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Trace metal residues in a tropical Watercourse sediment in Nigeria: Health risk implications

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ABSTRACT

This study aims to ascertain the possible health risks on humans to trace metals in Ossiomo River sediment via different exposure pathways. The pollution of river sediments by trace metals has raised countless concern for their potential biological noxiousness, environmental durability, and biological accumulation to humans along the food chain. Selected trace metals were analyzed based on required analytic approaches. Standard statistical tools were used to evaluate the records collected from the field. The outcomes from the field showed that the amount of the trace metals in the sediment were significantly higher in most samples and above set standard limits. The results of the hazard quotient (HQ) of the ingestion and dermal exposure were sourced from only Cd; 78.03, 6.93 and 7.47 for the ingestion pathway and 2840.20, 1445.46 and 1556.65 for the dermal pathway respectively. The hazard index (HI) obtained for Cd were ingestion (78.26, 6.96 and 7.49) and dermal (2841.87, 1446.31 and 1557.56) respectively. With more cumulative interactive effects in the children. The Cancer Risk gotten in this study was far greater in the children [Pb (0.644), Cr (3.35E+01) and Cd (4.76E+02)] than in the male [Pb (1.19E-01), Cr (6.20E+00) and Cd (8.82E+01)] and the female [Pb (0.128), Cr (6.67E+00) and Cd (9.50E+01)]. The TCR (Total Cancer Risk) values obtained were far beyond the set standards with Cd and Cr values of 659.09 and 46.32 respectively. We recommend further studies in this ecosystem in order to monitor the persistent anthropogenic impact and to anticipate any possible ecological risk that may propel human health risk impact.

Keywords: Cancer; Hazard Quotient; Trace metal; Total Carcinogenic Risk; Sediments; Ologbo.

1. INTRODUCTION

The fitness of any ecosystem, reflect the true picture of the activities therein. Anthropogenic impacts of an ecosystem pose an ecological risk which may propel human health risk impact. Most contaminants in a river ecosystem, are found in the benthic region; sediment.

The sediments are vital portion of the aquatic ecosystem (Cheng *et al.*, 2016). Trace metals contamination of river sediments have raised great concern for their probable natural noxiousness, ecological stability, and build-up to humans along the food chain (Reddy *et al.*, 2004; Varol, 2011; Jiang *et al.*, 2012; Anani and Olomukoro 2017).

Literature works on the health impacts of trace metals from sediment on humans via ingestion, inhalation and dermal contact have been documented (US EPA, 1989; Tao *et al.*, 2002; Wang *et al.*, 2005; Zabin *et al.*, 2008; Żukowska and Biziuk, 2008 Genthe *et al.*, 2013; Al-Saleh *et al.*, 2014; Sami and Saad 2015; Kamunda *et al.*, 2016).

In this study, the specific objectives are to:

- i) assess the levels of trace metals in Ossiomo River sediment,
- ii) evaluate the health hazards posed by the sediment on adults (male and female) and children through health risk quantifications.



2. METHODOLOGY

2.1 The area of study

About 2.2 km stretch of Ossiomo River (Ologbo axis), Benin City situated in the South West of Nigeria was surveyed for this study in the following geographical locations; Latitude $6^{\circ} 03'1''$ N - Longitude $5^{\circ} 40'3''$ E (Fig. 1).

Four sampling stations in the river stretch were surveyed to reveal the up-stream and the down-stream nature of the river, based on the possible amount of pollution, it received from agricultural and other anthropogenic activities with the following ecological factors and geographical locations in Table 1.

Stations	Location	Latitude (N)	Longitude (E)	Anthropogenic activities and source points.
1	Ologbo	6° 02'.890''	5° 39' 599''	A reference zone free from anthropogenic activities.
2	Ologbo	6° 01'.759''	5° 38'.344''	Closed to a timber factory and deck of boats and where human activities are very high; and crude oil exploration and processing.
3	Ologbo	6° 01'.859''	5° 36'.870''	Closed to a local distiller, palm oil farm (PRESCO), cassava farm and sawmills.
4	Ologbo	6° 01'.091''	5° 35'.199''	Closed to a large cassava farm and sawmill.

