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Environmental Monitoring and Human Health Implications of Potentially Toxic Elements in River Water, Akwa Ibom State, Nigeria

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ABSTRACT

The study was conducted at the upper coastal region of Qua Iboe River,Nigeria,between November 2018 and August 2019 (ten months), to access the concentrations of potentially toxic elements (PTEs) and human health risks associated with water from the river via ingestion. Eight PTEs were assessed from the four stations, using atomic absorption spectrophotometer. The findings were compared with Nigerian drinking water quality standards. The spatial mean concentrations of some PTEs (Mn, Cr, Ni, Cd, Fe and Pb) were exceeding the permissible limits due to anthropogenic activities and seasonal influences. The values for heavy metal pollution index (HPI) were exceeded the threshold (100), while comprehensive pollution index (CPI) indicating moderate to heavily pollution. The hazard quotient (HQ) values for Fe and Cr in children and adults, and hazard index (HI) values were exceeded the threshold value of 1. Daily chronic intake (CDI) values for Fe and Cr mostly were above the oral reference dose of contaminant (mg/kg/day). The findings showed that Fe and Cr were the dangerous PTEs contributed to higher HQs and HI values, indicated that the river is not suitable for domestic use via ingestion.

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INTRODUCTION

The potentially toxic elements (PTEs) commonly known as heavy metals in surface water are detrimental to the human lives exposed to the water body. The rural and urban communities make use of such water bodies for domestic purposes; water is serves as food for man and involved during the metabolic process in the body. The intensity of agricultural activities, industrialization, rapid urbanization, and exponential growth of the human population contribute to input of allochthonous toxic substances, including potentially toxic elements (PTEs) into the water body (Miapyen & Bozkurt, 2020; Jonah & Anyanwu, 2023). This problem remains an issue of major concern globally due to the toxicity of such elements to the environment and living organisms (Ferner, 2001). Moses & Etuk (2015) reported that the activities of oil industries are the major contributor of PTEs in aquatic ecosystems, while Okon *et al.* (2019) in a related study observed that a greater portion of PTEs in water bodies are linked with agricultural wastes, industrial discharge, municipal sewage, and domestic discharge. Monitoring the concentrations of these toxic elements in water bodies will help to remediate its effects on humans and aquatic organisms; even though some are essentially used as nutrients in small quantities, but harmful

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when the ingested concentrations exceeding the limits (Jonah & Anyanwu, 2023). Elements such as Cadmium (Cd), Mercury (Hg), Lead (Pb), Arsenic (As), and Chromium (Cr) are harmful with several adverse health problems even at very low concentrations (Rahman *et al*., 2012; Rovira & Domingo, 2019), while elements such as Zinc (Zn),Cobalt (Co), Iron (Fe), and Manganese (Mn) have been reported to have significant biological importance to humans (Ferner, 2001; European Union, 2002;Young, 2005). Pb, Cd, and Cr are considered to be the most toxic among the metals (ATSDR, 2019). Consumption of PTEs contaminated water can result in a number of health related issues like liver cirrhosis, neural disorder, renal failure, hemorrhage, nausea, skin irritation, ulceration, and dermatitis (Salem *et al*., 2000; Abah *et al*., 2013). Other health challenges associated with consumption of PTEs include kidney failure in children, attributed to the high content of Cu in drinking water; and hemochromatasis associated with high Fe content. The carcinogenic PTEs such as As, Cd and Cr may disrupt DNA synthesis and repair mechanisms (Clancy *et al*., 2012; Koedrith *et al*., 2013). Studies (Satarug *et al*., 2018; Balali-Mood *et al*., 2021) reported that Cd exposure is associated with bone, kidney, liver damage, gastrointestinal disorder and hypertension. Pb is a neurotoxic PTE that is associated with neurobehavioral effects, especially in children (WHO, 2007), while frequent exposure to Cr can also induce various diseases such as renal, neurological, dermal, gastrointestinal system disorders, and cancers (Fang *et al*., 2014). Therefore, assessment of PTEs in drinking water bodies is necessary to ascertain their suitability for human consumption as well as to provide an overall scenario about the content and source of these toxic elements, thereby opening an avenue for better planning for sustainable management of water bodies. Studies have employed heavy metal pollution index and human health risk assessment approach to evaluate potential adverse health risks associated with exposure to PTEs (Agneta *et al*., 2006; Muhammed *et al*., 2011; Liu *et al*., 2012; Ekere *et al*., 2014; Moses and Etuk, 2015; Balakrishnan & Ramu, 2016; Onyele & Anyanwu, 2018; Mgbenu & Egbueri, 2019; Egbueri, 2020; Karmakar *et al*., 2021). To the best of our knowledge, there are no data on PTEs content and health risk assessment from upper segment of Qua Iboe River. The Qua Iboe River is located in the Niger Delta region of Nigeria, exposed to large scale and incessant human activities that could contaminate the river water with PTEs. The study seeks to evaluate the concentration of some PTEs in the water and human health risks implications using pollution indices as well as potential non-carcinogenic health risk in the upper segment of Qua Iboe River, Akwa Ibom State, Nigeria.

