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Toxicity profile of metals in water, sediments and *Liza grandisquamis* from Iko River, South-South of Nigeria

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Abstract

Water pollution and the risks associated with the prolonged exposure to contaminated water source by human is becoming a serious problem globally. The concentrations, cancer and non-cancer risks of Cd, Cr, Ni, and Pb via exposure to water, fish, and sediments from Iko River were examined. Results obtained showed that, the mean concentrations of these metals in fish and sediments were within their recommended limits however; the levels in water were higher than their limits. Principal component analysis (PCA) indentified anthropogenic factor as the major source of all the toxic metals in the environmental media assessed. The estimated daily intake (EDI) rate of the metals revealed that, Cd in water and sediments for both the adult and children populations were higher than their recommended daily oral reference doses (Rfds). The EDI for Cr in all the samples and ages were within the Rfd. While the EDI of Ni in water and fish for both populations were within the Rfd limit, but it was higher in sediments for both populations. The EDI of Pb for all the samples and ages were higher than the Rfd. The hazard indices of these metals were higher than one in water and sediments but less than one in fish for both populations. However, the children class was more susceptible to the non-carcinogenic risks. The results obtained also showed that, Cd and Pb were the major contributors to the reported non-carcinogenic risks. The total cancer risks (TCR) of the metals in all the samples and ages were higher than the recommended limit and the risks were higher in the children than the adult's class.

Keywords: Iko River; Water pollution; Toxic metals; Cancer and non-cancer risks; Fish; Nigeria

1. Introduction

Aquatic environment receives wastes from different sources hence; most water bodies are perpetually polluted especially in the area under investigation where there are intensive oil exploration and processing activities [1-4]. Reports have shown that, human activities on earth are the principal source of environmental pollution and are a continuous process hence; it makes the control process very difficult especially in the aquatic ecosystem [5-7]. The natural source can also contaminate the aquatic environment with metals however; the level may be minimal [8]. Recent studies revealed elevated levels of toxic metals in the aquatic environment [9, 10]. Toxic metals are very harmful due to their bioaccumulation, persistence, and toxicity attributes (BPT). These metals include arsenic, cadmium, chromium, nickel lead, and mercury [11, 12]. These metal toxicants are capable of causing both the carcinogenic and non-carcinogenic human health problems [13-15].

Sediments in aquatic ecosystem act as the sink as well as sources of toxic metals in the aquatic ecosystem [16-18]. The studied fish (*Liza grandisquamis*) is mainly benthic that feeds on the debris within the aquatic ecosystem [11, 19].

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Benthic and semi-pelagic fishes have the tendency of accumulating very high levels of toxic metals into their tissues [20, 21]. Consequently, as a good source of protein, these toxic metals may be transferred into the consumers over time [22, 23].

Studies have shown that, for a comprehensive study on the health implications of toxic metals in a water body, the water, edible aquatic organisms, and sediments should be examined

[24, 25]. The evaluation of human health risks associated with exposure to toxic metals via aquatic ecosystem should also consider both the carcinogenic and non-carcinogenic risks [26, 27]. The principal component analysis (PCA) which confirms the source of contaminants/pollutants in an environment should also be incorporated into environmental studies (Huang *et al*., 2020). Notwithstanding, studies had been conducted in Iko River Channel, but these researches never considered all these parameters in a single study [28-32].A few of the previous studies in Iko River assessed the water, sediments and fish however; they were devoid of *Liza grandisquamis* and PCA model [33, 34].

Prolonged human exposure to toxic metals through contaminated water channel, sediments or seafoods may result in adverse health problems [35-37]. Hence, this work has evaluated the pollution status of Iko River Channel in relation to the toxic metals loads in water, fish, and sediments. The outcome of the study will ascertain the suitability or otherwise of these aquatic media. The principal component analysis will also establish the actual source(s) of these toxic metals in samples from the studied river. A comprehensive human health risks both the carcinogenic and non-carcinogenic associated with exposure to toxic metals in the studied samples will be highlighted. Finally, the negative influences of the post-oil activities in Iko River Channel will be identified and documented.

