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Health Risk Assessment of Heavy Metal Concentration in Mudzira Vimtim River in Adamawa State, Nigeria.

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ABSTRACT

Surface water of Mudzira Vimtim River is now a great concern because of the contamination with heavy metals. Therefore, characterization of carcinogenic and non-carcinogenic health risk due to the use of this water is a demand of time. This study is aimed to determine levels of heavy metals in surface water of Mudzira Vimtim River and to estimate human health risk associated with the use of water from this River via ingestion and dermal exposure. 5 study sites in Mudzira Vimtim River were selected for sampling during the study. The concentration of heavy metals (Zn, Cu, Cd, Cr, Mn, Fe and Mg) of the water samples were determined by Atomic Absorption Spectrophotometer (ASS). The mean concentrations of metals investigated during the study were Zn (1.06 mg L–1), Cu (4.02 mg L–1), Cd (1.22 mg L–1), Cr (5.84 mg L–1), Mn (0.75 mg L–1), Fe (2.40 mg L–1) and Mg (1.79 mg L–1). The Hazard Quotient (HQ) and Hazard Index (HI) for child via ingestion and dermal contact were greater than one except for the adult, whereas HI value greater than one indicating an unacceptable risk of non-carcinogenic effects on health. Carcinogenic Risk (CR) due to use of water of Mudzira Vimtim River ranged between 2.58×10–3(Cd) to 1.67×10–2 (Cr) and 5.66×10–3 (Cd) to 3.58×10–2 (Cr) for the child and the adult, respectively. The cumulative cancer risk for both the child and the adult indicates high risk for the studied metals. The health risk assessment of the heavy metals content in Mudzira Vimtim River indicating major adverse health risk effects but suggests attention to the risk status and to its remediation process.

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1.0 INTRODUCTION

Water is an essential component of life, fresh water constitute about 3% of the total water on the earth surface, only 0.01% of this fresh water is available (Hinrichsen and Tacio, 2002), with two thirds of the earth's surface covered by water and the human body consisting of 75% of it, it is evidently clear that water is one of the prime elements responsible for life on earth. Regrettably, even this small portion of fresh water is under pressure due to anthropogenic sources due to rapid growth in population and industrial activities (Li et al., 2009). Heavy metals are the main pollutants and elements of risk in drinking water (Enaam, 2013).

Investigation on water contamination by heavy metals has become the prime focus of environmental scientists in recent years (Fenglian and Qi, 2011). More attention should be given to toxic heavy elements because of bio accumulation and bio magnification potential, and their persistence in the environment. Some metals like copper (Cu) and zinc (Zn) are essential for normal body growth and functions of living organisms and are referred to as essential elements. Other elements are referred to as non-essential, high concentrations of these metals like cadmium (Cd), chromium (Cr), manganese (Mn), and lead (Pb) are considered highly toxic to human and aquatic life (Ouyang et al., 2002). A certain amount of Cr for instance is needed for normal body functions; but at the same time high concentrations may cause toxic effect such as liver, kidney problems and genotoxic carcinogen (Knight et al., 1997). Like Cr, Co is also one of the required metals needed for normal body functions as a metal component of vitamin B12 (Strachan, 2010). However, high intake of Co via consumption of contaminated food and water can cause abnormal thyroid artery, polycythemia, over-production of red blood cells (RBCs) and right coronary artery problems (Robert and Mari, 2003).

Generally, high concentrations of Mn and Cu in drinking water can cause mental diseases such as Alzheimer's and Manganism (Dieter et al., 2005). High Mn contamination in drinking water also affects the intellectual functions of 10-year-old children (Wasserman et al., 2006) .Like other heavy metals, sufficient amount of Zn is also very significant for normal body functions. Its deficiency can lead to poor wound healing, reduced work capacity of respiratory muscles, immune dysfunction, anorexia, diarrhea, hair loss (Strachan, 2010). Cd exposure can cause both chronic and acute health effects in living organisms (Barbee and Prince, 1999). Experimental data in humans and animals showed that Cd may cause cancer in humans, diarrhea, hair loss, dermatitis (Acrodermatitis enteropathica) and depression. The chronic effects includes kidney damage, skeletal damage and itai-itai (ouch-ouch) diseases (Jarup et al., 2000; Nordberg et al., 2002). These heavy metals are not only found in water, but soil, food (eg fish) and air.