MATERIALS AND METHODS

The research was carried out at the upper coastal region of Qua Iboe River, Akwa Ibom State, Nigeria; covering from Obot Akara to Essien Udim L. G. Area. The studied sections lies between Latitude 05^{o} 43 - 05^{o} 13'N and Longitude 07^{o} 34 – 07^{o} 40'E (Figure1). The river flows in South-Eastern direction towards the Atlantic Ocean Abia State. Four sampling stations were selected from the river, based on the observed human activities and closeness to human settlement. Station 1 (Ikot Amba) was located upstream, with negligible human activities and close to human settlements. The station receives wastes from municipal run-off and from human activities such as bathing, laundry and extraction of water for drinking purposes. Station 2 (Ikot Usurua) was located about 6km downstream of station 1. Human activities observed were sand mining, sand landing and laundering, bathing, and road construction at the upper section of the station. Wastes from residential areas, markets, and agricultural activities normally get into the river at this station via surface run-off. The river water in this station is extracted for domestic purpose by the nearby communities. Station 3 (Afaha Ikot Ebak) was about 4km downstream of station 2, while station 4 (Ekpenyong Attai) was about 3km downstream of

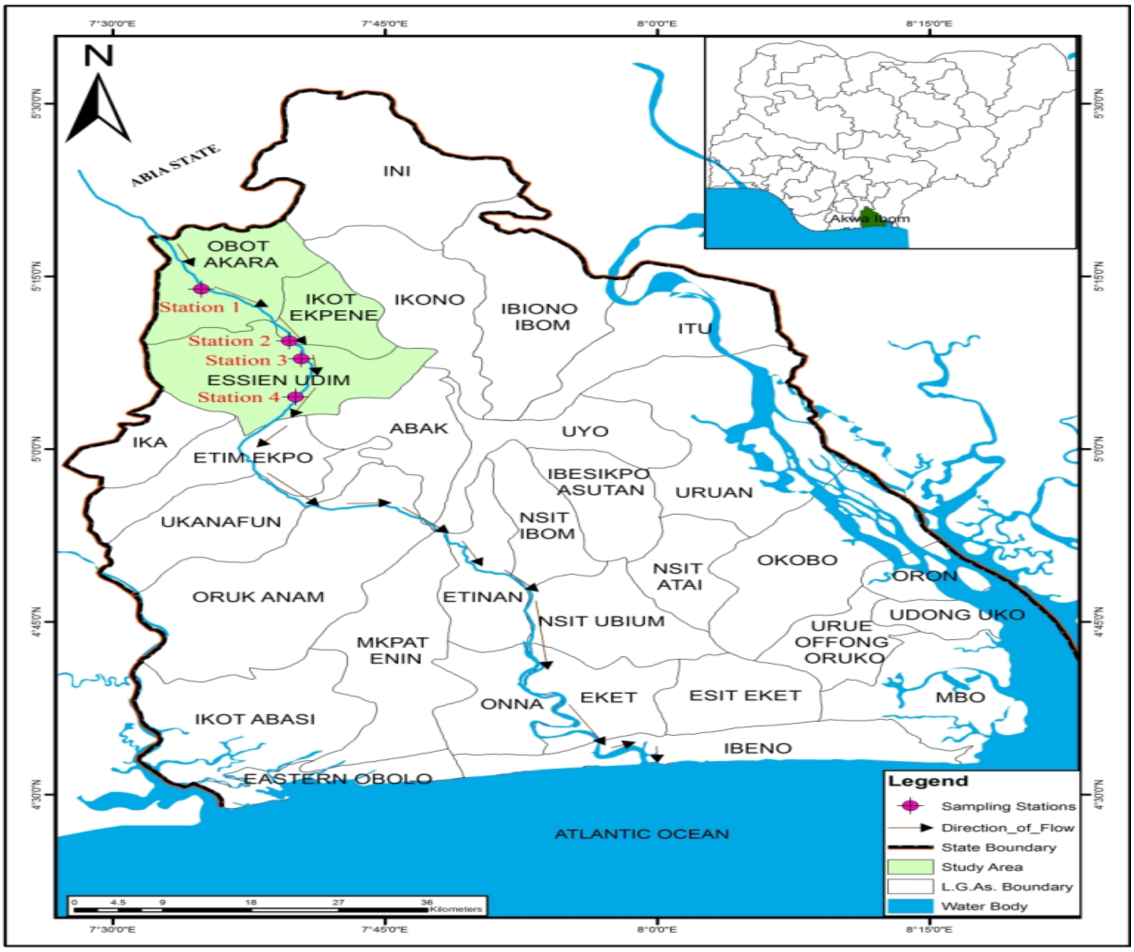

Fig. 1. Map of Akwa Ibom State showing Qua Iboe River with sampling stations

station 3. The observed human activities in stations 3 and 4 were intense farming on the left and right banks of the river, cattle rearing, sand dredging, bathing, laundering, water extraction for road construction, and domestic use by the nearby communities. The stations receive wastes from garbage dumped near the stations, municipal runoff, and abandoned battery factory after station 3 through surface run-off.