2. Materials and methods

2.1. Study Area

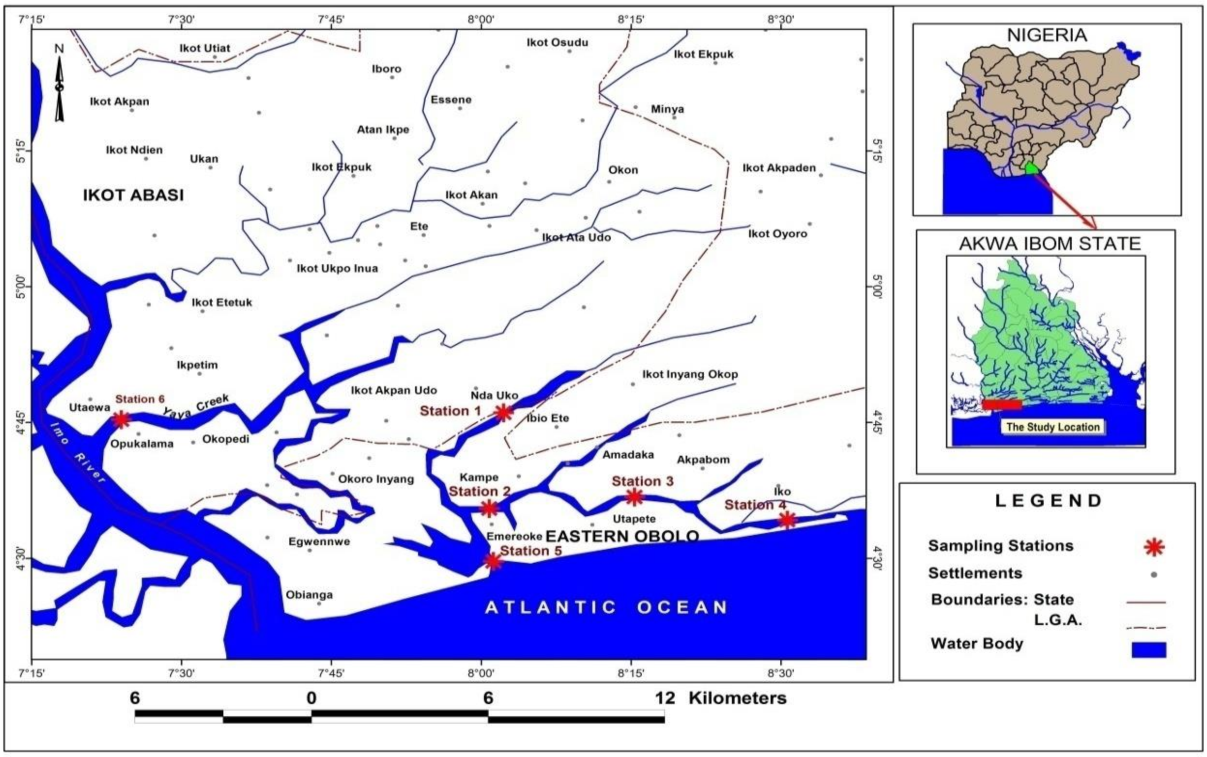

Figure 1 Map of the studied Iko River Channel

Iko River is in the Niger Delta Area of Nigeria, and originates from Qua Iboe River. The river has a link with Atlantic Ocean through Qua Iboe River Estuary. The River navigates through freshwater and mangrove swamps and is used for fishing by the local fishermen. Iko River has been highly contaminated by the industrial activities of Oil Companies, agricultural activities, and domestic wastes. Iko River stretches from latitude 4°30' to longitude 8°30' (Figure 1). The common plant species found along the river are Nypa palm (*Nypa fruticans*), oil palm (*Elaeis guineensis*), coconut Palm (*Cocos nucifera L.*), red mangrove (*Rhizophora racemosa*), and white mangrove (*Avicermia germinae*). As shown in Table 1, metals are constantly leached into the aquatic environment at stations 3, 4 and 5 from the abandoned Oil facilities. The intensive fishing activities in the river is also another source of metal contaminants into the water body as fuel is used for powering engine boats and the boats with metallic parts are used. The different sampling points, coordinates, and their pictorial views along the studied River are shown in Table 1.