Table 1. Sampling locations of Ossiomo River, Edo state Benin City

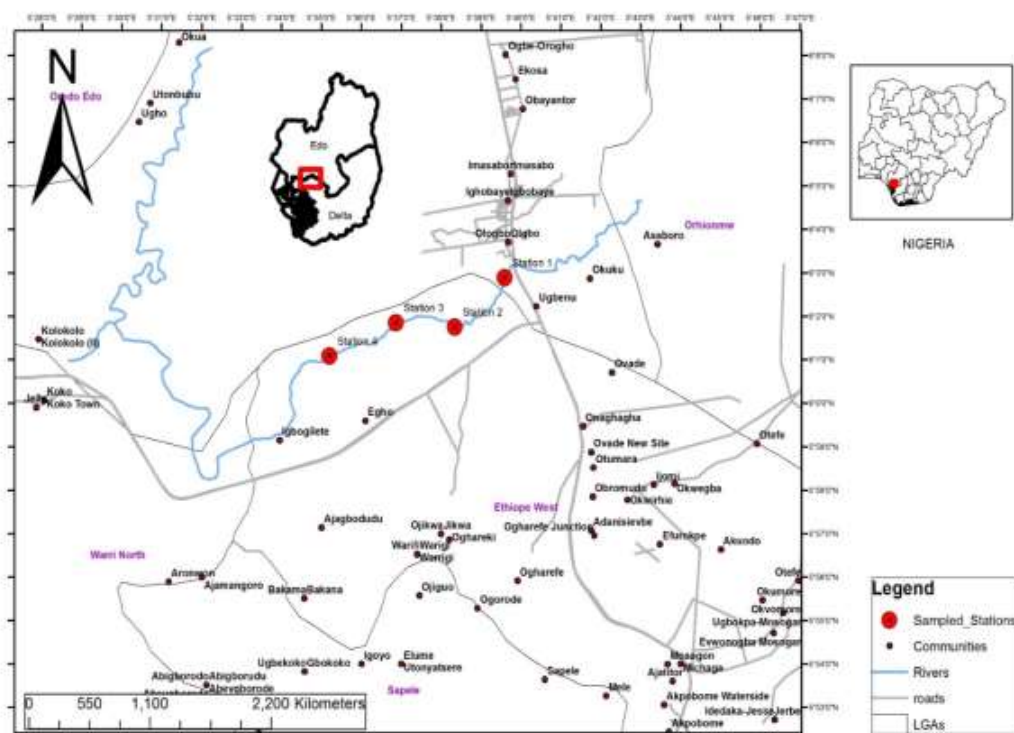


Fig. 1: Map of the study area showing the sampling stations of Ossiomo River, Edo state, Nigeria.

2.2 Sampling methods and trace metal extraction

Samples were collected from the field from March 2015 – August 2016 and were taken to the laboratory, analyzed in accordance with standard procedures as described by APHA (2005). The metal contents (iron, manganese, zinc, copper, chromium, cadmium, lead, nickel, and vanadium) in the sediment were digested according to the methods adopted from APHA (1998), Radojevic and Bashkin (1999). 1.0 g of the air-dried sediment was weighed up into a 125 ml Erlenmeyer flask pre-washed with perchloric acid and distilled water. Four (4) ml of perchloric acid, 25 ml concentration of HNO_3 and 2 ml concentration of H_2SO_4 were added. The mixture was spun mildly and permitted to digest gradually at low to high heat under a fume hood until dense white fumes appeared. Strong heat (medium to high heat) was finally applied for about thirty seconds (30 seconds) and the mixture was made to calm down. 40-50 ml of distilled water was added to the mixture and boiled for half a minute. The solution was allowed to cool down and was sieved totally with a wash bottle into a 100 ml pyrex volumetric flask. The solution was made up to mark with distilled water and filtered again with Whatman No. 42 filter paper. The filtrate from the digestion of soil samples and the standard solutions for each element was aspirated into the air-acetylene flame of Varian 220 using an Atomic absorption spectrophotometer (Solaar 969 Unicam Series model).

2.3 Data Analysis

The different stations were compared for significant differences using parametric analysis of variance (ANOVA) and Univariate analysis using PAST 3.0 software.

2.4 Health risk evaluation

The estimated chronic daily intake (ECDI) was calculated in accordance with the method of Huang *et al.*, (2014) as designed by US EPA, (1997). The reference dosages ($RfDs$) for the

ingestion and dermal in mg/kg/d used in this study were gotten from Li and Zhang (2010), Wu *et al.*, (2009), Iqbal and Shah (2012), IRIS and US EPA (2007), ATSDR (2007). The hazard quotient (HQ) was calculated using the modified method of Papadakis *et al.*, (2015). The HI (hazard index) was evaluated using the method of Paustenbach (2002).

