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Human and Ecological Risk Assessment of Heavy Metals in Water and Sediment of Elechi Creek, Port Harcourt, Nigeria.

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***Abstract**: Heavy metal pollution has been considered to be an ecological threat to man and other organisms especially when found in organs above the threshed concentrations. Elechi creek is a major source of water for domestic and industrial use. The concentration of heavy metals such as Cadmium (Cd), Chromium (Cr), lead (Pb) and Copper (Cu) in water and sediment were investigated using Atomic Absorption Spectrophotomer. The mean concentrations (mg/l) in water were respectively, Cd(0.0036 ± 0.277), Cr (0.0042 ± 0.196), Pb(0.00387± 0.136) and Cu(0.0068 ± 0.217) while that of sediment(mg/kg) were Cd(0.00494±0.203), Cr (0.00457 + 0.172), Pb(0.00468 ± 0.205) and Cu(0.00731 ± 0.204)) respectively. Apart from Cd which exceeded the TSE – 266 and WPCC limit and Pb which exceeded the criterion continuous concentration (CCC) other metals studied were within the TSE – 266, WPCl, CIW and EC water guideline. The order or magnitude of heavy metal concentration in water is Cu > Cr > Pb > Cd while that of sediment is Cu > Cd > Pb > Cr with Cu having the highest concentration in both media. The contamination factor (CF) and pollution load index (PLI) were all less than unity showing that there was little pollution and not pollution in the area. Elechi Creek is therefore contaminated though without potential danger for now but may pose risk with time depending on further degradation by agriculture and other anthropogenic activities in the area.*

***Keywords:** Human, Ecology, Risk assessment, Heavy metals, Water, Sediment, Elechi creek*

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I. Introduction

Heavy metal pollution has been considered as one of the major ecological threat to man and other organisms especially through food chain when found above the threshold concentrations. Owing to the severe effects on the human race and environment, pollutants such as heavy metals, pesticide, polychlorobiophenys (PCBs), polycylic aromatic hydrocarbon (PAHs) etc are now of utmost concern (Bhuvaneshwari *et al*, 2016). It is pertinent to note that increased levels of heavy metals in creeks, rivers, lakes, oceans and ponds are considered to be disastrous because they are the only sources of drinking water as well as the abode for aquatic organisms such as fishes and other invertebrates especially in developing countries (Ochieng *et al*, 2008). When heavy metals find their way into the aquatic environments as a result of urbanization, industrialization and other anthropogenic activities, they settle in the sediment and water in the various water bodies. These metals are eventually taken up or absorbed by fish, plankton and other biota through water, food and sediment whether they are essential or non – essential ones which get accumulated in their tissues (kalay and Canli, 2000).

When these metals accumulate in the tissues and water above threshold and finally consumed by man through food chain, they could cause potential consequences to man. According to Christophoridis, *et al*, (2008), sediment is known to be a sink and a potential source of aquatic pollutants or contaminants especially of heavy metal origin. Zabetoglou *et al*. (2002) opined that sediments are often found contaminated with different hazardous and toxic materials while Singh *et al;* (2005) considered sediments to be transporters and sink for pollutants thus reflecting the history of pollution.

Due to the fact that heavy metals cannot be biodegraded and cannot usually be removed from the aquatic ecosystem by natural means, they are therefore considered to be of great significance as indicator of ecological quality of all water flow considering their toxicity, persistence and bio-accumulative behaviour (Forstner and Wittman, 1981, Murray, 1996, Prosi, 1981, Moalla *et al*. 1998 and Purves, 1985). Heavy metals displace vital elements and obstruct their biological functions. These metals get into the body through food consumption, skin exposure, beverages, and air inhalation. Exposure of heavy metals by any means of food consumption will have confirmative negative effects to human health (Pan, *et al*, 2013). On this note it is important to undertake risk assessment of these toxins called metal ions in human even at low concentration especially in the occupational and environmental exposure to toxic metals (Sung and Huang, 2003).