Table 1 Location, Coordinates, and Pictorial views of the studied Locations

Location	**Coordinate**	**Pictorial View**
Station 1 NdaUko	Latitude 4°45’02.8’’N and longitude 8° 05’01.1’’E	
Station 2 Kampe	Latitude 4°36’38.03”N and longitude 8°01’03.1”E	
Station 3 Utapete Flow Station	Latitude 4°36’22.01” N and longitude 8°15’02.1”E	
Station 4 Iko	Latitude 4°34’05.22’’ and longitude 8°30’01.5”	
Station 5 Emereoke	Latitude 4°30’01.33” and longitude 8°06’05.1”	

Station 6 Jaja Creek	Latitude 4°50'01.5" N and longitude 7°16'30.4" E	

2.2. Sample Collection and Treatment

The collection of water, fish (*Liza grandisquamis*), and sediment samples were carried out between July 2017 and June 2018. This sampling period covered the two distinct seasons (dry and wet) of the area investigated.

Water samples were obtained at NdaUko, Kampe, Utapete Flow Station, Iko, Emereoke and Jaja Creek along Iko River Channel using polyethylene bottles. To each sample container, 1 mL of concentrated HNO_3 was added to fix the toxic metals. These samples were transported to the laboratory in an icebox and stored at a temperature of 4 °C before metal analysis. These techniques were done following the methods of Emmanuel *et al*. [27], Oladeji, [38], and Tombere *et al*. [39].

Grey mullets (*Liza grandisquamis)* fish from Iko River were purchased from local fishermen once a month for one year. The fish was placed in pre-acid cleaned polyethylene bags, preserved in icebox and conveyed to the laboratory. The fish was washed with distilled water and dried in an oven at 100 °C for 24 hours to a constant weight. After the drying, the bones and scales were removed while the edible parts were grounded with mortar and pestle. Two gram (2 g) of the sample was mixed with 5 mL HNO_3 and 2 mL $HClO_4$ on a hot plate and heated for 30 minutes. The residue was allowed to cool, filtered with Whatman No.1 filter paper into a 50 mL volumetric flask and made to mark with distilled water. The filtrate was transferred into a clean sample bottle and stored for metal analysis in a cool environment. The above-mentioned procedures were carried out according to Adebayo, [8] and Markmanuel *et al*. [40].

Surface sediments were obtained at all the designated locations along Iko River using Grab Sampler. Samples collected were put in polyethylene bags, preserved inside a cooler and taken to the laboratory. Samples obtained were oven dried at 105 °C for 48 hours, ground and sieved using a 2-mm plastic sieve. One gram (1g) of the sieved sample was mixed with 10 mL of Aqua regia, placed on a hot plate and digested for 45 minutes. The mixture was allowed to cool, on cooling it was filtered with Whatmann No. 1 filter paper into a 100 mL standard flask and made to mark with distilled water. The filtrate obtained was preserved in cool environment before toxic metal analysis. These procedures for sample collection, treatment and digestion were done based on the methods of Maanan *et al*. [41], Jia *et al*. [42], and Galarza *et al*. [43].

Table 2 Parameters used for estimating the cancer and non-cancer risks associated with the exposure to toxic metals through water, fish, and sediments from Iko River

Parameter	Value	Source
WATER		
Body weight	10 kg – child 70 kg – adult	Tombere *et al*. [39], USEPA IRIS, [44].
Ingestion rate (IR)	2kg/person/day – child 2kg/person/day – adult	Tombere *et al*. [39], USEPA IRIS, [44].
FISH		
Body weight	25 kg – child 60 kg – adult	Markmanuel *et al.* [40], USEPA, [45].
Ingestion rate (IR)	0.15mg/kg/person/day – child 0.3mg/kg/person/day – adult	Markmanuel *et al.* [40], USEPA, [45].

SEDIMENT		
Body weight	15 kg – child 70 kg – adult	USEPA IRIS, [44].
Ingestion rate (IR)	2kg/person/day – child 2kg/person/day – adult	Galarza *et al*. [43], USEPA IRIS, [44].
GENERAL PARAMETERS		
Oral reference doses of toxic metals ($mgkg^{-1}day^{-1}$)	Cd - 0.001; Cr -1.5; Ni-0.02; Pb – 0.004	USEPA, [46], USEPA, [47].
Oral cancer slope factor (CSF) of toxic metals	Cd - 0.500; Cr – 0.501; Ni – 1.70; Pb-0.0085	USEPA IRIS, [44], USEPA, [48].

2.3. Evaluation of associated Human health risks

2.3.1. Estimated daily intake

The estimated daily intake (EDI) of Cd, Cr, Ni, and Pb through water, fish, and sediments from Iko River Channel by the adult and children populations was calculated using Equation 1.

$$EDI = \frac{C \times RI}{BW} ---------------------------- (1)$$

Where C signifies the concentration of toxic metals in the studied water, fish, and sediments, RI is the daily intake rate, and BW indicates the body weight for both the adult and children. Values for these parameters are in Table 2.

