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HUMAN HEALTH RISK ASSESSMENT OF SOME HEAVY METALS IN A RURAL SPRING, SOUTHEASTERN NIGERIA

Onyinyechi G. Onyele* and Emeka D. Anyanwu

Department of Zoology and Environmental Biology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

ABSTRACT: *Human health risk of some heavy metals in a rural spring, Southeast Nigeria was assessed between January and June 2017 in 3 stations to determine its suitability for human consumption. Lead (Pb), Iron (Fe), Cadmium (Cd) and Chromium (Cr) were assessed by evaluating the chronic daily intake (CDI), the hazard quotient (HQ) to determine the hazard indices (HI) in the stations. The heavy metals considered exceeded the standards set by Nigerian Standard for Drinking Water Quality and World Health Organisation. Health risk assessment for all the sites indicated that there is no particularly dangerous single heavy metal, but their cumulative effect, indicated by the hazard index (HI) calls for concern. Hazard Index (HI) for all the stations highly exceeded threshold value (1). This concern is for both adults and children exposed to the spring water through ingestion. The heavy metal contamination observed was of geogenic source and more difficult to manage.*

KEYWORDS: Spring, Heavy Metal, Geogenic, Anthropogenic, Human Health Risk Assessment

INTRODUCTION

Water is essential for life on earth. Freshwater supply is less than 1% of the water available on earth and human existence mainly depends on it. Water quality is important for health and economic development, factors like seasons, anthropogenic influences and natural processes affect the chemical composition of water (Reagen and Bookins-Fisher, 1997). Spring water is usually safe from contaminants (i.e. pathogens, chemicals, metals); since groundwater is naturally filtered as it flows through the soil (Simiyu *et al.*, 2009). Hence, spring water is generally safe for human consumption (Hawley, 2003). Spring water quality may be altered due to exposure to metallic elements (Marcovecchio *et al*., 2007; Simiyu *et al*., 2009). Heavy metal pollution of soil and water has become one of the main concerns of human beings recently (Namaghi *et al.*, 2011). Although some elements are essential for humans, they can be dangerous at relatively high exposure levels (Domingo, 1994; Goorzadi *et al*., 2009). Heavy metals are considered as severe pollutants owing to their toxicity, persistence and bio-accumulative nature in the environment (Pekey *et al.*, 2004). Trace metals gain access into water bodies possibly through anthropogenic and natural sources. Natural sources include geological strata rich in some elements which may contaminate aquifers. Health risk assessment has been recognized as a useful tool for identifying health risks of human activities (Deventer *et al.*, 2004). It involves identifying the potential of a risk source to introduce risk agents into the environment, estimating the amount of risk agents that come in contact with the human environment boundaries (Yi *et al*., 2011), and quantifying the health consequences of exposure (Haung *et al.*, 2008). Carcinogenic or non-carcinogenic methods can be used to assess potential health risk caused by heavy metals (Agneta *et al*., 2006). Non-cancer risk assessment methods based on hazard quotient and hazard index are set by United

States Environmental Protection Agency (Agneta *et al*., 2006). Previous study showed that some drinking water parameters of Iyinna Spring exceeded standard limits (Anyanwu and Ihediwah, 2015); this study therefore was aimed at assessing the human health risk of some of the heavy metals in Iyinna spring to determine its suitability for human consumption.

MATERIALS AND METHODS

Description of Study area and sampling stations

Iyinna spring is located at Umuariaga Community in Ikwuano Local Government Area of Abia State, Southeast Nigeria. The Iyinna spring is located in a valley and surrounded by hills; originating from a rock and piped to an open area where the villagers can have access to it. Umuariaga Community is located on north-east of the state within a geographical location of N5º28'00" to N5º29'00" and E7º32'30" to E7º34'30", about a distance of 9-10 km from Umuahia, Abia State capital and less than 500 metres from the main gate of Michael Okpara University of Agriculture, Umudike, Nigeria (Fig. 1). The Iyinna spring has no nearby houses around but the villagers and farming community come there to fetch water for various domestic uses. The spring was divided into three stations for the purpose of this study. Station 1 is the source of the spring; the water is piped out to an open area from the rock. It is located in a valley which limits accessibility. This station is forested but has ferns (*Diplzium sammatii*) and three-cornered leek (*Allium triquetrum*) growing around the edge of water. The substrate is made of sharp white sand; soap particles, wrappers and refuse were dumped around the edge of the station. Children do normally fetch drinking water in this station. Station 2 is about 290 metres downstream of Station 1 and located within a palm bush. A number of Kolanut (*Kola nitida*) plants grow around the edge of the station. The channel is narrower and the substrate is sharp brown sand and no human activities were observed during the period of the study. Station 3 is about 300 metres downstream of Station 2. The substrate is a combination of silt and sand and the edge of the water was cleared. Human activities are intense here because it is easily accessible. The farming community use the water for drinking, washing, bathing, and fermenting of cassava (Anyanwu and Ihediwah, 2015).