This study was carried out in Elechi creek flowing through a densely populated area with so many anthropogenic activities such as oil and gas exploration, refining, agricultural activities etc taking place. These activities may contribute a huge amount of municipal sewage and industrial effluents containing heavy metals and other hydrocarbon compounds such as PCBs, PAHs etc. Due to modernization, the degree of heavy metal present in the water even in low concentration tends to cause serious threat to aquatic life and food web.
There is paucity of information in this creek with respect to risk assessment and pollution index on the water system hence the need for this research.

II. Materials and Methods

Water and sediment samples were collected in bottles and polythene bags respectively and transported to the laboratory for further analysis. Atomic Absorption Spectrophotometer was used to determine the heavy metals (Cd, Cr, Pb and Cu) concentration from the samples collected from the three stations(Fig.1) of Elechi creek following the procedure of APHA (1998).

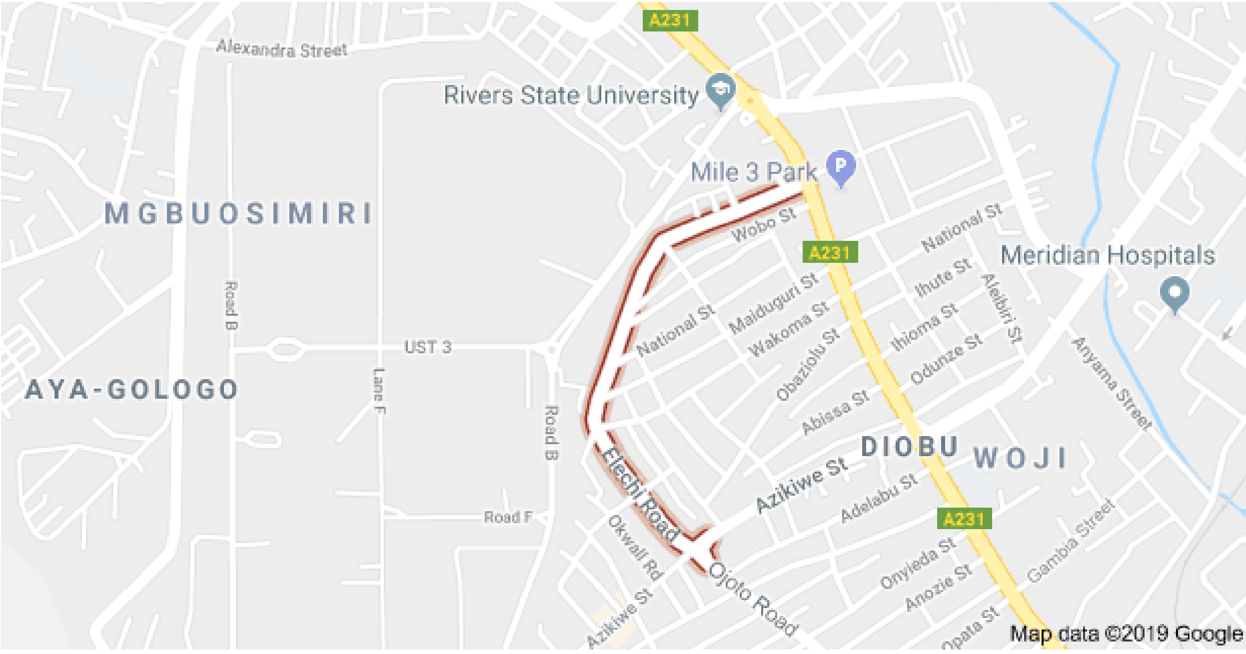

Figure1. Map of the study area showing the sampling stations

The health risk assessment of heavy metals through water consumption from Elechi Creek was determined using the measured mean concentration of heavy metals in water for calculation as shown below:

1) Hazard Quotient = $$\frac{C_w \times IR_w \times \sum f}{RfD \times Bw \times AT} \times 10^{-3} = \frac{ADD}{RfD}$$