2.3.2. Hazard quotients

The hazard index (HQ) for the exposure of adult and children populations to toxic metals via the studied water, fish, and sediments was computed with Equation 2.

$$HQ = \frac{EDI}{RfD} ------------------------------ (2)$$

EDI is the Equation indicates the estimated daily intake calculated in Equation 1, while RfD is the oral reference doses for the metals as shown in Table 2.

2.3.3. Hazard index

The hazard index (HI) for the exposure of the adult and children populations to toxic metals through the studied water, fish and sediments was determined by the means of Equation 3.

$$HI = \Sigma HQ = HQCd + HQCr + HQNi + HQPb ------------------ (3)$$

Where ΣHQ = the summation of hazard quotients (HQ) of the toxic metals in Equation 2 above.

2.3.4. Incremental lifetime cancer risk

The incremental lifetime cancer risk (ILCR) for the exposure to toxic metals through the studied water, fish, and sediments by the adult and children populations was obtained using Equation 4.

$$ILCR = CSF\ x\ EDI ----------------------------- (4)$$

Where CSF is the cancer slope factor for the toxic metals in Table 1 and EDI =estimated daily intake rate of the toxic metals calculated.

2.3.5. Total cancer risk

The total cancer risk (TCR) for the exposure of the adults and children populations to the toxic metals through water, fish, and sediments from Iko River was computed with Equation (5).

$$TCR = \Sigma ILCR = ILCRCd + ILCRCr + ILCRNi + ILCRPb ------------- (5)$$

Where $\Sigma ILCR$ = the sum of the incremental lifetime cancer risk for all the toxic metals as indicated in Table 2.

2.4. Analysis of Results obtained

Results obtained were analysed using IBM SPSS Statistics 20 (IBM USA). The Principal component analysis (PCA) was performed with Duncan's multiple range tests at 90% confidence limit. Varimax Rotational techniques were applied for the Factor analysis on the four (4) toxic metals determined and values from 0.729 and above were rated as significant.

Table 3 Concentrations (mgkg^{-1}) of Toxic metals in Water, Fish, and Sediment samples

	Cd	**Cr**	**Ni**	**Pb**
	WATER			
Min	0.010	0.050	0.080	0.120
Max	0.024	0.084	0.180	0.280
Mean	0.098	0.193	0.108	0.173
SD	0.096	0.317	0.038	0.067
[a]RL	0.003	0.05	0.007	0.01
	FISH			
Min	0.001	0.000	0.004	0.003
Max	0.026	0.012	0.207	0.030
Mean	0.007	0.003	0.063	0.012
SD	0.010	0.004	0.077	0.010
[a]RL	0.20	0.15	0.60	0.40
	SEDIMENT			
Min	2.800	1.310	4.280	1.660
Max	4.120	1.860	9.720	2.690
Mean	3.492	1.612	7.407	2.277
SD	0.511	0.231	2.099	0.389
[b]RL	6.0	30.0	50.0	40.0

[a]**WHO,** [49], [b]**FAO/WHO,** [50].

3. Results and discussion

3.1. Concentrations of toxic metals in water, Liza grandisquamis, and sediment samples from Iko River Channel

Results of toxic metals in water, fish, and sediment samples from Iko River are shown in Table 3. Results in Table 3 indicate that, concentrations (mg/L) of Cd, Cr, Ni, and Pb varied as follows: 0.01 – 0.024, 0.050 – 0.084, 0.080 – 0.180 and 0.120 – 0.280, respectively. The mean values obtained Cd (0.098±0.096 mg/L), Cr (0.193±0.317 mg/L), Ni

(0.108±0.038 mg/L), and Pb (0.173±0.067 mg/L) revealed that, concentrations of all the metals in the studied aquatic ecosystem were higher than their acceptable limits for unpolluted water body by WHO, [49].

Concentrations ($mgkg^{-1}$) of toxic metals in the studied fish ranged from 0.001 to 0.026 for Cd, 0.000 to 0.012 for Cr, 0.004 to 0.207 for Ni, and 0.003 to 0.030 for Pb (Table 3). The results obtained also showed the following mean concentrations ($mgkg^{-1}$) for the metals: (0.007±0.010) Cd, 0.003±0.004) Cr, 0.063±0.077) Ni and 0.012±0.010) Pb. These results revealed that, all the metals were within their acceptable limits by WHO, [49] as shown in Table 3.

