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HEAVY METALS CONTENT AND HEALTH RISK ASSESSMENT OF IKPE IKOT NKON RIVER, AKWA IBOM STATE, NIGERIA

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Abstract*: Heavy metals in water pose detrimental consequence on health of the consumers and aquatic organisms. Metallic pollutants in drinking water leads to dysfunction of organs and systems in the body with other associated health risk conditions. Study on heavy metal content and health risk assessment of water from Ikpe Ikot Nkon River was carried out between October 2020 and September 2021 (twelve months), to evaluate the suitability of the river water for human consumption. Eight heavy metals were assessed in the water samples collected from three stations using atomic absorption spectrophotometer after digestion. The findings were compared with Nigerian Standard for Drinking Water Quality. The mean concentration of some metals (Mn, Cr, Ni, Cd, Fe and Pb) exceeded the permissible limits due to anthropogenic activities and seasonal influences. The non-carcinogenic health risk assessment indicated that the chronic daily intake (CDI) and hazard quotient (HQ) values for Cr and Fe exceeded oral toxicity reference dosage and threshold value of 1respectively. The hazard index (HI) was high in all the stations and above the threshold value (1). The results of some heavy metals (Mn,Cr,Ni,Cd,Fe and Pb), CDI and HQ values for Cr and Fe, and the HI values calls for concern regarding their effects on human health, which could be detrimental to the people drinking from this river. Based on the results, the water is not suitable for human consumption.*

Keywords*: Heavy metals, Health risk, Human activities, Pollution, River***.**

1. Introduction

The term heavy metal refers to any metallic element with high density and applies to the group of metals and metalloids with atomic density greater than $5g/cm^3$ [1, 2]. Heavy metals in aquatic ecosystems have detrimental consequences on health of the consumers of water resource and aquatic organisms. Human beings are exposed to heavy metals toxicity by consuming metallic contaminated animal and direct consumption of water containing metals in higher concentration [3]; which have been reported to be responsible forvarious biochemical disorders [4].Some heavy metals are essential elements for healthy growth and development, but could result in detrimental health effect when the concentration consumed exceeded the recommended levels especially in drinking water [5]. Study affirm that long exposure of metal like manganese have deleterious health effects on human being, ranging from kidney, liver and neurological disorder, hyperkeratosis and cardiovascular disease [6]. Cadmium is associated with renal dysfunction and obstructive lung diseases, bone defects, osteoporosis and myocardic dysfunctions [4], while acute

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exposure zinc lead to system dysfunctions which impaired growth in human. Pollution of water with heavy metals should not be overlooked concern since it has sequences of health and environmental consequences [7]. Many researchers reported the activities of human in industries, mining and agricultural sectors as the major contributors to heavy metal pollution in aquatic ecosystem [7, 8]. Other sources of heavy metals in water bodies include leaching from metal contaminated soil, weathering of rocks and human activities (urbanization) [9, 10]. The intensity in the use of metal-based fertilizer in agricultural revolution has resulted in continued rise in the concentration of metal pollutants in fresh water bodies through surface runoff; leading to scarcity of good water for domestic uses [11]. The case is not different from Ikpe Ikot Nkon River; it is subjected to agricultural activities on the banks and along with other anthropogenic activities that could add heavy metals into the water body. The water body served as the only source of water for irrigation and drinking for the nearby communities. Hence, this study seeks to evaluate the concentration of some heavy metals and associated health risk of Ikpe Ikot Nkon River vis-à-vis its suitability for human consumption.

2. Materials and methods

Study area and sampling stations

Ikpe Ikot Nton River is located in Ini local Government Area, northern part of Akwa Ibom State. Geographically, the river lies between the Latitude 5º 20’59.0’’N – 5º 22’42.4”N and Longitude 7º 36’ 55.7’’E – 7º 49’27.5”E (Figure 1).The region is characterized by tropical humid climate with distinct dry season (November - March) and wet season(April - October). The river is within low land area where runoffs from communities are high, and receives wastes from different anthropogenic sources.

The sampling stations were chosen along the stretch of the river using the level and nature of human activities as a criterion for selection. Station 1 (control station) was located upstream, close to Ikot Abia community; human activities in this station are minimal with only bathing and laundry and extraction of water for drinking purpose. Station 2 was located (at the head bridge), about 2km downstream of station 1. The water in this station is also extracted for domestic uses and drinking purpose by the nearby communities. The observed human activities were farming on the left and right banks of the river, sand mining, landing and sales, lumbering, bathing, laundry. Station 3 was located at (the head bridge of Nkana), about 2km downstream of station 2. The observed activities were bridge construction, agricultural activities, intense fishing activities, and laundering. The inhabitants of the area and other nearby villages always extract water from this station for domestic uses, including drinking.