Where, Cw = concentration in water
IRW = daily water ingestion rate (Adult: 95th Percentile = 211 day
50th Percentile = 1.411day
Child: 95th percentile = 1.0811 day
50th percentile = 0.3811 day

Ef	=	Exposure frequency (365days/year)
ED	=	exposure duration (70 years) = average life time.
RfD	=	Oral reference dose (mg/kg/day)
Bw	=	body weight (Adult = 70kg) Child = 30kg
AT	=	Average exposure time (non-cancer risk – 70 years x 365 days/year)
10^{-3}	=	Conversion factor = 0.001

2. **Contamination Factor (CF):** This refers to the ratio of observed concentration of trace elements/heavy metals (mg/kg) over the background value of the trace elements/heavy metals (mg/kg) in sediment calculated using the formular:

Cf = Observed concentration of heavy metals (mg/kg)/
= Background value of the heavy metals (mg/kg)

3. **Pollution Load Index (PLI):** This refers to the index for pollution assessment derived by measuring the metal contents and deriving contaminating factors by reference to the baseline metals levels i.e background value of metals in India (Chandrasekhar *et al.,* 2003). It is usually evaluated using the proposed method by Tomlinson *et al* (1980):

PLI = $(CF_1 \text{ X } Cf_2 \text{ x } Cf_3 \ldots\ldots\ldots\ldots\ldots\ldots \text{ X } Cfn)^{1}/_{n}$

Where
n refers to the number of metals
Cf < 1 = low contamination
Cf 1 – 3 = Moderate Contamination
Cf 3 – 6 = considerable contamination
Cf > 6 = very high contamination

III. Results

The mean and ranges of the heavy metals, Cd, Cr, Pb and Cu in water and sediment are as presented in table 1 below. The magnitude of the metals were in the order Cu > Cd > Pb > Cr and Cu >Cr > Pb > Cd for sediment and water respectively. Copper mean concentration was highest in both sediment (0.0073±0.204mg/kg) and water (0.0068±0.217mg/l while chromium and cadmium were lowest in sediment and water respectively. The concentrations of all the studied heavy metals in water except Cd were within the respective MPL/WHO, WA WPCL and CMC recommended limits for natural water (Table 2). The oral reference dosages (RFD) of heavy metals in the sediment (mg/kg/day) are Cd(0.001), Cr (0.05), Pb (0.004) and Cu (0.04) (Table 3).

The hazard quotient (HQ) resulting from the exposure of cadmium was higher in adult (0.13 x 10^{-3} and 0.072 x 10^{-3}) than child (0.054 x 10^{-3} and 0.0014 x 10^{-3}) at 95th and 50th percentile respectively though lower than unity (Figure 2). The HQ for other metals at 95th and 50th percentile were Cr(0.024 x 10^{-3} and 0.017 x 10^{-3}) for adult and 0.013 x 10^{-3} and 0.004 x 10^{-3} for child, Pb (0.028 x 10^{-3} and 0.019 x 10^{-3}) for adult and 0.015 x 10^{-3} and 0.0053 x 10^{-3}) for child, Cu (0.045 x 10^{-3} and 0.0034 x 10^{-3}) for adult and 0.0026 x 10^{-3} and 0.0009 for child. Cu had the lowest HQ value (figure 2).

Figure 3 showed the contamination factor (CF) for the various heavy metals in the study area to include Cr (0.000063), Pb (0.00026) and Cu (0.000131) which is less than unity (1).

The PLI value $(2.145 \text{ x } 10^{-12})^{1}/_{3}$ is less than unity signifying low contamination in the area.