To quantify the carcinogenic risk (CR) of the sediment, the methods of US EPA (1989) were employed. The slope factor (SFing) values for Cd, Cr, and Pb used for this study were gotten from US EPA (1989), Vieira *et al.*, (2011) and Yu *et al.*, (2010). The carcinogenic risks standard limits used for the trace metal exposure was by US EPA (2010) guideline. The modified total cancer risk method by Gržetić and Ghariani (2008) was also employed in this study. The assumptions used in this study are highlighted in Table 2.

Table 2: Values used for the calculations of ingestion and dermal pathways in adults and children

Variables	Adults				Children	References		
	Units	Male	Female	References				
Ingestion rate of the sediment (IR_{sediment})	mg/kg	100	100	USDOE (2011)	200	USDOE (2011)		
Exposure frequency (EF)	L/day	350	350	USDOE (2011)	350	USDOE (2011)		
Exposure duration (ED)	Day/year	30	30	Qu <i>et al.</i> , (2014)	6	Qu <i>et al.</i> , (2014)		
Body weight (BW)	Kg	70	65	Ezemonye <i>et al.</i> , (2015a), Sami and Saad 2015 and Grzeric <i>et al.</i> , (2008)	10	Ezemonye <i>et al.</i> , (2015)		
Surface area	Cm^2/day	5700	2800	USDOE (2011)				
Average life time (AT)	Day	8760	8760	Huang <i>et al.</i> , (2014)	2190	Huang <i>et al.</i> , (2014)		
Dermal surface factor (AF)	mg/cm	0.07	0.07	USDOE (2011)	0.2	USDOE (2011)		
Dermal absorption factor (ABS)	Unit less	0.13	0.13	US EPA (2002)	0.13	US EPA (2002)		
Carcinogenic slope factor (CF)	Unit less	0.001	0.001	Ozekeke <i>et al.</i> , 2015	0.001	Ozekeke <i>et al.</i> , 2015		
Elements	Fe	Zn	Mn	Cu	Pb	Cr	Cd	Ni
<i>Rfdos</i> ingestion (mg/kg/d)	700	24	300	40	3	0.5	0.001	1.4
<i>Rfdos</i> dermal (mg/kg/d)	140	0.96	60	8	0.075	0.025	0.00001	0.42

3. RESULTS

3.1 The quantification of the trace metals in Ossiomo River

The trace metals concentrations in the sediment of Ossiomo River are shown in Table 3. Most of the values were above the set standard limits and were considered significant ($P < 0.05$); Fe, Mn, Cu, Cr, Cd, Pb, Ni and V exempting Zinc which did not show significant difference at $P > 0.05$ across the studied locations.

It was likewise observed from this study that station 2 had the highest impact followed by stations 3, 4 and 1. This was shown by the cumulative impact (CI) of the trace metals in these stations (Table 3).

Table 3: Total concentration in mg/kg of trace metals in the sediments of Ossiomo River

Stations/Metals	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V	CI
Station 1	156.49	13.33	28.38	4.52	1.99	1.8	1.41	1.08	0.98	23.33
Station 2	329.14	24.5	43.63	10.73	4.89	5.89	6.36	2.65	2.23	47.78
Station 3	284	20.92	39.17	9.84	3.98	5.26	4.86	2.3	1.97	41.37
Station 4	226.8	19.08	34.92	7.2	3.03	3.25	3.1	1.89	1.7	33.44
Mean	249.11	19.46	36.53	8.07	3.47	4.05	3.93	1.98	1.72	
Standard deviation	74.61	4.66	6.49	2.80	1.25	1.88	2.15	0.68	0.54	
Minimum	156.49	13.33	28.38	4.52	1.99	1.80	1.41	1.08	0.98	
Maximum	329.14	24.50	43.63	10.73	4.89	5.89	6.36	2.65	2.23	
Median	255.40	20.00	37.05	8.52	3.51	4.26	3.98	2.10	1.84	
Geometric mean	240.00	19.00	36.08	7.66	3.29	3.67	3.41	1.88	1.64	
FEPA 2003 Limits	0.03	0.03	0.0123	0.3	-	0.04	0.06	-	-	
P-Values	P<0.05	P<0.05	P>0.05	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05

NB: CI: Cumulative Impact

3.2 The results of the CDI (chronic daily intake), HQ (hazard quotient) and HI (hazard index) of Ossimo River sediment

Tables 4-6 summarize the estimated values of the CDI, HQ and HI for the male, female and children.