Surface water samples for analysis of PTEs were collected between November 2018 and August 2019. The samples were collected with 500 mL polyethylene bottles once monthly and acidified with Nitric acid (HNO_3) immediately. The digestion was made using concentrated Nitric acid as described by Akan *et al*. (2009) and Moses & Etuk (2015). After appropriate digestion, eight PTEs (Mn, Cr, Ni, Cd, Cu, Fe, Pb and Zn) were investigated using an atomic absorption spectrophotometer (UNICAM 939/959 model). For accurate analysis, blanks and sample duplicates were included in the PTEs analytical process. 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 $P <0.05$. The analyzed PTEs were subjected to human health risks assessment, to evaluate the impacts of PTEs contaminants in the water body using pollution indices (heavy metal pollution index and comprehensive pollution index). The index is based on weighted arithmetic mean method as described by Prasad & Bose (2001) using the formula developed by Mohan *et al.* (1996). The index indicates the overall quality of water in respect to PTEs contaminants (Horton, 1965; Mohan *et al*., 1996). To compute HPI, unit weightage (Wi) is considered as a value inversely proportional to the recommend standard (Si) for the investigated PTEs (Prasad & Bose, 2001). The HPI was determined using the formula below:

$$\text{HPI} = \sum \frac{Qi\,x\,Wi}{\sum Wi} \tag{1}$$

Where Qi is the sub-index of *i*-th heavy metals and Wi is the unit weightage of the *i*-th parameters. The Qi is calculated with the equation below:

$$\text{Qi} = 100 \text{ x } \frac{Ci}{Si} \tag{2}$$

Where Ci is the measured value of *i*-th parameter and Si is the standard limit of *i*-th parameter set by SON (2015). The acceptable value for HPI is 100 for drinking water (Prasad & Bose, 2001); hence any value above 100 is not healthy for human consumption. All the parameters exceptions of Mn were considered in computing HPI and the weightage (Wi) was taken as the inverse of Nigerian Drinking Water Quality Standard (SON, 2015).The comprehensive pollution index (CP1) provides vital information about water quality for effective management. Seven parameters (Cr, Ni, Cd, Cu, Fe, Pb, and Zn) were used to calculate the CP1 using the formula below:

$$\text{CP1} = \frac{1}{n} \sum_{i=0}^{n} \text{P1i}; \tag{3}$$

Where n is the number of considered heavy metals and P1*i* is the pollution index number *i*. The P1*i* is calculated using the equation below:

$$\text{P1i} = \frac{Ci}{Si}\ ; \tag{4}$$

Where Ci is the concentration of each PTE and Si is the acceptable limit of each PTE recommended by Nigerian Drinking Water Quality Standard (SON, 2015). The calculated value per station was compared with the water quality rating of CPI, where a value > 0.21 is clean water, between 0.21 and 0.40 regarded as sub-clean water, values from 0.41 to 1.00 refers to slightly polluted water, and between 1.01 and 2.00 regarded as moderately polluted water, while values >2.01 is an indication of heavily polluted water (Imneisi & Aydin, 2018; Matta *et al*., 2018).

Human health risk assessment was carried out for non-carcinogenic using chronic daily intake (CDI), hazard quotient (HQ), and hazard index (HI) as described by USEPA (2011), Muhammad *et al*. (2011), Caylak (2012) and Naveedullah *et al*. (2014). The CDI of PTEs of the river water was calculated by the equation below.

$$\text{CDI} = \frac{Cw \times IR \times EF \times ED}{Bw \times AT}; \tag{5}$$

Where CDI is the daily doses intake of PTEs (mg/kg/day) to which consumers could be exposed, Cw is the concentration of PTEs in the water sample (mg/L), IR represents the ingestion rate (2L for adults and 1L for children per day), EF is the exposure frequency (365 days/ year for both adult and the children), ED is the exposure duration (30 years for adult and 6 years for children), Bw is the body weight of the exposed person (70.0kg for adult and 15.0kg for children), and AT represent the averaging time in days (10,950 AT for adult and 2,190 AT for children). The hazard quotient (HQ) for non-carcinogenic risk was calculated using equation below:

$$HQ=\frac{CDI}{RFD} \tag{6}$$

Where CDI is the daily dose intake of PTEs (mg/kg/day) to which consumers could be exposed to and RFD is the oral toxicity reference dose of the contaminant (mg/kg/day). 1f HQ value > 1, it indicates adverse non-carcinogenic effects, and value < 1 is the acceptable limit (Han *et al*., 1998; USEPA, 1999). The hazard index of the PTEs was determined by using equation below:

$$HI= \sum_{i-1}^{n}(HQ)i \; ; \tag{7}$$

Where HI is the hazard index for the overall toxic risk and *n* is the total number of PTEs considered. The HI is the arithmetic sum of HQ value (USEPA, 2011). The non-carcinogenic adverse effect can be considered to be insignificant if HI < 1 (Ayantobo *et al*., 2014).

RESULTS AND DISCUSSION

The summary of PTEs is presented in Table 1. The concentration of PTEs varied between the stations; the mean values of copper (Cu) and zinc (Zn) were within the recommended range set by SON (2015) while the other metals exceeded the standard limits for drinking water.