Samples collection and analyses

Water samples for the heavy metals evaluation were collected between October 2020 and September 2021 with 500mL polyethylene bottles and acidified with Nitric acid (HNO_3) immediately after collection. The water samples were digested as described by [12, 13] using concentrated Nitric acid and heavy metals concentration in each water sample were determined with atomic absorption spectrophotometer (UNICAM 939/959 model). All data were summarized in Microsoft excel and subjected to statistically analysis using single factor ANOVA while Tukey Pairwise posthoc was used to compare the means between the stations with significant difference set at $P<0.05$.

Human Health Risk Assessment

Health risk assessment was carried out for non-carcinogenic using Chronic Daily Intake (CDI), Hazard Quotient (HQ) and Hazard Index (HI) as described by [14, 15].The chronic daily intake (CDI) of the heavy metals was calculated by the equation below:

$$\textbf{CDI} = \frac{Cw \times IR \times EF \times ED}{Bw \times AT} (1)$$

where, CDI is the daily doses intake of heavy metal (mg/kg/day) to which consumers could be exposed to, Cw is the concentration of heavy mental in the water sample (mg/L), IR is the ingestion rate (2L per day); EF is the exposure frequency (365 days / year), ED is the exposure duration (70 years); Bw is the body weight of the exposed person (70.0kg) and AT represent the averaging time in days (25,550 days).

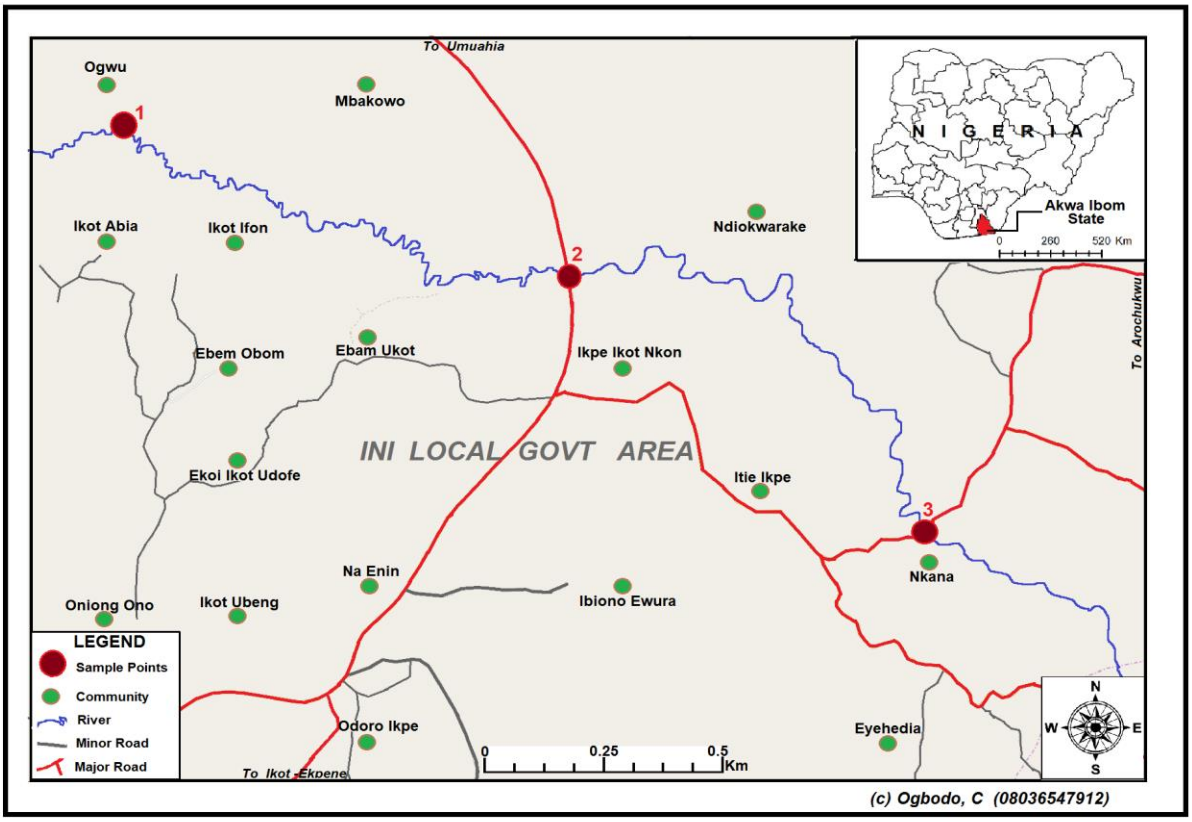

Fig. 1: Map of Ini Local Government Area showing the Location of Sampling Stations