The CDI values obtained for this study were generally lower than 1 (CDI < 1) for the adult (male and female) in all the metals. In the quantification of the exposure factor in the male, female and children, it was observed that the HQ of the ingestion and dermal exposure were sourced from only Cd; 78.03, 6.93 and 7.47 for the ingestion pathway and 2840.20, 1445.46 and 1556.65 for the dermal pathway respectively. More so, the quantification of the HI of the oral exposure in the adults and children, Cd also had greater influence individually in the ingestion and dermal pathways. In the children, male and female, the HI obtained for Cd were ingestion (78.26, 6.96 and 7.49) and dermal (2841.87, 1446.31 and 1557.56) respectively.

Table 4: Probable non-carcinogenic risk of trace metals in Ossimo sediment on the male

Trace metals	sediment	Rfd ingestion (mg/kg/d)	Rfd dermal (mg/kg/d)	ECDI ingestion	ECDI dermal	HQ Ingestion	HQ Dermal
Fe	249.11	700	140	4.80	1.75	0.01	0.01
Mn	19.46	300	60	0.37	0.14	0.00	0.00
Zn	36.53	24	0.96	0.70	0.26	0.03	0.27
Cu	8.07	40	8	0.16	0.06	0.00	0.01
Cr	3.47	0.5	0.025	0.07	0.02	0.13	0.97
Cd	4.05	0.001	0.00001	0.08	0.03	78.03	2840.20
Pb	3.93	3	0.075	0.08	0.03	0.03	0.37
Ni	1.98	1.4	0.42	0.04	0.01	0.03	0.03
V	1.72	NS	NS	0.03	0.01	0.00	0.00
HI						78.26	2841.87

Table 5: Probable non-carcinogenic risk of trace metals in Ossimo sediment on the female

Trace metals	sediment	Rfd ingestion (mg/kg/d)	Rfd dermal (mg/kg/d)	ECDI ingestion	ECDI dermal	HQ Ingestion	HQ Dermal
Fe	249.11	700	140	0.43	0.89	0.00	0.01
Mn	19.46	300	60	0.03	0.07	0.00	0.00
Zn	36.53	24	0.96	0.06	0.13	0.00	0.14
Cu	8.07	40	8	0.01	0.03	0.00	0.00
Cr	3.47	0.5	0.025	0.01	0.01	0.01	0.50
Cd	4.05	0.001	0.00001	0.01	0.01	6.93	1445.46
Pb	3.93	3	0.075	0.01	0.01	0.00	0.19
Ni	1.98	1.4	0.42	0.00	0.01	0.00	0.02
V	1.72	NS	NS	0.00	0.04	0.00	0.00
HI						6.96	1446.31

Table 6: Probable non-carcinogenic risk of trace metals in Ossimo sediment on the children

Trace metals	sediment	Rfd ingestion (mg/kg/d)	Rfd dermal (mg/kg/d)	ECDI ingestion	ECDI dermal	HQ Ingestion	HQ Dermal
Fe	249.11	700	140	0.46	0.96	0.00	0.01

Mn	19.46	300	60	0.04	0.07	0.00	0.00
Zn	36.53	24	0.96	0.07	0.14	0.00	0.15
Cu	8.07	40	8	0.01	0.03	0.00	0.00
Cr	3.47	0.5	0.025	0.01	0.01	0.01	0.53
Cd	4.05	0.001	0.00001	0.01	0.02	7.47	1556.65
Pb	3.93	3	0.075	0.01	0.02	0.00	0.20
Ni	1.98	1.4	0.42	0.00	0.01	0.00	0.02
V	1.72	NS	NS	0.00	0.01	0.00	0.00
					HI	7.49	1557.56

NB: C stands for concentration of trace metal in sediment, ECDI stands for estimated chronic daily intake, Rfd stands for reference dosage, HQ stands for hazard quotient, NS stands for not specified and HI stands for hazard index.