On the other hand, the mean values of all the parameters except chromium (Cr) in stations 1, 3 and 4 exceeded the recommended values set by FMEnv (2011) for aquatic life. The values of manganese (Mn) ranged between 0.01 and 0.68 mg/L, with the highest mean value (0.34 mg/L) recorded in station 3 while the lowest (0.19 mg/L) was in station 1. The Mn is significant to living organisms and humans during physiological processes and could become toxic when the concentrations exceed the recommended limit. The levels of Mn recorded could be attributed to geological and anthropogenic influences (Anyanwu and Nwachukwu (2020). These could pose detrimental effects to aquatic life and human being drinking from this water body (Begum *et al*., 2009). Neurotoxicity has been associated with Mn in adults over 50 years (Bouabid *et al*., 2016; Jonah & Mendie, 2022). The chromium (Cr) values recorded ranged between 0.01 and 0.19 mg/L, with the highest mean value (0.07 mg/L) recorded in station 2 (0.07 mg/L) while the lowest (0.03 mg/L) was recorded in station 4. The values were within the range reported by Ahmad & Goni (2010) in water samples collected near an industrial area, Dhaka, Bangladesh, and exceeded the values reported by Ayobahan *et al*. (2014) in Benin River, Nigeria. The value in station 2 (0.07 mg/L) exceeded the standard limits (0.05mg/L) for drinking and aquatic life water quality and suggests anthropogenic influences (Okonkwo & Mothiba, 2005; Jonah

Table 1. Spatial mean, range of PTEs and pollution index values recorded in the upper segment of Qua Iboe River during the study period

PTEs (mg/L)	STATION 1 X ±S.E.M	STATION 2 X ±S.E.M	STATION 3 X ±S.E.M	STATION 4 X ±S.E.M	*P* value	SON (2015)	FMEnv (2011)
Mn	0.19±0.03[c] (0.01 - 0.30)	0.22±0.04[a] (0.01 - 0.62)	0.34±0.02[b] (0.02 - 0.67)	0.20 ±0.03[a] (0.02 - 0.32)	*P*<0.05	0.2	0.05
Cr	0.05±0.02[c] (0.1 – 0.13)	0.07±0.02[b] (0.01 - 0.19)	0.05±0.01[c] (0.01 – 0.17)	0.03±0.01[a] (0.01 – 0.10)	*P*<0.05	0.05	0.05
Ni	0.03±0.01[a] (0.1 – 0.6)	0.02±0.00[b] (0.01 – 0.08)	0.04±0.02[c] (0.02 – 1.00)	0.03±0.02[a] (0.02 – 0.14)	*P*<0.05	0.02	0.01
Cd	0.01±0.00[a] (0.00 – 0.06)	0.02±0.01[a] (0.01 – 0.09)	0.03±0.01[a] (0.03 – 0.08)	0.01±0.01[a] (0.00 – 0.03)	*P*>0.05	0.003	0.005
Cu	0.27±0.37[a] (0.08 – 0.58)	0.46±0.15[b] (0.18 – 0.46)	0.29±0.35[a] (0.14 – 0.39)	0.22±0.21[a] (0.11 – 0.84)	*P*<0.05	1.0	0.001
Fe	1.25±0.02[c] (0.19 – 1.63)	1.50±0.03[b] (0.78 – 1.96)	1.44±0.09[a] (0.64 – 2.00)	1.37±0.06[a] (0.89 – 3.92)	*P*<0.05	0.3	0.05
Pb	0.03±0.00[a] (0.21 – 0.54)	0.05±0.01[b] (0.31 – 0.74)	0.08±0.00[a] (0.32 – 1.15)	0.07±0.00[a] (0.12 – 0.54)	*P*<0.05	0.01	0.01
Zn	0.24±0.28[a] (0.01- 0.53)	0.32±0.33[b] 0.02 – 0.84	0.41±0.15[c] (0.09 – 0.37)	0.26±0.29[a] (0.08-0.43)	*P*<0.05	3.0	0.01
HPI	**297.26**	**550.22**	**693.58**	**373.97**			
CPI	**1.78**	**2.59**	**3.49**	**2.28**			

X = mean**, ±SEM** = standard error of the mean; means with different superscripts in the same row are significantly difference at P < 0.05.