Heavy metal pollution in aquatic environments has received considerable global attention due to its potential to cause irreversible damage to human health (Chowdhury et al., 2016; Ali et al., 2016). Heavy metals are considered systemic toxicants that may lead to multiple organ damage along with teratogenic and carcinogenic effects (Tchounwou et al., 2012).

Human health risk assessment is considered as the characterization of the potential adverse health effects of humans as a result of exposures to environmental hazards (USEPA, 2012). This process employs the tools of science, engineering, and statistics to identify and measure a hazard, determine possible routes of exposure, and finally use that information to calculate a numerical value to represent the potential risk (Lushenko, 2010). A human health risk assessment involves four steps which are: hazard identification, dose-response assessment, exposure assessment, and risk characterization. Health risk assessment classifies elements as, carcinogenic or non-carcinogenic. The classification determines the procedure to be followed when potential risks are calculated. Non-carcinogenic chemicals are assumed to have a threshold; a dose below which no adverse health effects will be observed where an essential part of the dose-response portion of a risk assessment includes the use of a reference dose (RfD). Also, carcinogens are assumed to have no effective threshold. This assumption implies that there is a risk of cancer developing with exposures at low doses and, therefore, there is no safe threshold for exposure to carcinogenic chemicals. Carcinogens are expressed by their Cancer Potency Factor (Lushenko, 2010). The aim of this research work is to assess the health risk of heavy metal concentration in mudzira Vimtim River and suggest possible way of reducing these risks

2. 0 MATERIALS AND METHOD

2.1 Study Area

Mubi North is among the 21 Local Government Area of Adamawa State. Mubi Area of Adamawa state is located on latitude $11^{o}5^{1}$Nand longitude $13^{o}5^{1}$E. It has altitude of 696m above sea level with an annual mean rainfall of 1,220mm and a mean temperature of 15.2^{o}c during Hamattan periods from November to February and 39.7^{o}c in April (ADADP, 1986). The town is essentially a mountainous landscape transverse by river Yedzaram and many tributaries, Mandara and Adamawa Mountains formed part of this undulating landscape (Mansir, 2006).