Table 1: Concentrations and Ranges of Heavy Metals(HM) in Water and Sediment of the Study Area

Mean Values of HM in	Cd	Cr	Pb	Cu
Water(mg/l)	0.00361±0.277	0.0042±0.196	0.00387±0.136	0.00682±0.217
Range	0.00060-0.0070	0.0100-0.0900	0.00200-0.0060	0.0030-0.0100
Sediment(mg/kg	0.00494±0.203	0.00457±0.172	0.00468±0.205	0.00731±0.204
Range	0.00050-0.0090	0.00060-0.0080	0.00110-0.0140	0.0020-0.0120

Table 2: Acceptable level (mg/l) of Heavy Metals in Natural Waters(Water Guideline)

Heavy Metal	**Cd**	**Cr**	**Pb**	**Cu**
Maximum Permissible Limit (MPL	0.003	0.05	0.01	NA
Threshold Concentration for aquatic lifeTC	0.01	0.05	0.10	NA
Bureau of Indian Standards BIS	0.01	0.05	0.05	NA
World Average of trace element in unpolluted rivers (WA)	0.001	NA	0.04	NA
Turkish Standard,2006) (TSE-266)	0.005	0.05	0.01	2.0
Water Pollution Control (WPCL,2004)	0.003	0.02	0.01	0.02
Annonymous Criterion of the Irrigation Water (CIW,1997)	0.01	0.10	5.0	0.20
World Health Organisation (WHO)	0.01	0.05	0.05	2.00
European Community (EC)Water Guideline	5	50	10	2.00
Environmental Protection Agency (EPA)	0.01	0.05	0.05	1.30
Fresh Water Quality Criteria				
Criterion Maximum Concentration (CMC) (USEPA,2006)	0.002	0.016	0.07	NA
Criterion Continous Concentration (CCC) (USEPA,2006)	0.0003	0.011	0.003	NA

NA= not available

Table 3: Oral Reference Doses(Recommended Standard) of Heavy Metals in Sediment

Heavy Metal	Cd	Cr	Pb	Cu
RFD(mg/kg/day	0.001	0.05	0.004	0.04
Background Value of Metals in India (BV)(Chandrasekhar et al.,2003	NA	73	18	56
Unpolluted Sediment (US)(Kumar et al.,2010)	NA	NA	19	33
Threshold effect level (TEL)(ISQG)(CCME,2002)	NA	37.3	35	35.7
Probable effect level (PEL)(Chandrasekhar et al.,2003	NA	90	91.3	197
Threshold effect concentration(TEC) (NOOA,2009)	0.99	43.4	35.8	31.6
Lowest Effect Level (LEL) (NOOA,2009)	0.60	26.0	31.0	16.0
Probable Effect Concentration(PEC) (NOOA,2009)	4.90	111.0	128.0	149.0
Severe Effect Level (SEL) (NOOA,2009)	10.0	110.0	250.0	111.0
USEPA TOXICITY CLASSIFICTION				
Non-Polluted	NA	NA	<40	25
Moderately polluted	NA	NA	40-60	25-50
Heavily polluted	NA	NA	>60	>50
NOAA				
ERL	NA	NA	46.7	34
ERM	NA	NA	218	270

Source: USEPA,2011,2012, Chandrasekhar et al.,2003, NA-Not available

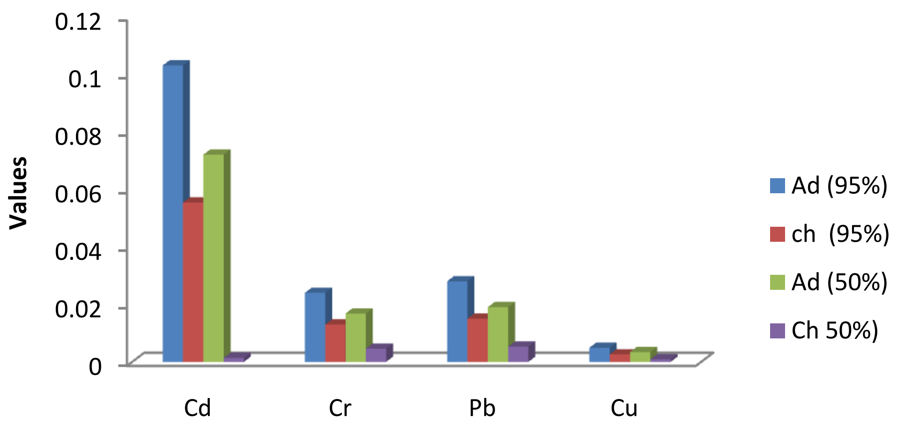

Figure 2: Hazard Quotient of Heavy Metals through Consumption of Water from Elechi Creek

