shown in Equation (v). Under the assumption that there is no antagonism and synergism between pollutants, the integrated carcinogenic risk can also be identified as the sum of carcinogenic risks exposure by various pollutants via different pathways. Table 7 shows the carcinogenic risks for adults by ingestion of heavy metals from river water at sampling villages.

Table 7: Carcinogenic risk by ingestion of heavy metals in river water at different sites in Kilolo division

Village	Season	Fe	Mn	Cu	Pb	Zn	Cd
Kinyika	Wet	2.577×10^{-2}	4.4×10^{-3}	5.343×10^{-3}	4.714×10^{-3}	6.506×10^{-2}	9.429×10^{-4}
	Dry	6.286×10^{-3}	9.429×10^{-4}	1.571×10^{-3}	4.714×10^{-3}	1.571×10^{-3}	9.429×10^{-4}
Mboliboli	Wet	1.791×10^{-2}	1.886×10^{-3}	6.29×10^{-4}	3.143×10^{-4}	1.131×10^{-2}	3.143×10^{-4}
	Dry	4.400×10^{-3}	1.257×10^{-3}	9.43×10^{-4}	3.143×10^{-4}	2.200×10^{-3}	3.143×10^{-4}
Kisanga	Wet	1.823×10^{-2}	2.514×10^{-3}	3.14×10^{-4}	3.143×10^{-4}	3.771×10^{-3}	0.000
	Dry	4.4×10^{-3}	3.143×10^{-4}	6.290×10^{-4}	3.143×10^{-4}	1.571×10^{-3}	3.143×10^{-4}
Iseke	Wet	1.383×10^{-2}	1.886×10^{-3}	2.2×10^{-3}	3.143×10^{-4}	8.171×10^{-3}	0.000
	Dry	5.971×10^{-3}	3.143×10^{-4}	1.886×10^{-3}	3.143×10^{-4}	3.143×10^{-4}	6.286×10^{-4}

The carcinogenic risk of heavy metals through ingestion of river water varied from 0.00 – 6.505 x 10^{-2}. According to Li *et al.,* (2017), carcinogenic risk values can be rated in seven levels which is extremely high risk (Table 8).

Table 8: Levels and values of risk assessment standards (Li *et al.*, 2017)

Risk Grade	Rating of risk	Range of risk value	Acceptability
Grade one	Extremely low risk	$CR < 10^{-6}$	Completely acceptable
Grade two	Low risk	$1 \times 10^{-6} < CR< 1 \times 10^{-5}$	Not willing to care about the risk
Grade three	Low-medium risk	$1\times 10^{-5} < CR < 5 \times 10^{-5}$	Do not mind about the risk
Grade four	Medium risk	$5\times 10^{-5} < CR < 1 \times 10^{-4}$	Care about the risk
Grade five	Medium-high risk	$1\times 10^{-4} < CR < 5 \times 10^{-4}$	Care about the risk and willing to invest
Grade six	High risk	$5 \times 10^{-4} < CR < 1 \times 10^{-3}$	Pay attention to the risk and act to solve it
Grade seven	Extremely high risk	$CR > 10^{-3}$	Reject the risk and must solve it

About 54.2% of the analyzed samples are at grade seven which is an extremely high-risk position, while the rest are at high-risk side. These results suggest that the carcinogenic risk of heavy metals from ingestion of water contaminated by different heavy metals makes adults be at risk due to cancer.

The maximum carcinogenic risk (CR) from ingestion of Cd was 5.546×10^{-4} and Pb 1.546×10^{-4} (Table 9).

Table 9: The carcinogenic risk (CR) from ingestion of Pb and Cd in the water

Site	Season	Pb	Cd
Kinyika	Wet	5.546×10^{-4}	1.546×10^{-4}
	Dry	1.109×10^{-4}	1.546×10^{-4}
Mboliboli	Wet	3.697×10^{-5}	5.152×10^{-5}
	Dry	3.697×10^{-5}	5.152×10^{-5}
Kisanga	Wet	3.697×10^{-5}	0.000
	Dry	$3.697 x 10^{-5}$	$5.152 x 10^{-5}$
Iseke	Wet	$3.697 x 10^{-5}$	0.000
	Dry	3.697×10^{-5}	1.030×10^{-4}

Caspah *et al*,. (2016), indicated there are difference in determination of maximum threshold according to country or continent. For example, the USA recommends 1×10^{-6} to 1×10^{-4} (USEPA 1992; 1999) the United Kingdom generally adopts 1×10^{-5} (*Zakir et al.,* 2020), in practice, and the Netherlands suggests a 1×10^{-4} (Liyin, *et al*, 2018). Therefore, the maximum carcinogenic risk (CR) in this study was within acceptable limit ranges of 1 ×10−6 to 1 ×10−4. These values are similar to values observed earlier in China by Liyin, *et al.*, (2018) where the CR values exceeded the 10^{-4} level of concern. The levels of Cd near old industrial areas exceeded the Cd exposure standard (2.6% of CR values > 10^{-4}).

CONCLUSION AND RECOMMENDATIONS

The Great Ruaha river watersheds in the southern highland of Tanzania are exposed to contamination by heavy metals and metalloids from natural and anthropogenic sources and agricultural activities are the main sources. The magnitude of heavy metal contamination in the studied rivers requires more frequent monitoring and supervision of the household (who discharge their liquid waste into water bodies).

The assessment of carcinogenic and non-carcinogenic risks due to exposure to heavy metals through the routes of ingestion and dermal contact showed adults are more risks. These findings demonstrate the urgent need for effective policies to control and reduce the pollution levels of the rivers whose waters are destined for a variety of uses. Therefore, further studies on other heavy metals in the Great Ruaha and sediments are recommended.

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