3.3 *The results of the carcinogenic risk (CR) and total carcinogenic (TCR) of Ossiomo River sediment*

The carcinogenic risk and total carcinogenic values of the additional lifespan cancer risks were computed in Table 7 and Figure 2. For the male, the CR for all metals studied were Pb (1.19E-01), Cr (6.20E+00) and Cd (8.82E+01), the female; Pb (0.128), Cr (6.67E+00) and Cd (9.50E+01) and the children Pb (0.644), Cr (3.35E+01) and Cd (4.76E+02). For the quantification of the TCR, the values gotten after computation were; Pb (0.82), Cr (46.32) and Cd (659.09).

Figure 2 shows the bar chart of the carcinogenic and total carcinogenic and total carcinogenic hazards of the metals in Adult (male and female) and children exposed to Ossiomo sediment. It was noticed that the rank of the carcinogenic increase was in this order; CR children > CR female > CR male. This current findings of this study showed that the quantified sediment concentrations of all the elements studied will produce important carcinogenic lifetime threat consequent of consistent intake of Cd and Cr via ingestion of the sediment.

Table 7: Probable carcinogenic risk of trace metals in Ossiomo sediment on the adults (male and female) and children

Trace metals	ECDI male	ECDI female	ECDI children	<i>Sfing</i>	CR male	CR female	CR children	TCR
Pb	0.01	0.02	0.08	8.50E+0 0	1.19E- 01	0.128	0.644	0.89
Cr	0.01	0.01	0.07	5.00E+0 2	6.20E+0 0	6.67E+0 0	3.35E+01	46.32
Cd	0.01	0.02	0.08	6.10E+0 3	8.82E+0 1	9.50E+0 1	4.76E+02	659.0 9

NB: *SF* stands for slope factor, *CR* stands for carcinogenic risk and TCR stands for total for carcinogenic risk.

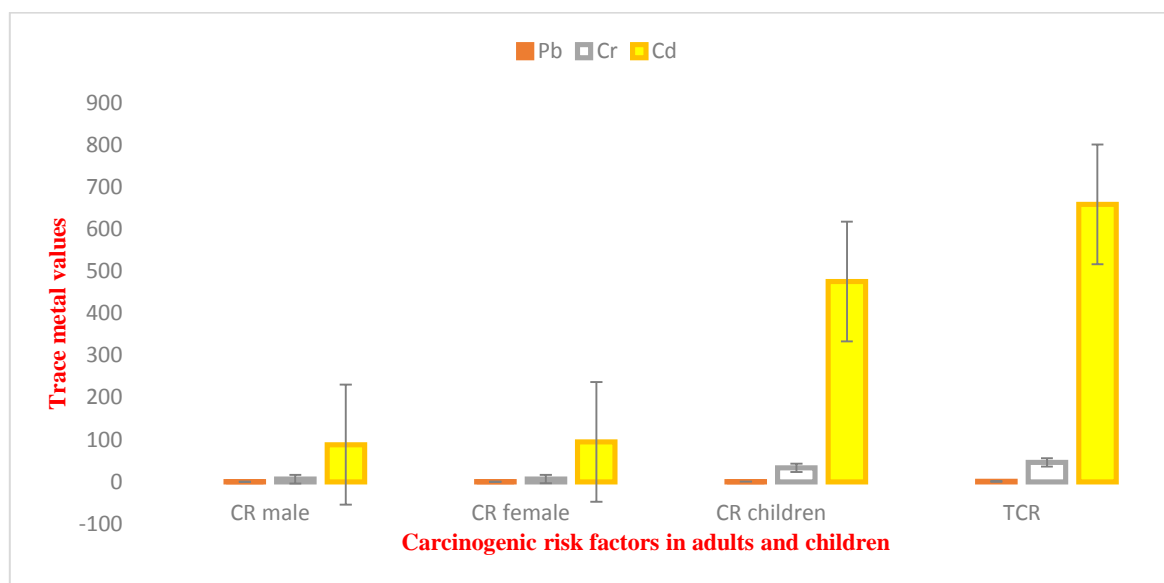


Fig. 2: The carcinogenic and total carcinogenic risk factors of trace metals in the adults (male and female) and children exposed to Ossiomo River sediment.

4. DISCUSSIONS

4.1 *The characterization of the trace metals contents in Ossiomo River*

The variations of the concentrations of the trace metals in the surveyed stations could be accredited to the large-range of man-made activities closed these stations and the environmental circulation of raw materials in the benthic regions of the studied river. The variations in the concentration of the trace metals in this study may be related to the metamorphoses in the sandy features of the benthic sediment.