NOTE: Ad (95% & 50%)= Adult at 95 & 50 percentile,

Ch (95% &50%) = Child at 95 & 50 percentile

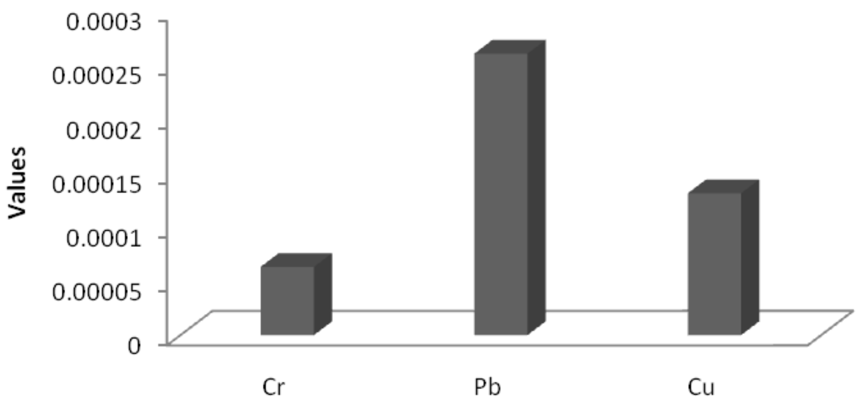

Figure 3: Contamination Factor of Heavy Metals in Sediment of Elechi Creek

IV. Discussion

The mean values of heavy metals (Cd, Cr, Pb and Cu) observed in water in this study are lower than that of sediment except copper. The result of this study is in conformity with that of Davies *et al* (2006) where all the heavy metal values in the sediment were higher than that of the water. The result of this study is also in agreement with the assertion by Christophoridis *et al* (2008) that sediment acts as sink and a potential source of different contaminants in the aquatic ecosystem. The high concentration of copper in both sediment and water in this study is also in line with the finding of Nwoko *et al* (2014) which was attributed to the anthropogenic activities in the area.

The cadmium levels in this study which ranged from 0.0006 – 0.007mg/l with the mean value of 0.00361 + 0.277mg/l is lower than the range of 0.001 to 0.034mg/l in Asa river reported by Eletta (2007). The mean concentration of cadmium in this study (0.00361 + 0.277mg/l) is slightly above the maximum permissible limit (WHO/MPL) for drinking water and world average of trace element in unpolluted rivers (WA) but lower than the threshold concentration for aquatic life (TC) and Bureau of Indian Standards (BIS). Therefore, based on the drinking water standards of World Health organization and World Average of trace elements in unpolluted rivers, this result showed that there is contamination of the surface water with cadmium. Cadmium concentration is also slightly higher than the Criterion Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) of USEPA (2006). Cadmium is relatively mobile and its environmental levels are influenced by industrial operations since it has both natural and anthropogenic sources. Cadmium concentration in this study is also comparable to the 0.006mg/l reported by Trocine and Trefry (1996) in Indian Rivers, Florida USA, and 0.005mg/l reported by Okonkwo and Motheba 92005) in Madanzhe river.

The mean concentration of Chromium (Cr) observed in this study (0.0042 + 0.196mg/l) is also in agreement with the value (0.04mg/l) reported by Eletta (2007) in Asa River, Nigeria which is below the WHO and BIS permissible values for drinking water quality. The value is also below the criterions maximum concentration (CMC) and criterion continuous concentration (CCC) of USEPA (2006).