Results obtained for metals in sediments indicated that, Cd ranged between 2.800 and 4.120 $mgkg^{-1}$, Cr varied from 1.310 to 1.800 $mgkg^{-1}$, Ni ranged from 4.280 to 9.720 $mgkg^{-1}$, while Pb varied between 1.660 and 2.690 $mgkg^{-1}$. The mean concentrations ($mgkg^{-1}$) of Cd, Cr, Ni, and Pb were 3.492±0.511, 1.612±0.231, 7.407±2.099, and 2.277±0.389, respectively. These mean concentrations reported were within their acceptable limits by FAO/WHO, [50]. Results in Table 3 indicate that, standard deviations for most of the toxic metals in water samples and fish were high. This shows the high level of variability in the levels of these metals from one location to another as previously reported by Ebong *et al*. [51]. Higher levels of toxic metals were recorded in sediment samples than in water and fish [52, 53]. It could be inferred from the results obtained that, human exposure to untreated water from Iko River may result in adverse health problems. However, exposure to the fish (*Liza grandisquamis*) and sediments from the studied Iko River may not pose immediate health implications. Nevertheless, since metals can bio-accumulate, persist for a long time, and are toxic, prolonged exposure should be discouraged [12].

3.2. Human concerns of metal toxicity

Cadmium (Cd) is highly toxic and soluble in water; it can cause problems to the human kidney, renal dysfunction, damage the bones, lungs, cause diarrhea, and stomach irritation [54, 55]. Prolonged exposure to high level of Cd may result in cancer and birth defects [56, 57]. Chromium (Cr) compounds can exist in sediments for a very long time, Cr occurs in various oxidation states however; the stable compounds of Cr are in the +3 and +6 oxidation states. The element can affect human body in diverse ways including Ulcer, alters the synthesis of hemoglobin, damage to DNA [58, 59]. Persistent exposure to high levels of Cr can also cause cancer, dermal, neurological, and renal problems in humans [60]. Nickel (Ni) is highly available in the aquatic environment and persistent exposure to high level of the metal can affect the skin and kidney, cause asthma, cancer, respiratory, gastrointestinal, and cardiovascular diseases [61, 62]. Human exposure to high concentrations of Pb can result in headache, hypertension, edema, renal dysfunction, and loss of appetite, vertigo, sleeplessness, hallucination, and arthritis [63]. According to Martin and Griswold [64], toxicity of Pb may cause birth defect, damage to the brain and kidney, mental retardation, weight loss, and psychosis. It can as well lead to dyslexia, paralysis, autism, hyperactivity, weakness of muscles, and may result in death [65].

Results obtained revealed that, prolonged human exposure to water from the studied Iko River might result in immediate health problems associated with high levels of Cd, Cr, Ni, and Pb as stated above. The human exposure to *Liza grandisquamis* and sediments from the studied river may not result in immediate health problems however; since metals can bio-accumulate their levels should be closely monitored.

3.3. Multivariate Analysis

Table 4 Principal Component analysis (PCA) of Toxic Metals in the studied samples from Iko River Channel

	WATER	**FISH**	**SEDIMENT**
	F1	**F1**	**F1**
METAL			
Cd	-0.813	0.987	0.984
Cr	0.727	0.960	0.975
Ni	0.783	0.993	0.998
Pb	0.940	0.946	0.927
% Total Variance	67.2	94.4	94.3
Cumulative %	67.2	94.4	94.3
Eigen value	2.69	3.78	3.77

Principal component analysis (PCA) was used for the identification of the real source of these toxic metals in the studied samples as opined by Ebong *et al*. [66]. The PCA data in Table 4 indicate one fundamental source for these toxic metals in each of the studied samples. In water samples, the one factor that influenced the accumulation of toxic metals showed Eigen value of 2.69 and a total variance of 67.2%. The factor showed significant positive loadings on Cr, Ni, and Pb, but strong negative loading on Cd (Table 4). This is an indication of the negative impacts of anthropogenic factor on the quality of Iko River Channel [67]. The factor that influenced the presence of these toxic metals in *Liza grandisquamis* had Eigen value of 3.78 and 94.4% total variance. The factor indicated significant positive loadings on Cd, Cr, Ni, and Pb (Table 4). This signifies the negative influence of anthropogenic inputs on the toxic metals loads of *Liza grandisquamis* [68, 69]. The PCA also indentified one principal factor for the accumulation of these toxic metals in sediments from Iko River. The factor had an Eigen value of 3.77 and a total variance of 94.3% with strong positive influence by Cd, Cr, Ni, and Pb. This indicates mainly the negative influence of anthropogenic factor on the metals loads of the studied sediments [70, 71]. The results in Table 4 have also confirmed the strong relationship between *Liza grandisquamis* and water sediments [19, 72].