Hazard Quotient (HQ): The Hazard Quotient for non-carcinogenic risk was calculated using equation [16]:

$$HQ = \frac{CDI}{RFD} (2)$$

Where, CDI is the daily dose intake of heavy metals (mg/kg/day) and RFD represent oral reference dose of the contaminant (mg/kg/day). 1f HQ value > 1, it indicates adverse non -carcinogenic effects, while value < 1 represents acceptable level.

Hazard Index (HI): The hazard index of the heavy metals was determined by using equation below:

$$\text{HI} = \sum_{i=1}^{n} (HQ)i (3)$$

Where, HI is the hazard index for the overall toxic risk and n is the total number of heavy metals considered. The non-carcinogenic adverse effect can be considered to be insignificant if HI <1. The hazard index is treated as the arithmetic sum of HQ values [14].

3. Results and discussion

Heavy metal concentrations: Heavy metals in aquatic ecosystems occurred naturally and through human induced activities in the environment [18]. Some metals are essential for animals and human physiological activities, but could be detrimental when the concentration is higher or lower than the concentrations required by human and the recommended standard limits in drinking water [19].The range and mean values of the heavy metals are presented in Table 1.

Table 1:
The mean, range values of Heavy Metal and Pollution Index recorded from Ikpe Ikot Nkon River (October 2020 and September 2021)

Heavy Metals (mg/L)	Station 1 X ±S.E.M	Station 2 X ±S.E.M	Station 3 X ±S.E.M	*P* value	SON (2015)
Manganese (Mn)	0.13 ±0.08[a] (0.08 - 0.31)	0.24±0.02[b] (0.13 - 0.48)	0.16±0.10[a] (0.04 - 0.34)	*P*<0.05	0.2
Chromium (Cr)	0.04±0.02[a] (0.01 – 0.14)	0.07±0.003[b] (0.01 - 0.16)	0.08±0.002[b] (0.02 – 0.12)	*P*<0.05	0.05
Nickel (Ni)	0.04±0.01 (0.005 – 0.06)	0.04±0.01 (0.005 –0.08)	0.05±0.01 (0.002 –0.11)	*P*>0.05	0.02
Cadmium (Cd)	0.01±0.00 (0.002 – 0.02)	0.01±0.00 (0.001 – 0.03)	0.01±0.00 (0.001– 0.04)	*P*>0.05	0.003
Copper (Cu)	0.03±0.08[a] (0.001 – 0.08)	0.09±0.03[b] (0.02 – 0.16)	0.02±0.03[a] (0.001 – 0.18)	*P*<0.05	1.0
Iron (Fe)	0.43±0.46[a] (0.36 – 1.00)	0.69±0.34[b] (0.33 – 1.67)	0.84±0.46[c] (0.28 – 1.14)	*P*<0.05	0.3
Lead (Pb)	0.01±0.13 (0.00 – 0.10)	0.02±0.01 (0.00 – 0.46)	0.03±0.23 (0.006 – 0.16)	*P*>0.05	0.01
Zinc (Zn)	0.45±0.05[a] (0.14-0.59)	1.17±0.03[b] 0.84 – 1.36	0.94±0.08[c] (0.28 – 1.01)	*P*<0.05	3.0

***X** = mean, **±S.E.M** = standard error of mean; means with different superscripts (a, b, c) in the same row indicate significantly difference at P <0.05.*

The mean values of copper (Cu) and zinc (Zn) were within the recommended limit set by SON [17], while the others exceeded the acceptable limits. This is consistent with the findings of studies by [18] in River Dilimi, Jos North, Plateau State, Nigeria and [19] in Ikwu River, Umuahia, Abia State, Nigeria.