The mean value of lead (Pb) observed in this study (0.00387 + 0.136mg/l) is also below the permissible limit or standard of WHO, BIS, WA, TC and CMC but slightly higher than the Criterion Continuous Concentration of USEPA (2006). Therefore, with respect to CCC (USEPA, 2006), Elechi surface water is not contaminated with Pb.

The presence of Cadmium (Cd) in both water and sediment in this study is in disconformity with the finding of Mwamburi (2003) where there was presence of Cd in water but absent in the sediment. The values of Cd among the heavy metals observed in this study except chromium are contrary and less than that reported by Davies *et al* (2006) from Elechi creek, Port Harcourt, Nigeria.

With the exception of heavy metal such as Cd value in this study which exceeded the TSE – 266 (Turkish Standards, 2006) and WPCL (water pollution control legislation, 2004), guideline other heavy metals concentrations such as Cr, Cu and Pb did not exceed the TSE-266 Wpd (2004), CIW (Anonymous, criterion of the irrigation water, 1997) and EC (European Community, 1998) water guideline. Therefore with respect to TSE – 266 (2006) and WPCL (2004) standard, Elechi creek is polluted with cadmium.

The concentration of Cu in the water in this study is lower than the 0.01mg/l in Avsar Dam lake reported by Ozturk *et al* (2009) and the 0.02mg/l and 0.034mg/l in Demirkopru Dam lake and Gediz River reported by Ozturk *et al* (2008) and Uzunoglu (1999) respectively. Comparing the mean concentration of Cu in this study with the water guideline of TSE-266 (2005), WPCL (2004), CIW (Anonymous, 1997), WHO (1993), EC (1998) and EPA (2002), Elechi Creek is not polluted with copper.

The order or magnitude of concentration of heavy metals in the sediment in this study (Cu > Cd > Pb > Cr) differs from the order (Cr > Cu > Pb) reported by Bhuvaneshwari *et al* (2016) in River Cauvery and the Cu > Cr > Pb > Cd reported by Ozturk *et al*., (2009) in Avsar Dam Lake in Turkey. The sediment heavy metal(Cd, Cr, Pb and Cu) concentrations observed in this study area are all lower than the BV – Background values of metal in India, (Chandrasekhar *et al*., 2003), US – unpolluted Sediment (Kumar *et al*., 2010), ISQG – Interim sediment Quality Guidelines (CCME, 2002), PEL – probable effect level and PL – permissible limit (Chandrasekhar *et al*., 2003). These values are also lower than the lowest effect level (LEL – NOAA 2009) and Severe Effect Level (SEL–NOAA,2009). According to the Canadian Sediment Quality Guidelines, there is no indication of possibility of adverse effects in consuming the water and its resources.

Considering United State Environmental Protection Agency (USEPA) toxicity classification, Elechi creek is a non–polluted lake since all the studied heavy metals (Cr, Pb and Cu) concentrations were within the permissible limit of the standard except Cd. The level of contamination of Elechi creek is therefore not hazardous to man and other organisms.

According to Ukoha *et al* (2014), health risk assessment is an essential tool to determine the consequences of human action and to measure the adverse effect of public health.

The HQ of cadmium in this study is higher than any other metals studied though below unity (K1) just as others which will not pose health risk. The HQ of all metals studied are higher in adult at both 95^{th} and 50^{th} percentile than children which indicates more health risk in adult than children which is in line with the assertion that difference in age and exposure conditions might also contribute to risk.
The HQ value of all the metals in this study is within the range of values reported by Wu *et al* (2009) in the waters from Yangtze River, China and Huguet *et al* (2009 in Ebro River, Spain but far lower than that reported by Bhuvaneshwari *et al* (2016) in River Cauvery.