The high geometric mean and median concentrations also indicated a high anthropogenic impact across the stations which in turn reflect ecosystem pollution by human activities, this was also supported by Zhang *et al.*, (2012 and 2016) and Anani and Olomukoro (2017). Organisms exposed to such deleterious trace metals will have serious health conditions associated with diarrheal diseases and chest pains and even cancer risk factor.

4.2 *Non-carcinogenic risk quantifications*

The values gotten from the computation of the CDI were considered too low for this study. This is analogous to the works of Wang *et al.*, (2017). However, the CDI value of the children was considered greater than 1 sourced from Fe (1.75). However, Cd showed a high potential hazard risk with value far greater than the US EPA, (1989 and 2004) unity limits (HQ values < 1). This a sign of a non-carcinogenic potential hazard to the adults and children who are exposed to these trace metals (Tables 4-6). Similarly, the great influence of Cd in the ecosystem was also noticed in the HI. This further explains that Cd exposure to individuals may pass different pathways and there is a great probable non-carcinogenic hazard aimed at individuals exposed to the sediment. In accordance with the toxicological profiles of the trace metals, IRIS, (2007), RAIS, (2007) and ATSDR, (2007), confirm the adverse health effects of Cd on humans, and an induced non-carcinogenic and carcinogenic risk factor by this carcinogen. Consequent on this, health effect associated with Cd toxicity may revealed long-lasting effects to exposed individuals especially cancer. The findings of this study revealed a high health risk factor for Cd in this ecosystem.

4.3 *Carcinogenic risk (CR) and total carcinogenic (TCR) quantifications*

In this study, the CR were far greater in the children than in the male and female. The values were far higher than the slated unity values of the US EPA, (1989, 2010 and 2011). This further revealed that they are more at risk to the carcinogens Cd and Cr. The ingestion pathway appears to be the main route to additional lifespan cancer risk. The values of the carcinogenic dermal pathway were not computed for this study because of the difficulty of dermal permeability of the sediment via the pores of the skin as reported by Kamunda *et al.*, (2016). However, studies by Bryan and Langston (1992) and Tao *et al.*, (2012) stated that lead was the most bio-concentrated element in some water animals in terms of bio transfer into the food chain. The results obtained in this current study is in contrast with theirs. Lead contributed insignificantly in this current ecosystem. However, Cd and Cr were more significant in the ecosystem and might have greater impacts on the exposed individuals via ingestions pathway. Cd has been found to cause adverse health effects on the organs-systems in humans (Żukowska and Biziuk, 2008; Al-Saleh *et al.*, 2014). This is also true for Cr which might also present similar effects and at chronic conditions, become carcinogenic.

The computed values gotten from this study revealed high TCR sourced from cadmium (Cd) and chromium (Cr). These values obtained are not considered acceptable for Cd and Cr according to literatures (Guney *et al.*, 2010; Wu *et al.*, 2015). These values are also considered greater than the cancer-causing risk of 1.0×10^{-6} set by US EPA, (2011). It is evident here in this findings that cancer-causing hazards of trace metals via ingestion are very important in ascertaining likely health risk factor in humans. The findings of this study is

similar to the studies on metals risk of soil by Islam *et al.*, (2017) and Hu *et al.*, (2017a, b). Therefore, the hazard that may likely develop due to contact to trace metals in the sediment of this present ecosystem (Ossiomo River) will contribute more to the overall cancer hazards that it is entirely significant therein. This is contrary to the works of Grzetic *et al.*, (2008) and Sami and Saad, (2015). This current findings of this study showed that the quantify sediment concentrations of all the elements studied will produced important carcinogenic lifetime threat in consequent of consistent intake of Cd and Cr via ingestion of the sediment.

5. CONCLUSION

This work has confirmed that the sediment contamination in Ossiomo River is important. Risk valuation computed for a lifespan contact, showed that the cancer-causing hazard is totally significant, but the non-cancer-causing hazard tends to become important mostly for children, which may likely have the highest impact. There were mainly dangerous trace metals; Cd and Cr and their cumulative effect expressed in the children. Ingestion and dermal hazardous index should be considered highly significant because the results gotten from this study are highly alarming.

More works should be done in this area of research in order to monitor the long-term anthropogenic impact on the ecosystem in order to anticipate any possible ecological risk that may propel human health risk impact.

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