3.4. Human health risk evaluation

Table 5 The estimated daily intake (EDI) rate, hazard quotient (HQ), and hazard index (HI) of Toxic metals in water, fish, and Sediment from Iko River investigated

	EDI Adult	EDI Children	HQ Adult	HQ Children
	WATER			
Cd	2.80E-03	9.80E-03	2.80	9.80
Cr	5.50E-03	1.93E-02	3.70E-03	1.30E-02
Ni	3.09E-03	1.08E-02	1.55E-01	5.40E-01
Pb	4.94E-03	1.73E-02	1.24	4.33
HI			**4.19**	**14.68**
	FISH			
Cd	3.50E-04	4.20E-04	3.50E-02	4.20E-02
Cr	1.50E-04	1.80E-04	1.00E-05	1.20E-05
Ni	1.50E-03	3.78E-03	1.58E-02	1.90E-02
Pb	6.00E-04	7.20E-04	1.50E-02	1.80E-02
HI			**6.60E-02**	**7.90E-02**
	SEDIMENT			
Cd	1.00E-01	4.66E-01	100.0	466.0
Cr	4.60E-02	2.15E-01	3.10E-02	1.43E-01
Ni	2.12E-01	9.88E-01	10.6	49.4
Pb	6.50E-02	3.04E-01	16.25	76.0
HI			**126.88**	**591.54**

3.4.1. Non-carcinogenic human health risks

The non-carcinogenic implications of human exposure to these toxic metals via water, fish, and sediment in Iko River was assessed using the estimated daily intake (EDI), hazard quotient (HQ), and hazard index (HI) [73, 74]. The cancer and cancer-related health risks of these metals due to human exposure to the studied media from Iko River were evaluated with the incremental lifetime cancer risk (ILCR) and total cancer risk (TCR) [15, 39].

3.4.2. Estimated daily intake rate of toxic metals

Results in Table 5 indicate that, EDI values for Cd in water and sediments for both the adult and children populations and in fish for the children population were higher than their recommended oral reference dose. The EDI values for Cr in all the samples and for both populations were within their recommended oral reference dose. The EDI values for Ni in water and fish were within their acceptable oral dose however; the values in sediment for both the adult and children populations were higher than their recommended oral reference dose. The values for Pb in all the samples and populations were above the recommended oral reference dose. Consequently, prolonged exposure to the studied samples with EDI values higher than their recommended oral limit may result in severe health hazards. The EDI results also revealed that, the children population was more susceptible to the health risks related to the persistent exposure to these toxic metals through the studied samples as reported by Rakib *et al*. [75].

3.4.3. Hazard quotient of toxic metals

The mean hazard quotients (HQs) of Cd, Cr, Ni, and Pb in water samples for the adult population were 2.80, 3.70E-03, 1.55E-01, and 1.24, respectively (Table 5). However, higher mean HQ values were reported for the children population in water as 9.80, 1.30E-02, 5.40E-01, and 4.33 for Cd, Cr, Ni, and Pb, respectively. The mean HQ values for Cd and Pb in the studied water samples were higher than one (1.0) (Table 5). Hence, Cd and Pb had higher potential of affecting those exposed to water from Iko River persistently.

The mean HQ values for the metals in fish varied for 1.00E-05 to 3.50E-02 between Cr and Cd in the adult population. The values for the children population ranged from 1.220E-05 for Cr to 4.20E-02 for Cd (Table 5). The results obtained showed that, the mean HQ values for both populations varied as Cd > Ni > Pb > Cr. Results obtained for HQ in fish revealed that, the consumption of *Liza grandisquamis* from Iko River may not pose immediate health problems on the consumers however, the trend should be closely monitored to avoid bioaccumulation and the attendants human health implications.