According to Puyate *et al* (2007) contamination factor (CF) with value less than 1 (unity) refers to low contamination, therefore Elechi creek has low contamination. The calculated values of CF for Cd, Cr, Pb and Cu in this study which are all less than unity is in agreement with that reported by Bhuvaneshwari *et al* (2016) in the Cauvery River which was said to cause minimum hazard to the aquatic organisms. Also, the pollution load index (PLI) less than unity and far less than 0.5 obtained in this study showed that there is low or no contamination and therefore cannot cause hazard to the aquatic organisms. This simply means that the environment is safe for the organisms which is in turn safe for human consumption

V. Conclusion

The heavy metal concentrations of the water and sediment showed that there was no pollution except cadmium which exceeded the drinking water standard such as WHO/MPL and WA. This shows that potential danger may exist in years to come depending on agricultural activities and other anthropogenic activities in the area.

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References

[1]. Anonymous,(CIW)(1997). Gediz Havzası Çalışmaları. T.C. İzmir Çevre İl Müdürlüğü, Türkiye. (In Turkish).
[2]. APHA.(1998). *Standard methods for the examination of water and waste water*.20^{th}(Ed), Washington D.C1213pp .
[3]. Bhuvaneshwari,R, A.Paneer,S S. Srimurali, K. Padmanaban, R. B. Rajendran(2016).Human and Ecological Risk evaluation of Toxic Metals in the Water and Sediment of River Cauvery. *International Journal of Scientific and Research Publications*, 6(3).
[4]. Bureau of Indian Standards (1991). Indian standard drinking water specifications, (IS: 10500), New Delhi. Bureau of Indian Standards.
[5]. Chandrasekhar K., Chary N.S., Kamala C.T., Suman Raj D.S. and Sreenivasa Rao, S. (2003). Fractionation studies and bioaccumulation of sediment –bound heavy metals in Kolleru Lake by edible fish. Environmental International, 29: 1001 - 1008.
[6]. CCME (2002). Canadian Sediment Quality Guidelines for the protection of aquatic life. Summary Tables. Updated 2002. In: Canadian Environmental Quality Guidelines, 1999.
[7]. Christoforidis A., Stamatis N., Schmieder K. and Tsachalidis, E. (2008). Organochlorine and mercury contamination in fish tissues from the River Nestos, Greece. Chemosphere, 70: 694 - 702.
[8]. Davies O. A., Allison M.E and Uyi, H. S.(2006).Bioaccumulation of heavy metals in water, sediment and periwinkle (*Tympanotonus fuscatus var radula*) from the Elechi Creek, Niger Delta. *African Journal of Biotechnology* 5 (10), 968-973.
[9]. EC (European Commission), (1998). Council Directive 98/83/. EC of 3 November 1998 on the quality of water intended for human consumption. L 330/32, 5.12.98.
[10]. EC (European Commission), (2005). Commission Regulation (EC) No 78/2005 of 19 January 2005 amending Regulation (EC) No 466/2001 as regards heavy metals, L 16/43–45.
[11]. EPA (Environmental Protection Agency), (2002). Risk assessment: Technical background information. RBG Table. Available from http://www.epa.gov./reg3hwmd/risk (online update: 23.03.2009).
[12]. Eletta O.A.A. (2007). Determination of some trace metal levels in Asa river using AAS and XRF techniques. International Journal of Physical Science, 2(3): 56 - 60.
[13]. Food and Agricultural Organisation. (1983). Compilation of legal limits for hazardous substances in fish and fishery products. FAO Fish Circular, 464: 5 – 100.
[14]. Förstner, U. and Wittman, G.T.W. (1981) Metal Pollution in the Aquatic Environment. 2nd Edition, Springer-Verlag, Berlin, 486.
[15]. Huguet F.N., Nadal M. and Schuhmacher M. (2009). Human health risk assessment for environmental exposure to metals in the Catalan Stretch of the Ebro river, Spain. Human and Ecological Risk Assessment, 15: 604 - 623.
[16]. Kalay M. and Canli M. (2000). Elimination of essential (Cu, Zn) and non-essential (Cd, Pd) metals from tissues of a freshwater fish Tilapia zilli following an uptake protocol. Turkish Journal of Zoology, 24: 429 - 436.
[17]. Kumar B., Senthil Kumar K., Priya M., Mukhopadhyay D. and Shah R. (2010). Distribution, Partitioning, Bioconcentration potential of trace elements in Water, Sediment and fish collected from Sewage fed fish ponds in Eastern Kolkata, India. Toxicological and Environmental Chemistry, 92(2): 243 - 260.
[18]. Moalla, S.M.N., Awadallah, R.M., Rashed, M.N., Soltan, M.E., 1998.Distribution and chemical fractionation of some heavy metals inbottom sediments of Lake Nasser. Hydrobiologia 364, 31–40.
[19]. Murray, W. (1996). Mechanisms controlling the distribution of trace elements in oceans and lakes. Advances in Chemistry Series, 216, 153-184.