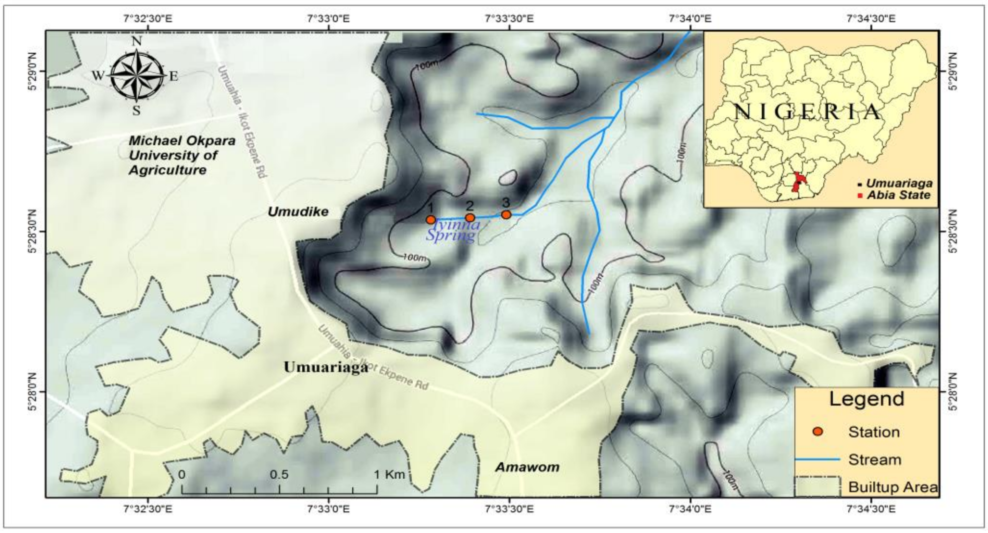

Fig. 1: Sampling Stations of Iyinna Spring, Umuariaga, Abia State, Southeast Nigeria.

Samples collection and analyses

Water samples were collected from Iyinna Spring monthly from January to June 2017. The samples were collected with a 1 litre water sampler, transferred into a clean 250ml plastic bottle and acidified with Nitric acid (HNO_3) according to Sharma and Tyagi (2013). The water samples were digested using concentrated Analar Nitric acid according to Zhang (2007). The UNICAM Solaar 969 atomic absorption spectrometer (AAS) which uses acetylene-air flame was used for the determination of Heavy Metals. All the results were statistically analysed using single factor ANOVA and Least Significant Difference (LSD) test was performed to determine the location of significant differences (Ogbeibu, 2014).

Human Health Risk Assessment

The human health risk assessment method used in this study was for Non-carcinogenic as described by Muhammed *et al* (2011). The Chronic Daily Intake (CDI) of heavy metals in Iyinna spring water was evaluated by the equation (USEPA, 2011):

$$CDI = \frac{C_W \ x \ IR \ x \ EF \ x \ ED}{B_W \ x \ AT}$$

Where, CDI is the daily dose of heavy metals (mg/l) to which consumers might be exposed. C_W (mg/l) is the concentration of heavy metals in the spring water, IR is the Ingestion rate, EF is the Exposure frequency, ED is the Exposure duration, BW is the Body weight, AT is the Averaging Time. The input parameters used in evaluating CDI values are presented in Table1.

Table 1: Input parameters to characterize CDI values

Factor/parameter	Symbol	Units	Adult	Children
Exposure Duration	ED	Years	30	6
Exposure frequency	EF	Days/year	350	350
Averaging time	AT(ED x 365)	Days	10950	2190
Body weight	BW	Kg	70.0	15.0
Ingestion rate	IR_W	L/day	2.0	1.0

Source: USEPA (2004, 2006).