The mean HQ values for the exposure of adult population to Cd, Cr, Ni, and Pb via sediment samples were 100.0, 3.10E-02, 10.6, and 16.26, respectively. Nevertheless, for the exposure of the children population to Cd, Cr, Ni, and Pb via sediments, the HQ values were 466.0, 1.43E-01, 49.4, and 76.0, respectively (Table 5). The mean HQ values for all the toxic metals were higher than 1 except for Cr. Hence, prolonged exposure to sediments from the river investigated may result in non-carcinogenic health problems associated with Cd, Ni, and Pb. The reported higher mean HQ values for the toxic metals especially Cd are consistent with the results obtained by Maigari *et al*. [76] and Mallongi *et al*. [77].

3.4.4. Hazard index of trace metals

The mean hazard indices (HIs) for the exposure to toxic metals through water from Iko River for the adult and children populations are 4.19 and 14.68, respectively (Table 5). The mean HI values for both populations were higher than one (1) consequently; human exposure to the studied water may result in severe non-carcinogenic health risks and the children class was more vulnerable. The results showed that Cd and Pb contributed 67 and 29%, respectively to the obtained mean HI values for both populations. The results obtained are consistent with those reported by Enuneku and Ineh, [78] and Anyanwu and Nwachukwu, [79].

The mean HI values for the exposure to toxic metals determined through the consumption of *Liza grandisquamis* from Iko River were 6.60E-02 and 7.90E-02 for the adult and children populations, respectively (Table 5). This shows that the consumption of *Liza grandisquamis* from the studied river may not be predisposed to immediate non-carcinogenic health challenges. The results obtained for fish in this study is similar to the findings by Jajere *et al*. [80]. Despite the low mean HI values reported, Cd still contributed a significant 53% to the total values obtained for both the adult and children populations [81].

The average HI values of toxic metals via exposure to the studied sediments for the adult and children classes were 126.88 and 591.54, respectively (Table 5). This is evidence that, human exposure to sediments from Iko River could be very risky as it may result in adverse non-carcinogenic health implications. The mean HI values reported are lower than the results obtained for metals in sediments by Hasaballah *et al*. [82]. Children were more vulnerable to the non-carcinogenic risks exhibited by these toxic metals due to exposure to the studied sediments [83]. The high non-carcinogenic potentials of Cd was also observed in sediment as it contributed a significant 79% of the total mean HI values for both the adult and children populations.

3.4.5. Carcinogenic human health risks

Table 6 Incremental lifetime cancer risk (ILCR) and total cancer risk (TCR) of toxic metals via exposure to water, fish, and sediment samples from Iko River Channel

	ILCR Adult	**ILCR Children**	**ILCR Adult**	**ILCR Children**	**ILCR Adult**	**ILCR Children**
	WATER		**FISH**		**SEDIMENT**	
Cd	1.40E-03	4.90E-03	1.75E-05	2.10E-05	5.00E-02	2.33E-01
Cr	2.76E-03	9.67E-03	7.52E-06	9.02E-06	2.31E-02	1.08E-01
Ni	5.25E-03	1.84E-02	5.36E-04	6.43E-04	3.60E-01	1.68E+00
Pb	4.20E-05	1.47E-04	5.10E-07	6.12E-07	5.53E-04	2.60E-03
TCR	9.45E-03	3.31E-02	5.62E-04	6.74E-04	4.34E-01	2.024

Results of the carcinogenic potentials of Cd, Cr, Ni, and Pb for the adult and children populations exposed to water, fish (*Liza grandisquamis*), and sediments from Iko River Channel are shown in Table 6. Results in Table 6 indicate the mean incremental lifetime cancer risk (ILCR) for the exposure of adult population to Cd, Cr, Ni, and Pb via the studied water as 1.40E-03, 2.76E-03, 5.25E-03, and 4.20E-05, respectively. While the mean ILCR values for the exposure of children class to Cd, Cr, Ni, and Pb via the studied water were 4.90E-03, 9.67E-03, 1.84E-02, and 1.47E-04, respectively. Results obtained indicated that for both populations, the trend for the carcinogenic potentials of the metals was in the order: Ni > Cr > Cd > Pb. Hence, Ni exhibited the highest cancer causing potentials via the studied water for both the adult and children populations.