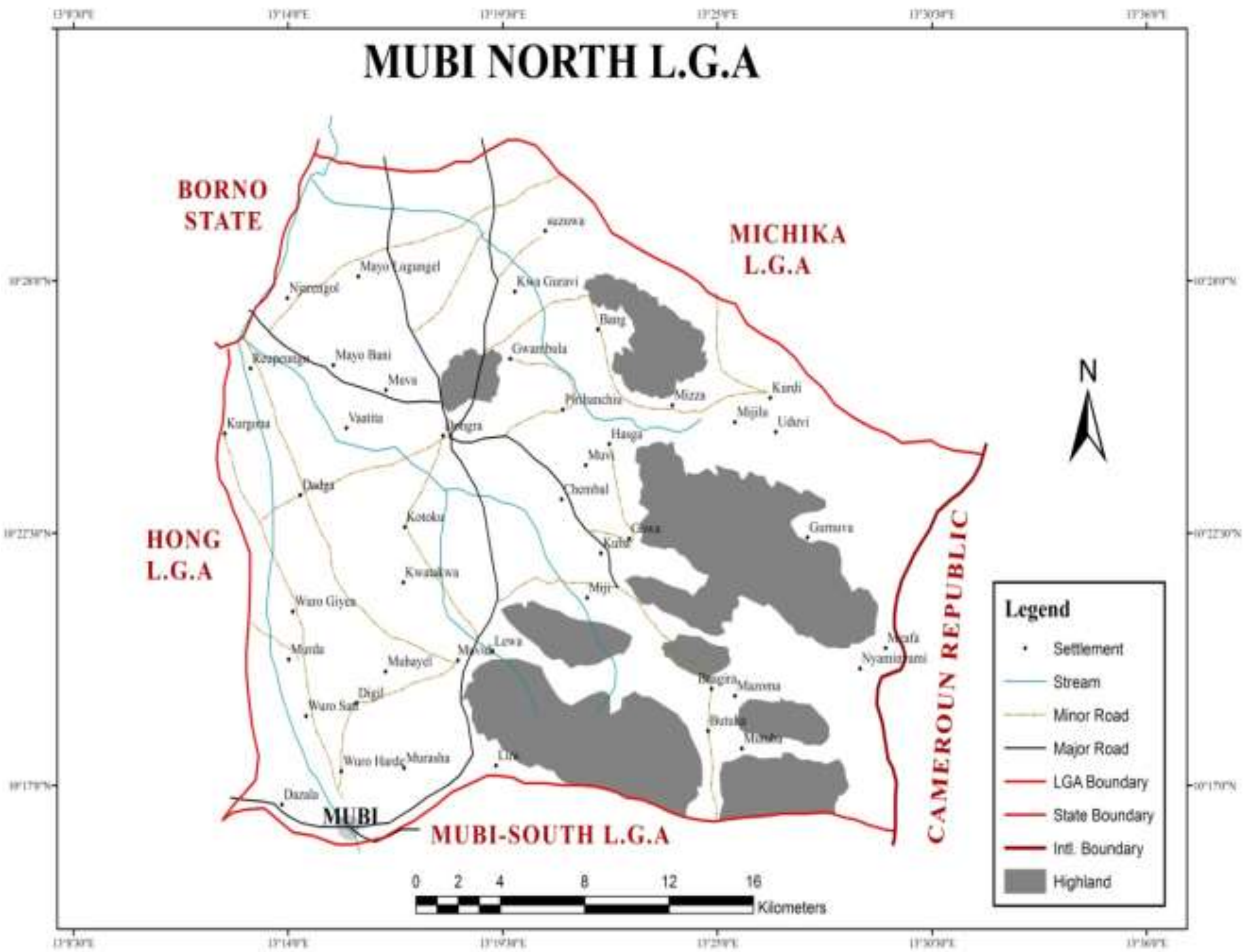

Fig.2.1. Map of Mubi North Local Government Area of Adamawa State

2.2 Water Sample

Water samples were collected at mid depth below the surface from the various sampling sites using plastic sampling bottles that were pre-washed with 10% HCl acid and also pre-rinsed with deionized water to avoid any contamination from metal and non-metal ions. Samples were collected at three separate locations from each sampling sites. These were then mixed up together to give one representative samples for that site. Samples were then taken to the laboratory stored in the refrigerator after addition of 2M of HNO_3 in order to prevent microbial activities. To each of the 100cm^3 of the sample were digested with 15 ml concentrated HNO_3 solution and 10ml of 50% concentrated HCl in ratio of 2: 1 (Wufem et al., 2009). Samples were evaporated to almost dryness on a hot plate and then 7 ml of 50% concentrated hydrochloric acid was added and heated for 10 minutes. The digested samples were allowed to cool to room temperature. These were filtered through a Whatman 0.45µm filter paper and the final volume was adjusted to 50ml with double distilled water and stored for analysis. . The elemental concentrations of the digested water samples were carried out using Atomic Absorption Spectrophotometer (AAS) 210 VPG Buck Scientific Model.

Fig.2.2 Sampling Points along Mudzira Vimtim River

2.3 Human Health Risk Assessment Indices

Human health risk assessment indices were calculated for both non-cancer and cancer risks from ingestion and absorption of studied metals for the child and the adults. The Average Daily Dose (ADD) intake was calculated according to Iqba and Shah 2013. Following the Eq.1 and 2:

$$ADD_{ingestion} = \frac{C_W \times IR \times ED \times EF}{BW \times AT} \quad (1)$$