Hazard Quotient (HQ)

The HQ for non-carcinogenic risk was calculated using the equation by USEPA (1999):

$$HQ = \frac{CDI}{RfD}$$

Where, CDI is the daily dose of heavy metals (mg/l) to which consumers might be exposed and RfD is the reference dose which is the daily dosage that enable individual to sustain this level of exposure over a long period of time without experiencing any harmful effects. The oral toxicity reference dose (RfD) values for the heavy metals are presented in Table 2:

Table 2: Oral reference dose (RfD) for heavy metals.

Metal	RFD (mg/kg/day)
Lead (Pb)	0.0035
Iron (Fe)	0.007
Cadmium (Cd)	0.0005
Chromium (Cr)	0.0003

Source: USEPA IRIS (2011).

If, HQ>1, it represents adverse non-carcinogenic effects of concern while HQ<1 represents acceptable level (no concern).

Hazard Index

Since more than one toxicant is present, the interactions are considered. The toxic risks due to potentially hazardous substances present in the same media are assumed to be additive. The HQs may then be summed to arrive at the overall toxic risk, the Hazard Index (Kolluru *et al*., 1996; Paustenbach, 2002; Zheng *et al.*, 2010).

$$HI = \sum_{i=1}^{n} (HQ)i$$

Where, HI is the hazard index for the overall toxic risk and n is the total number of metals under consideration.

If, HI<1.0, the non-carcinogenic adverse effect due to this exposure pathway or chemical is assumed to be negligible.

RESULTS

The Chronic Daily Intake (CDI)

The Chronic Daily Intake (CDI) of the assessed heavy metals of Iyinna spring is presented in Table 3. The CDI values of 0.0011 mg/kg/day and 0.0026 m/kg/day for adult and children respectively was recorded for Pb in Stations 1 and 2 while 0.00466 mg/kg/day and 0.0109 mg/kg/day were recorded for adult and children respectively in Station 3.

The CDI values of Fe for adult and Children in Station 1 was 0.073 mg/kg/day and 0.17 mg/kg/day respectively in station 1, station 2 (0.0075 mg/kg/day and 0.1752 mg/kg/day) respectively and station 3 (0.0745 mg/kg/day and 0.1740 mg/kg/day) respectively.

The CDI values of Cd for adult and children in station 1 was 0.011mg/kg/day and 0.0026 mg/kg/day respectively, station 2 (0.0008 mg/kg/day and 0.0019 mg/kg/day) respectively and station 3 (0.0038 mg/kg/day and 0.0090 mg/kg/day) respectively.

The CDI values of Cr adult and children in station 1 was 0.0082 mg/kg/day and 0.0019 mg/kg/day respectively, station 2 (0.0008 mg/kg/day and 0.0019 mg/kg/day) respectively and station 3 (0.0025 mg/kg/day and 0.0058 mg/kg/day) respectively.

Table 3: The Chronic Daily Intakes of the Heavy Metals.

Metal	Station 1		Station 2		Station 3	
	Adult	**Children**	**Adult**	**Children**	**Adult**	**Children**
Lead (Pb)	0.0011	0.0026	0.0011	0.0026	0.00466	0.0109
Iron (Fe)	0.073	0.17	0.0075	0.1752	0.0745	0.1740
Cadmium (Cd)	0.0011	0.0026	0.0008	0.0019	0.0038	0.0090
Chromium (Cr)	0.00082	0.0019	0.0008	0.0019	0.0025	0.0058

Hazard Quotient (HQ)

The Hazard Quotients (HQ) of the assessed heavy metals are presented in Table 4. The HQ of Pb for adult and children are 0.3 and 0.7 respectively in stations 1 and 2 and 0.1 and 3.1 in station 3. Only the HQ of Pb for children in station 3 was greater than 1.

The HQ of Fe for adult and children are 10.4 and 24.3 respectively in station 1, 1.1 and 25.0 in station 2 and 10.6 and 24.9 in station 3. These results were far greater than 1.

The HQ for CD for adult and children are 2.2 and 5.2 respectively in station 1, 1.7 and 3.8 in station 2 and 7.7 and 17.9 in station 3. These values are greater than 1.

The HQ for Cr for adult and children respectively in station 1 are 2.7 and 6.3 respectively, in station 2 it is 2.7 and 6.4 respectively, in station 3 it is 8.2 and 19.2 respectively. These values were greater than 1.

Hazard Index

The hazard indices (HI) recorded for adults and children in the 3 stations were far greater than threshold value (1). Hence, the non-carcinogenic adverse effect is not negligible.