& Mendie, 2022). Nickel (Ni) ranged from 0.1 to 0.14 mg/L; the highest mean value (0.04 mg/L) was recorded in station 3. The observed value in station 3 is attributed to intense sand mining in the station (Emurotu & Habib, 2019). Salem *et al*., 2000; Salnikow & Denkhaus (2002) in a similar study, reported loss of hair, lung fibrosis, cardiovascular and kidney diseases in humans associated with high ingestion of Ni contaminated water. The highest mean value (0.03 mg/L) of cadmium (Cd) was recorded in station 3 while the lowest (0.01mg/L) was in stations 1 and 4. Both exceeded the acceptable limit of 0.003 mg/L for drinking water and 0.005 mg/L for aquatic life. Chen *et al*. (2015) regarded Cd as the most toxic heavy metal in water even at low concentrations; their presence in drinking water results in deleterious effects in humans. Durmishi *et al*. (2016) reported hypertension, kidney damage and potential prostate cancer in human due to high content of Cd in drinking water. The recorded values in this study could be attributed to geogenic influence exacerbated by extensive agricultural activities in the watershed (Jonah and Mendie, 2022) sand dredging (Anyanwu *et al*., 2020). Ileperuma (2000) in a related study, affirm that the consistent use of pesticides, herbicide and fertilizer near water bodies has been identified as the major source of Cd in aquatic ecosystem. Copper (Cu) is an essential element for man, but poses an adverse impact when the concentration is above the acceptable limit of 1.0 mg/L (SON, 2015). Acute exposure to drinking water with high Cu concentrations affects growth and reproduction as well as alteration of brain function in humans, while kidney failure is reported in young children. The values for Cu recorded ranged from 0.08 to 0.84mg/L; the highest mean value of 0.46 mg/L was recorded in station 2, while the lowest of 0.22 mg/L was recorded in station 4. These values were within the acceptable limit (1.0 mg/L) set by SON (2015) for drinking purpose, and 0.001mg/L by FMEnv (2011) for aquatic life sustainability. The elevated value recorded in station 2, is possibly connected to leaching from discarded wastes and other waste from human settlement into the water through surface runoffs. Iron (Fe) values ranged between 0.19 and 3.92 mg/L, with the highest mean value (1.50 mg/L) in station 2 while the lowest (1.15mg/L) was in station 1. The concentrations of Fe were higher than other PTEs, ascribed to higher concentrations of Fe on earth (Asaolu & Olaofe, 2004; Anyanwu and Nwachukwu, 2020; Jonah *et al*., 2023). On other hand, the elevated values suggest negative impacts of precipitation accompanied by surface runoffs, which was responsible for transferring Fe from the contaminated soil into the water body. The mean values of Fe exceeded the limit of 0.3 mg/L for drinking water and 0.05 mg/L for aquatic life set by SON (2015) and FMEnv (2011) respectively. Zhang *et al*. (2003) pointed that acute exposure to Fe comes with neurological dysfunction and other health risk problems. Lead (Pb) is both toxic and non-essential metal, having no nutritional value to living organisms, including humans. High ingestion of Pb associated with the disorder of body systems (nervous and reproductive systems), and inhibition of the synthesis of hemoglobin (Ogwuegbu & Muhanga, 2005). Stations 3 and 4 had the highest mean values (0.08 mg/L) and (0.07 mg/L) respectively. All values exceeded recommended limit of 0.01 mg/L set by SON (2015) for drinking purpose, and FMEnv (2011) for aquatic life. The elevated value recorded in stations 3 and 4 suggested that Pb emanated from human activities, coupled with surface runoffs from contaminated soil. Station 3 is close to the abandoned battery industry (Obasi & Madukwe, 2020). Zinc (Zn) had the highest mean value in station 3, while the lowest (0.24 mg/L) was recorded in station 1. The concentrations of zinc were within the standard limit (3.0 mg/L) for drinking purpose (SON, 2015), while exceeding 0.01 mg/L set by FMEnv (2011) for aquatic life. Zn is of biological importance; having many physiological functions in humans (Nriagu, 2007). Adverse scenario in humans occurs when Zn is deficient or excess in concentration. Bytyçi *et al*. (2018) in a related study reported that consumption of zinc in higher concentrations affects bone development and normal function of reproductive organs in man.