The mean ILCR values for the exposure of both populations to Cd, Cr, Ni, and Pb via the consumption of the studied *Liza grandisquamis* as shown in Table 6 are 1.75E-05, 7.52E-06, 5.36E-04, and 5.10E-07, respectively for the adult population. Whereas, the mean ILCR values for the exposure of the children population to Cd, Cr, Ni, and Pb via the studied fish were 2.10E-05, 9.02E-06, 6.43E-04, and 6.12E-07, respectively. Thus, the sequence for the cancer-causing potentials of these toxic metals for both populations followed the order Ni > Cd > Cr > Pb. Consequently, Ni still exhibited the highest carcinogenic risks for the consumers of the studied fish.

The mean ILCR values for the exposure of adult population to Cd, Cr, Ni, and Pb via sediments from Iko River were 5.00E-02, 2.31E-02, 3.60E-01, and 5.53E-04, respectively. Exposure of the children class to Cd, Cr, Ni, and Pb through the studied sediments indicated higher mean ILCR values of 2.33E-01, 1.08E-01, 1.680, and 2.60E-03, respectively (Table 6). The trend for the cancer-causing hazards of these toxic metals for both populations via exposure to the studied sediments also followed the order Ni > Cd > Cr > Pb. Thus, Ni also showed the highest ability for causing cancer in those exposed to the sediments than other elements.

The general results for incremental lifetime cancer risk assessment showed that, cancer risk for the exposure Cd by both population via water and sediments from Iko River channel was in the high cancer risk class, but was in the medium cancer class in *Liza grandisquamis* [84]. Exposure to cancer risks of Cr for both the adult and children via the studied water and sediments were in the high cancer risk class, but in *Liza grandisquamis* it was in the negligible class [84]. Cancer risks of Ni via exposure to all the studied samples were in the high cancer class according to USEPA [84] classifications. Cancer risks of Pb through human contact with water and sediment was in the high class, but in the negligible cancer class via the consumption of *Liza grandisquamis.* The outcome of this study revealed that, Ni exhibited the highest cancer-causing potentials in all the studied samples [85-87]. The study also revealed that cancer risks of the toxic metals in all the studied samples were higher in the children than in adult population as reported by Liu *et al*. [83].

3.4.6. Total cancer risks of toxic metals

Results of the total cancer risks (TCR) for the adult and children populations through exposure to toxic metals via water, fish (*Liza grandisquamis*), and sediments from Iko River channel are in Table 6. The mean TCR values for the exposure of adult population to toxic metals through water, fish, and sediments were 9.45E-03, 5.62E-04, and 4.34E-01, respectively. Exposure of the children class to these toxic metals via water, fish, and sediments from the studied river indicated higher mean TCR values of 3.31 E-02, 6.7 E-04, and 2.02, respectively. The higher mean TCR values obtained for the children class is similar to the report by Etuk *et al*. [4]. The results of TCR indicated that, mean values reported for water and sediments from Iko River for the adult and children populations were higher than the permissible limit of 1.00E-06 – 1.00E-04 by USEPA [84]. However, the mean TCR values recorded for both populations via the consumption of the studied fish was within the permissible limit by USEPA [84]. The sequence for TCR in all the studied samples followed the order: Sediment > Water > Fish for both the adult and children populations. Consequently, prolonged exposure to water and sediments from Iko River Channel may result in cancer and cancer-related ailments in both the adult and children populations. Nevertheless, based on the TCR results obtained, the children population could be more susceptible to cancer risks via water and sediments from Iko River as reported by Shabanda *et al*. [88].

4. Conclusion

This study has shown the negative influence of human activities on the quality of Iko River Channel. The high levels of these toxic metals in water samples from the studied river in an indication of pollution and may affect the aquatic life over time. The reported high levels of these toxic metals may result in serious human health and environmental problems within the studied aquatic ecosystem. With the dependence of inhabitants on the studied river as source of water and sea foods, the levels of these toxic metals should be properly controlled. The outcome of the research indicated high carcinogenic and non-carcinogenic potentials for these toxic metals. It has also shown that, the children population was more susceptible to both the cancer and non-cancer risks. This could be a serious threat to the human life both within and beyond the study area. The PCA model indicated anthropogenic factor as the main source of these toxic metals to the studied aquatic environment. Hence, standard waste management strategies should be adopted for the treatment of both domestic and industrial waste products. Proper water treatment plant and other sources of potable water should also be provided for the inhabitants of the area to forestall exposure to metal toxicity and the related health risks.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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