Table 4: Hazard Quotients and Total Hazard Index of the Heavy Metals

Metal	Station 1		Station 2		Station 3	
	Adult	**Children**	**Adult**	**Children**	**Adult**	**Children**
Lead (Pb)	0.3	0.7	0.3	0.7	0.1	3.1
Iron (Fe)	10.4	24.3	1.1	25.0	10.6	24.9
Cadmium (Cd)	2.2	5.2	1.7	3.8	7.7	17.9
Chromium (Cr)	2.7	6.3	2.7	6.4	8.2	19.2
HI	15.5	36.6	6.0	36.1	26.7	65.1

DISCUSSION

The lead CDI values for adult and children were below oral reference dose (RfD) for lead (0.0035 mg/kg/day) in stations 1 and 2 but higher in station 3. Lead is of health concern in station 3 especially for children. Maigari *et al* (2016) equally recorded low lead CDI values while Ayantobo *et al* (2014) and Ekere *et al (*2014) recorded high lead CDI values. However, WHO (2017) reported that exposure to lead through water is generally low as the main source of lead in drinking water is old lead piping and lead-combing solders. The amount of lead that may dissolve in water depends on acidity (pH), temperature, water hardness and standing time of the water. High concentration of lead can affect the central nervous, renal, hematopoietic, cardiovascular, gastrointestinal, musculoskeletal, endocrine, reproductive, neurological, developmental and immunological systems (ATSDR, 2015).

The CDI values of iron for adult and children were all above oral reference dose (RfD) (0.007mg/kg/day). Ekere *et al* (2014) and Maigari *et al* (2016) equally recorded high iron CDI values. Thus, high iron CDI values recorded could be attributed to geogenic influence exacerbated by low pH because water solubility of some iron compounds are increased at lower pH (Lenntech, n.d.). In high concentration, iron may produce neurological effects (Zheng *et al*., 2003). Long-term iron toxicity may involve iron-mediated oxidative damage to the mitochondrial genome leading to progressive dysfunction (De Freitas and Meneghini, 2001).

CDI values of cadmium for adult and children were above oral reference dose (RfD) (0.0005mg/kg/day). Ayantobo *et al* (2014), Ekere *et al* (2014) and Maigari *et al* (2016) recorded similar higher cadmium CDI values. The high cadmium CDI values could be as a result of geogenic input in the spring water. Thus, cadmium pose health risk for those exposed to drinking water from the spring. At high concentrations, cadmium affects the liver, placenta, kidneys, lungs, brain, and bones. Experimental data in humans and animals showed that cadmium may cause cancer in humans (Jarup *et al.*, 2000; Nordberg *et al*., 2002).

CDI values of chromium for adult and children were above oral reference dose (RfD) (0.0003 mg/kg/day). Ayantobo *et al* (2014) and Ekere *et al* (2014) equally recorded high chromium CDI values. Chromium levels in Iyinna could be as a result of geogenic influence than anthropogenic considering minimal human activities in the area. Chromium pose health risk for those exposed to drinking water from the spring. High concentrations of chromium may cause liver and kidney toxicity and genotoxic carcinogen (Strachan, 2010).

The hazard quotient (HQ) values of the metals in all the stations were greater than 1. In stations 1,2and 3, Iron, Cadmium and Chromium exceeded unity for both adult and children while in station 3, Lead exceeded unity for children. In all the stations, HQ values were generally high for children thereby making more vulnerable especially for a rural setting like Umuariaga. Ekere et al (2014) equally recorded HQ > 1 for some of the metals considered in this study in the rivers studied while Maigari *et al* (2016) did not recorded any except for cobalt, which was not considered in this study. The high HQ values recorded in this study were as result of high CDI values of the metals involved. These metals pose long term health risk to the water users in all the stations concerned.

All the hazard index (HI) values recorded in this study were well above 1. It is in line with the findings of Ayantobo *et al* (2014), Ekere *et al* (2014) and Maigari *et al* (2016). The long-term health risk is high and the non-carcinogenic adverse effect is not negligible.

CONCLUSION

The heavy metals considered exceeded the standards set by Nigerian Standard for Drinking Water Quality and World Health Organisation. Health risk assessment for all the sites indicated that there is no particularly dangerous single heavy metal, but their cumulative effect, indicated by the hazard index (HI), calls for concern. Hazard Index (HI) for all the stations highly exceeded threshold value (1). This calls for concern for both adults and children exposed to the water through ingestion. The heavy metal contamination observed was of geogenic source and more difficult to manage.

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