The values of heavy metal pollution index (HPI) and comprehensive pollution index (CP1) are shown in Table 1. The HPI values ranged from 297.26 to 693.58, while CPI values ranged between 1.78 and 3.49. Higher values of both indices were recorded in station 3 while the lowest was in station 1. The HPI values exceeded the threshold and critical index value (100), indicating moderate to severe metallic contamination. The CPI value in stations 2, 3 and 4 reflects severe pollution, while a moderate level was recorded in station 1. The observed variation of HPI and CPI values between the stations attributed to differences in level of human activities ranging from intense sand mining, domestic waste discharge and agricultural activities and level of exposure to other sources of metallic pollutants like the abandoned battery factory. The higher values in both indices recorded in station 3 may suggest to that intense sand mining, agricultural activities, domestic discharge, lower inland water flow, transported pollutants from the contaminated soil from the abandoned battery factory into the water. Anyanwu & Umeham (2020) in Eme River, Umuahia, Abia State and Jonah *et al*. (2023) in waters from north-west zone of Akwa Ibom State, Nigeria, reported higher HPI values, attributed it to intense anthropogenic activities and surface runoff.

The values of chronic daily intake (CDI) for adults and the children are presented in Table 2. The values for Mn, Ni, and Pb were lower than their respective oral reference dosage (RFD)

Table 2. The spatial chronic daily intake (CDI) and oral reference dose (RFD) recorded in the upper segment of Qua Iboe River

PTEs	Station 1		Station 2		Station 3		Station 4		RFD*
	AD	CH	AD	CH	AD	CH	AD	CH	
Mn	0.005	0.013	0.006	0.015	0.009	0.022	0.006	0.013	0.14
Cr	0.002	0.003	0.002	0.005	0.002	0.003	0.0008	0.002	0.0003
Ni	0.0008	0.002	0.0006	0.002	0.001	0.003	0.0008	0.002	0.2
Cd	0.0003	0.0006	0.0006	0.002	0.0008	0.002	0.0003	0.0006	0.0005
Fe	0.036	0.083	0.042	0.10	0.041	0.096	0.039	0.092	0.007
Pb	0.0008	0.002	0.002	0.003	0.002	0.003	0.002	0.005	0.0035

*USEPA IRIS (2011); AD = Adults; CH = Children (mg/kg/day), which is considered of no potential risk to those drinking from this water. The CDI values for Cr and Fe were above their respective RFD values (mg/kg/day); having potential health risks to both children and adults drinking from this river.

The Mn CDI values for adults ranged between 0.005 and 0.009 mg/kg/day; the highest value was recorded in station 3, and for the children, the values ranged from 0.013 to 0.022 mg/kg/day, with the highest value also recorded in station 3. The values were less than the RFD value of 0.14 mg/kg/day. The Cr CDI values for children ranged between 0.002 and 0.005 mg/kg/day, while the adults were from 0.002 to 0.0008 mg/kg/day. The highest value for children was recorded in station 2, while the lowest was recorded in station 4. These values were greater than the RFD value of 0.0003 mg/kg/day; which could lead to disorder of gastrointestinal system and cancers disease (Fang *et al*., 2014).The Ni CDI values for adults ranged from 0.0006 to 0.001 mg/kg/day, with the highest value in station 3 and the lowest was in station 2, while for children, the values ranged between 0.002 and 0.003 mg/kg/day with the highest value recorded in station 3. These values recorded were less than the RFD value (0.2 mg/kg/day). The Cd CDI values for children ranged between 0.0006 and 0.002 mg/kg/day, while for the adults, values ranged from 0.0003 to 0.0006 mg/kg/day. The highest values for children were recorded in stations 2 and 3, while the lowest were recorded in stations 1 and 4 respectively. Fe CDI values ranged for adult from 0.036 to 0.042 mg/kg/day; with the highest value recorded in station 2, while values for children ranged between 0.083 and 0.1 mg/kg/day. All the values exceeded the oral reference dose of 0.007 mg/kg/day. The Pb CDI for adult ranged from 0.0008 to 0.002 mg/kg/day, the highest values were in stations 2, 3 and 4, while values for children ranged from 0.002 to 0.005 mg/kg/day, with the highest in station 4. The values for Pb did not exceed the RFD value (0.0035mg/kg/day). The Cd CDI value for adult in stations 2, 3 and station 4 for children pose potential adverse effects. The high Cr CDI values recorded could be as a result of combine effects anthropogenic activities, domestic waste discharge and surface runoffs from urban area during the study, while the higher CDI values for Fe could be as a result of Fe contents of the river owing to high occurrence of Fe in Nigerian soil (Ekere *et al*., 2014), which find their way into the water through surface runoffs. The findings corroborate with the reports of Ekere *et al*. (2014), Maigari *et al*. (2016), Onyele & Anyanwu (2018), Anyanwu & Nwachukwu (2020) and Anyanwu *et al*. (2022) in related studies, recorded higher CDI values of Cr and Fe. Higher Cd CDI value recorded in stations 2 and 3 for adults and 1 and 4 for children could be suggest to extensive agricultural activities at banks of the river. Ileperuma (2000) reported that the consistence use of pesticides, herbicide and fertilizer near the water body have a detrimental effects the water body and the consumers of such water.