The manganese (Mn) ranged between 0.04 and 0.48 mg/L, with the highest mean value (0.24 mg/L) recorded in station 2 and the lowest in station 1 (0.13mg/L). Station 2 was significantly (P < 0.05) higher than stations 1 and 3 and exceeded the standard limit of 0.2 mg/L set by SON [17]. The mean values of Mn in this study recorded exceeded the threshold (0.2 mg/L). The higher mean value recorded in station 2, suggests to intense anthropogenic activities ranging agricultural, sand mining, and laundering [19]. Manganese (Mn) is biological importance to living organisms including human during physiological process [23].

Chromium (Cr) values ranged from 0.01 - 0.16 mg/L, with the highest mean value (0.08 mg/L) recorded in station 3 and lowest (0.04 mg/L) in station 1. Analysis of variance indicated that station 1 was significantly (P < 0.05) lower than stations 2 and 3.The higher value of Cr observed in stations 2 and 3 suggests to influenced of anthropogenic activities and leaching from domestic wastes dumped near the stations. Chromium (Cr) is life-threatening if the ingested concentration is high. It is associated with anemia in human [20]. The mean values recorded are lower than the values reported by [10] and [21] and exceeded the values reported by [22] in Benin river. Statistical analysis showed significant differences in station 1 ($P < 0.05$).

The mean values of nickel (Ni) recorded were higher than 0.02 mg/L, the stipulated standard [17], with higher mean value in station 3(0.05 mg/L). Similar values were reported [23] from Obuburu River, Kogi state. The observed values could be attributed to the sand mining activities in the stations. Problems associated with Ni toxicity include loss of hair in human, lung fibrosis, cardiovascular and kidney diseases if the concentration is high in drinking water [24, 25].

Cadmium (Cd) ranged between 0.001 and 0.04 mg/L. The same mean values (0.01 mg/L) were recorded across the stations. The mean values exceeded the stipulated limit of 0.003 mg/L [17]. However, [26] regarded Cd as the most toxic metal in water even at low concentration. Its concentrations in the drinking water should not be overlooked, as it associated with enormous health risk problems. The values could be attributed to the combined effects of human activities such agricultural, and intense sand mining activities in the stations. Study [27] reported that the use of agrochemicals like pesticide, herbicide and fertilizer in agricultural activities near the water body is linked to the concentrations of Cd in aquatic ecosystem.

Copper (Cu) is an essential element for man, but pose adverse impact when the concentration is above the recommended limit of 1.0 [17]. Acute exposure to drinking water contaminated with Cu leads to alteration of brain function in human and kidney failure in young children. Copper (Cu) ranged from 0.001 to 0.18 mg/L, with the highest mean value (0.09 mg/L) recorded in station 2 and lowest (0.02 mg/L) in station 3. This is consistent with the findings of [23]in Obuburu River, Okene, Kogi State, Nigeria. The elevated value in station 2 could be linked to leaching from wastes dumped near the station and anthropogenic activities going on in the station. Statistical analysis showed significant differences ($P<0.05$).

Iron (Fe) ranged between 0.28 and 1.67 mg/L, with the highest mean value recorded in station 3 (0.84 mg/L) while lowest was recorded in station 1 (0.43 mg/l). The values recorded were the same with values reported by [28] in Ossa River. Most of the values exceeded 0.3 mg/L set by [17] in all the stations. High levels of Fe in water samples may be due to the discharge of iron laden wastes and scraps into the water [13], and the fact that Fe is more abundant in freshwater body than other metals, due to its high occurrence on Earth [29, 30]. According to [31], Fe in higher concentrations is associated with high risks of endocrine problems, cancer, heart diseases, arthritis, diabetes and liver disease. Statistical analysis showed significant differences ($P<0.05$).

Lead (Pb) is generally well-known to be a toxic element, having no biological importance to human being. According to [32] and [33], no concentration of Pb in drinking water is considered safe for human consumption. The concentrations of Pb exceeded 0.01 mg/L set by Standard Organization of Nigeria [17]. The higher value in station 3 (0.03 mg/L) suggest to combine effects of anthropogenic activities going on in this station. High exposure to Pb has been implicated in some learning disorders in children [34].

The levels of zinc recorded throughout the study were lower than acceptable limit (3.0 mg/L) for drinking water [17] and ranged between 0.14 and 1.36 mg/L. The highest mean value (1.17 mg/L) was recorded in station 2. Statistical analysis showed significant differences between the stations ($P<0.05$). Study [35] reported that ingestion of Zn contaminated water affect bone formation in children. With these, the concentration of Zn in the water body should not be ignoring due to it antagonistic effects on the toxicity of other metals [35].