where, $ADD_{ingestion}$ (mg kg^{-1} day^{-1}) represents the exposure dose through ingestion, C_w is the mean concentration of the trace elements in water (mg L^{-1}); IR is both direct and indirect intake rate of drinking water (1 L day^{-1} for the child and 2 L day^{-1} for the adult), ED is the exposure duration (6 years for the child and 30 years for the adult), EF is the exposure frequency to pollutants (365 days/year), BW represents the total body weight (15 kg for the child and 70 kg for the adult), AT is equal to ED×365 for non-carcinogenic risk, which is 2190 and 10950 for the child and the adult, respectively. For carcinogenic risk, AT is the average life expectancy of people, which is 70×365 = 25550 for both the child and the adult:

$$ADD_{dermal} = \frac{C_W \times SA \times Kp \times ET \times EF \times ED \times CF}{BW \times AT} \quad (2)$$

where, ADD_{dermal} (mg kg^{-1} day^{-1}) is the average daily dose of heavy metal through dermal absorption. SA is the exposure area of skin (6600 cm^2 for the child and 18,000 cm^2 for the adults); Kp is the dermal permeability coefficient of pollutants in water (cm h^{-1}) in this study, 0.002 cm h^{-1} for Cr, 0.001 cm h^{-1} for other metals, 0.001 cm h^{-1} for Cd and Cu and 0.0006 cm h^{-1} for Zn; ET is the exposure time (h day^{-1}), in this study, ET is 0.6 h day^{-1}; CF is unit conversion factor 0.001 L cm^{-3}.
The health risk from river water ingestion and dermal absorption was assessed in relation to its non-carcinogenic hazard quotient effects based on the Eq.3:

$$\text{Hazard Quotient } (HQ_{ingestion/\,dermal}) = \frac{ADD_{ingestion/dermal}}{RfD_{ingestion/dermal}} \quad (3)$$

where, $ADD_{ingestion/dermal}$ and $RfD_{ingestion/dermal}$ are in mg kg^{-1} day^{-1}. RfD (reference dose) was taken from the United States Environmental Protection Agency, The Integrated Risk Information System USEPA 2012 as shown in table 2. According to Lim *et al* 2008, HQ value greater than 1.0 indicates an unacceptable risk of adverse non-carcinogenic effects and HQ value less than 1.0 indicates an acceptable level of risk for human health. However, the potential risk to human health through the mixture of all chemicals was assessed by Eq. 4:
Target Hazard Quotient (THQ) was used to analyze the potential non-carcinogenic effect of the metals in the water samples by relating the estimated ADD of each elements with their reference dose (RFD) for each exposure pathway as described in equation 3.

$$Hazard\ index(HI_{ingestion/dermal}) = \sum_{i=1}^{n} HQ_{ingestion/dermal} \quad (4)$$

where, $HI_{ingestion/dermal}$ is potential hazard through ingestion and dermal absorption of heavy metals, $HQ_{ingestion/dermal}$ is the hazard quotient through ingestion or dermal absorption, i is the pathways of exposure; n is the kinds of trace elements; HI>1 means an unacceptable

risk and HI<1 means an acceptable level of risk of non-carcinogenic effects on health . Lim *et al* 2008.
The carcinogenic risk is the multiplication of ADD (mg kg^{-1} day^{-1}) and Cancer Slope Factor (CSF) (mg kg^{-1} day^{-1}). Cancer risk due to ingestion of contaminated water with heavy metals was calculated according to Wongsasuluk *et al 2014* following the Eq.5:

$$CR_{ingestion} = ADD_{ingestion} \times CSF \quad (5)$$

where, $CR_{ingestion}$ is cancer risk through ingestion of heavy metals contaminated water, $ADD_{ingestion}$ is average daily dose (mg kg^{-1} day^{-1}) of heavy metals and CSF is cancer slop factor (mg kg^{-1} day^{-1}). During the present study, the carcinogenic risk values were calculated for Cd and Cr according to Masok *et al* 2017, Md. A.Haque et,al 2018.

3.0 RESULTS AND DISCUSSION

3.1 Concentration of Heavy Metals in Surface Water

Descriptive statistics of heavy metals in surface water of Mudzira Vimtim River is shown in Table 3.2. The average concentration of studied metals followed the decreasing order of: Cr (5.84 mg L^{-1})> Cu (4.02 mg L^{-1})>Fe (2.40 mg L^{-1})>Mg (1.79 mg L^{-1})> Cd (1.22 mg L^{-1})>Zn (1.06 mg L^{-1})>Mn (0.75 mg L^{-1}). Therefore, it was observed that Cr is the most concentrated metal in the surface water of the Mudzira Vimtim River.