The hazard quotient (HQ) and hazard index (HI) values are shown in Table 3. The Mn HQ values for adults ranged from 0.036 to 0.064, while 0.09 to 0.16 was for the children. Cr values for adults ranged from 2.67 to 6.67; while for the children, 6.67 to 16.6. Ni values for adults were between 0.003 and 0.005, while 0.01 and 0.015 was for the children. Cd value for adults was between 0.6 and 1.6, while 1.2 and 4 was for the children. Fe values for the adults ranged from 5.14 to 6.0, while the children were between 11.8 and 14.3. The Pb values for adults recorded were from 0.23 to 0.571; while between 0.57 and 1.43 was for the children.

The HQ value for adults recorded in Cr and Fe for both adult and children across the stations; Cd values for adults in stations 2 and 3 and for children except in station 1 exceeded the acceptable limit (1), and poses adverse health risk as the values exceeded the threshold of 1. The values for Cd and Cr corroborate with the findings of Anyanwu *et al*. (2022) in Ikwu River in Abia state, Nigeria. The HQ values recorded was higher in children than the adult which is consistent with the report of Fallahzadeh *et al*. (2017), indicating that children are more susceptible. According to Basu *et al*. (2011) and Xiao *et al*. (2020), oral ingestion is the major

Table 3. Hazard quotients (HQ) and Hazard Index (HI) for adults and children recorded in the upper segment of Qua Iboe River

PTEs	Station 1		Station 2		Station 3		Station 4	
	AD	CH	AD	CH	AD	CH	AD	CH
Mn	0.036	0.09	0.043	0.10	0.064	0.16	0.043	0.09
Cr	6.666	10.0	6.666	16.6	6.666	10.0	2.666	6.67
Ni	0.004	0.01	0.003	0.01	0.005	0.02	0.004	0.01
Cd	0.600	1.2	1.200	4	1.600	4	0.600	1.2
Fe	5.14	11.8	6.000	14.3	5.857	13.7	5.570	13.2
Pb	0.23	0.57	0.571	0.86	0.571	0.86	0.57	1.43
HI(ΣHQ)	12.676	23.67	14.483	35.87	14.763	28.74	9.453	22.6

pathway of non-carcinogenic exposure to pollutants than dermal contact. The hazard index (HI) values recorded in all the stations exceeded 1, with the highest values in children. These are attributed to the higher values of Cr, Cd, Fe and Pb resulting from diverse and multiple discharge routes of pollutants into the water body.

CONCLUSION

The study revealed that river is polluted based on the concentrations of PTEs recorded. Some PTEs values (Mn, Cr, Ni, Cd, Fe, and Pb) exceeded the permissible standards limit for drinking water, and for the aquatic life due to anthropogenic activities and surface runoffs. The values for HPI, CPI, CDI, and HQ (Cr, Cd, Pb and Fe), and HI values further affirmed that the water is not suitable for human consumption. These need urgent attention and it should be of concern to the government and other related water pollution and environmental agencies in Nigeria, that further delay, could have more adverse effects on the humans exposed to the river water through ingestion.

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LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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