Health risk assessment: Chronic Daily Intake (CDI): Thechronic daily intake (CDI) values recorded are presented in Table 2. The values for Cr and Fe exceeded the oral toxicity reference dosage (RfD), while values for Mn, Ni, Cd, Pb and Zn did not exceed oral toxicity reference dosage. Manganese (Mn) had CDI values ranging from 0.003 to 0.006 mg/kg/day, Ni CDI ranged from 0.001 to 0.002 mg/kg/day, and Cd was 0.0002 mg/kg /day across the stations while Pb was 0.0002 to 0.008 mg/kg /day and Zn ranged from 0.012 to 0.033 mg/kg /day. Mn, Ni, Cd, Pb and Zn did not pose any health risk effects to the people using the river water for drinking, while Cr and Fe posed significant health risk to those exposed to drinking water from the river. Chromium (Cr) according to [36] and [37] is considered carcinogenic and genotoxic at higher concentrations. While [38] reported that kidney diseases, liver and tissue dysfunctions in human are as a result of long exposure to chromium in high concentration. However, the CDI values of Fe corroborated with the values reported in related studies [15, 39]. Iron in high concentrations is associated with venomous effect, leading to health risk and issues such as cancer, endocrine dysfunction, heart and liver diseases [31]

Table 2:
Chronic daily intake (CDI) and oral toxicity reference doses (RfD) for heavy metals from Ikpe Ikot Nkon River (October 2020 - September 2021)

Heavy Metals (Mg/L)	***RfD (**mg/kg/day)	**Station 1**	**Station 2**	**Station 3**
Mn	0.14	0.003	0.006	0.004
Cr	0.0003	0.001	0.002	0.002
Ni	0.2	0.001	0.001	0.002
Cd	0.0005	0.0002	0.0002	0.0002
Fe	0.007	0.012	0.019	0.024
Pb	0.0035	0.0002	0.0005	0.0008
Zn	0.3	0.012	0.033	0.026

*__Source [14]__

Hazard Quotients (HQ): The values recorded in station 1 were ranged from 0.005 to 3.34. In station 2, the HQ values were between 0.005 and 6.67while station 3 was between 0.01 and 6.67(Table 3).Higher HQ values were recorded for Iron (Fe) and Chromium (Cr) in all the stations that are greater than the threshold value (1.0).The HQ values for Mn, Ni, Cd, Pb, and Zn across the stations were lower than the threshold value (< 1.0). The results revealed that Cr and Fe are the major metals that contributed to the potential non-carcinogenic risk associated with drinking water from the river. This is attributed to geogenic source influenced by anthropogenic activities and surface runoffs. Related studies reported high HQ values for Cr and Fe [28, 29, 40].

Table 3:
Hazard quotients (HQs) and Hazard Index (HI) values for heavy metals from Ikpe Ikot Nkon River (October 2020 -September 2021)

Heavy Metals	Station 1	Station 2	Station3
Mn	0.021	0.042	0.028
Cr	3.34	6.67	6.67
Ni	0.005	0.005	0.01
Cd	0.4	0.4	0.4
Fe	1.72	2.72	3.43
Pb	0.06	0.14	0.23
Zn	0.04	0.11	0.08
HI(ΣHQ)	**5.58**	**10.08**	**10.85**

Hazard Index (HI): The HI values recorded in all the stations exceeded the threshold value (1.0). Higher values were recorded in stations 2(10.08)and 3(11.85) compared to 5.58recordedin station 1(Table 3).The values could be attributed to the high metal, CDI and HQ values recorded in the stations linked to high human activities; indicating that there is potential adverse health risk to humans exposed to drinking water from the river. Similar findings were reported by [13] in Qua Iboe River Estuary and [19] for adults in Ikwu River, Umuahia Nigeria.

4. Conclusion

The study revealed that the river is polluted due to the concentration of heavy metals recorded. Metals such as Mn, Cr, Ni, Cd, Fe and Pb exceeded the permissible standards to anthropogenic activities. Water with high concentration of metals portends serious health challenge ranging from dysfunction of organs and systems in the body to other associated health risk conditions. The values of some heavy metals, CDI and HQ values for Cr and Fe, and the HI values calls for concern regarding its effects on human health, which could have adverse effects on the people drinking from the river. Based on the result of findings, the water is not suitable for human consumption.

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