Table 3.1. Levels and Values of Assessment Standards According to Li et al 2017

Risk grade	Range of risk value	Acceptability
Grade I(Extremely low risk)	$<10^{-6}$	Completely accept
Grade II(Low risk)	10^{-6},10^{-5}	Not willing to care about the risk
Grade III(Low-medium risk)	10^{-5},5x10^{-5}	Do not mind about the risk
Grade IV(Medium risk)	5x10^{-5},10^{-4}	Care about the risk
Grade V(Medium High risk)	10^{-4},5x10^{-4}	Care about the risk and willing to invest
Grade VI(High risk)	5x10^{-4},10^{-3}	Pay attention to the risk and take action to solve it
Grade VII(Extremely high risk)	$>10^{-3}$	Reject the risk and must solve it

Table: 3.2 Mean Concentrations of Heavy Metals in Water Samples Collected from River Mudzira Vimtim

Water sample	Mean concentration of Heavy metals in samples [mg/L]						
	Zn	Cu	Mn	Cr	Cd	Fe	Mg
Position 1	0.40±0.003	2.50±0.010	0.40±0.002	4.30±0.156	0.90±0.005	2.00±0.004	1.62±0.005
Position 2	1.00±0.004	3.60±0.051	0.60±0.003	5.00±0.003	1.10±0.005	2.10±0.014	1.70±0.002
Position 3	1.40±0.002	4.20±0.003	0.65±0.005	7.30±0.004	1.20±0.009	2.30±0.003	1.80±0.003
Position 4	1.80±0.026	4.80±0.006	1.00±0.003	8.40±0.003	1.40±0.005	2.50±0.007	1.87±0.008
Position 5	0.70±0.007	5.00±0.131	1.10±0.005	4.20±0.010	1.50±0.003	3.10±0.007	1.95±0.004
W. H. O Standard	5.0	1.0	0.01	0.05	0.005	0.3	0.20

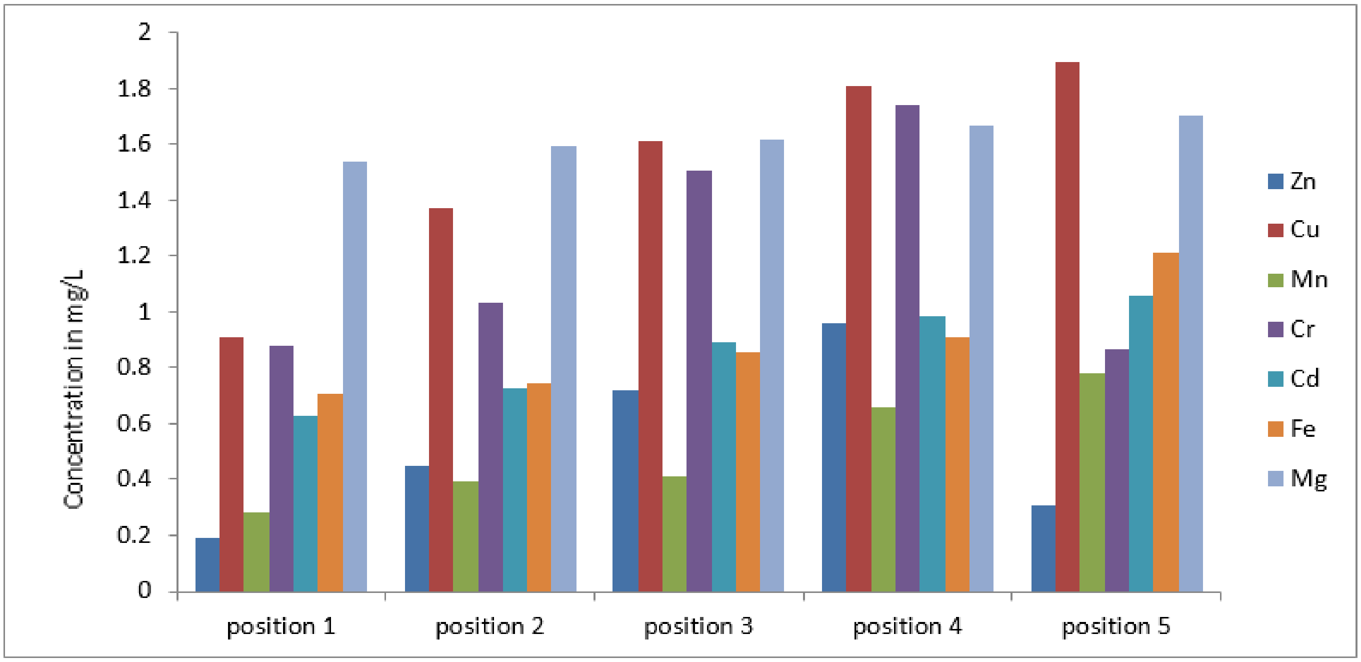

Fig. 3.1 Level of Concentration of Elements (Zn, Cu, Mn, Cr, Cd, Fe, Mg) in Water at Positions 1 – 5.

According to Eastmond *et al 2008*, high concentration of Cr (III) in the cell can cause DNA damage; therefore, a long-term drinking of Cr contaminated water of the Mudzira Vimtim River can be a threat to human health. During the study, Cu was found to be the second most abundant metal of the samples of surface water studied. Prasad, A.S.,2003 stated that acute adverse effects of high intake of zinc include nausea, vomiting, loss of appetite, abdominal cramps diarrhea and headache, while Hambidge , K. M and N.F Krebs, 2007 considered Zn as an essential mineral for biological and public health organisms. The high contamination of Cr and Cu observed in this river water may be attributed to contaminants from household activities and other small anthropogenic activities in the study area. However, the average concentrations of all the studied metals were higher than the World Health Organization (WHO) with the exception of Zn which was within the permissible limit WHO 2008, 2011. During the study, among the 5 water samples, 80.00% of samples exceeded the WHO 2008, 2011. While for Zn, 20.00% samples that did exceed the drinking water standard of the WHO 2008, 2011.

3.2 Human Health Risk Assessment to Heavy Metals in Surface Water

The carcinogenic and non-carcinogenic health risk owing to ingestion and dermal exposure to the studied heavy metals for both the child and the adult are shown in Table 3.5 and 3.6 respectively. Average levels of non-carcinogenic risk (HQ) in surface water were observed in the descending order of: Cd>Cr >Zn>Cu> Mn via.ingestion and Cr>Cd>Zn >Cu> Mn via. Dermal contact for the child (Table). In case of the adult, this trend was Cd >Cr>Mn>Cu>Zn via. Ingestion and Cr>Cd>Zn>Mn>Cu via. Dermal contact (Table 3.5). According to Liang *et al*.2011, the heavy metal pollutant can pose potential adverse health effects when the HQ value of a metal is greater than 1. In the present study, the HQ values for each metal were all lower than 1 with the exception of Mn in children, both ingestion and dermal HQ are greater than 1. Therefore, the result of the present study indicates that, the studied metals were not capable to pose any adverse health effect through ingestion or bathing in the water of Mudzira Vimtim River for adult but children are at high risk. Hazard index (HI) value obtain in this study was above 1 for the child via. Ingestion pathway (1.07) and dermal contact (1.08), therefore the studied metals have a cumulative potential to cause adverse health to the child through direct ingestion and dermal contact of water. The HI value obtained via dermal contact (1.11) for the child (Table 3.5) and via. Ingestion (1.43) and for the adult were below the risk value of (1) (Table 3.5).

Lifetime cancer risk calculated in this study through ingestion of Cd, and Cr was 2.58×10^{-3} and 1.67×10^{-2} for the child (Table 3.6) and 5.66×10^{-3} and 3.58×10^{-2} for the adult (Table 3.6), respectively. The cumulative cancer risk of studied metals was 1.93×10^{-2} for the child and 4.15×10^{-2} for the adult.

These results indicated higher cancer risks for the child than the adult. The evaluation of cancer risks from exposure to Cr, Cd and cumulative cancer risk value in the present study were found to be above the acceptable cancer health risk range of 1.00×10^{-6} to 1.00×10^{-4}.

Table3.3: Reference Doses (RfD) in mg/kg/day and Cancer Slope Factors (CSF) for Individual Heavy Metals per Exposure Pathways

Elements	$RfD_{Ingestion}$	RfD_{Dermal}	$CSF_{Ingestion}$
Cd	5.60E-04	5.00E-04	3.80E-01
Cr	3.00E-03	6.00E-05	5.00E-01
Cu	3.70E-02	2.40E-02	-
Zn	3.00E-01	7.50E-02	-
Fe	-	-	-
Mn	4.60E-02	1.84E-03	-

Source: Bwatanglang et, al 2019

Table 3.4: Average Daily Dose (ADD) Values in mg/kg/day for Adult and Child in Water from Mudzira Vimtim River

Elements	$ADD_{Ingestion}$		ADD_{Dermal}	
	Adult	Child	Adult	Child
Zn	1.29E-02	6.06E-03	4.21E-04	1.44E-05
Mn	9.18E-03	4.28E-03	4.96E-05	1.69E-05
Cr	7.15E02	3.33E-02	7.72E-04	2.64E-04
Cd	1.49E-02	6.79E-03	8.07-E05	2.76E-05
Cu	4.29E-02	2.29E-02	2.69E-04	9.09E-05
Fe	2.90E-02	1.37E-02	1.59E-04	5.43E-05
Mg	2.19E-02	1.02E-02	1.18E-04	4.05E-05

Table 3. 5: Hazard Quotient (HQ) and Hazard index (HI) Values for Heavy Metals in Adults and Children for Water from Mudzira Vimtim River for Non-Carcinogenic risk

	$THQ_{ingestion}$		THQ_{dermal}	
Elements	Adults	Child	Adults	Child
Cd	6.23E-05	1.45E-04	6.98E-05	1.63E-04
Cr	5.57E-03	1.29E-02	2.78E-05	6.48E-05
Cu	3.08E-01	1.11E-01	1.01E-01	2.86E-02
Zn	1.01E-01	2.37E-01	4.04E-03	9.43E-03
Mn	4.58E-01	1.07	6.30E-02	1.08
Fe	-	-	-	-
Mg	-	-	-	-
HI	8.72E-01	1.43	1.68E-01	1.11

Table 3. 6: Cancer Risk (RI) Values for Heavy Metals in Adults and Child for Water from Mudzira Vimtim River

	$CRI_{Ingestion}$		CRI_{Dermal}	
Elements	Adults	Children	Adults	Children
Cd	5.66E-03	2.58E-03	4.03E-08	1.38E-08
Cr	3.58E-02	1.67E-02	4.63E-08	1.58E-08
Cu	-	-	-	-
Zn	-	-	-	-
Mn	-	-	-	-
Fe	-	-	-	-
Mg	-	-	-	-
TCRI	4.14E-02	1.92E-02	8.66E-08	2.96E-08

According to Pawelczyk, A., 2013 , a risk of 1.00×10^{-3} indicated the risk will absolutely require protective measures and therefore, compared to the above range of risk, the results of the present study implies that a lifetime exposure to present heavy metal concentration poses cancer risks for both the child and the adults. The risk grade of studied metals falls in grade-VI for Cr and Cd, for both the child and the adult according to Li et al 2017 as shown in table 3.1. However, the cumulative cancer risk grade was VI for both the child and the adult too.

4.0 CONCLUSION

The findings of this study indicate that high concentrations of Cd, and Cr in Mudzira water may present unacceptable risks to human health in this areas. Humans are at risk of developing cancer and non-cancer health complications associated with exposure to heavy metals via several ingestion- and dermal contact. The exposure-related risks are higher among children than adults, mainly via ingestion and dermal exposure. Communities in the vicinity should take precaution to reduce the frequency of exposure to this water in order to reduce the probability of developing a health complication. Data of the present study will be valuable for management of the sustainable use of Mudzira Vimtim River regarding maintenance of public health.

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