[20]. Mwamburi J. (2003). Metal Sources And Distribution In Rivers Within The Lake Victoria (Kenya) Catchment Area. Lake Victoria Fisheries: Status, biodiversity and management. *Aquatic Ecosystem Health and Management Society*.

[21]. NOAA (National Oceanic and Atmospheric Administration), (2009). SQUIRT, Screening Quick Reference Tables for in Sediment, http://response.restoration. noaa.gov/book_ shelf/122_ NEW-SQuiRTs.pdf (online update: 23.03.2009).

[22]. Ocheing E.Z., Lalah J.O. and Wandiga S.O. (2008). Water quality and trace metal distribution in a Pristine Lake in the Lake Basin in Kenya. *Bulletin of Environmental Contamination and Toxicology,* 80: 362 - 368.

[23]. Okonkwo J.O. and Mothiba M. (2005). Physico-chemical characteristics and pollution levels of heavy metals in the rivers in Thohoyandou, *South Africa Journal of Hydrology*, 308: 122 - 127.

[24]. Öztürk,M.G. Özözen, O. Minareci,E. Minareci (2009).Determination Of Heavy Metals In Fish, Water And Sediments Of Avsar Dam Lake In Turkey. *Iran. J. Environ. Health. Sci. Eng., 2009, Vol. 6, No. 2, Pp. 73-80*

[25]. Öztürk, M., Özözen, G., Minareci, O., and Minareci, E., (2008). Determination of heavy metals in of fishes, water and sediment from the Demirköprü Dam Lake(Turkey). Journal of Applied Biological Sciences, **2(**3**):** 99–104.

[26]. Pan X.D., Tang J., Chen Q., Wu P.G. and Han J.L. (2013). Evaluation of direct sampling method for trace elements analysis in Chinese rice wine by ICP–OES. *European Food Research and Technology*, 236: 531–535.

[27]. Puyate Y.T., Rim-Rukeh A. and Awatefe J.K. (2007). Metal Pollution Assessment and Particle Size Distribution of Bottom Sediment of Orogodo River, Agbor, Delta State, Nigeria. *Journal of Applied Sciences Research,* 3(12): 2056 - 2061.

[28]. Purves, D., 1985. Trace Element Contamination of the Environment. Elsevier, Amsterdem.

[29]. Sung Y.H. and Huang S.D. (2003). On-line preconcentration system coupled to electrothermal atomic absorption spectrometry for simultaneous determination of bismuth, cadmium and lead in urine. Analytica Chimica Acta,495: 165-176.

[30]. TFC, Turkish Food Codes, (2002). Official Gazette, 23 September 2002, No. 24885.

[31]. Trefry (1996) Metal concentrations in sediment, water and clams from the Indian River Lagoon, Florida. Marine Pollution Bulletin 32:754-759.

[32]. TSE–266 (Turkish standars), (2005). Insani tüketim amaçlı sular hakkında yönetmelik. Türk Standartları, Ankara. (In Turkish).

[33]. Tomlinson D.L., Wilson J.G., Harris C.R. and Jeffney D.W.(1980). Problems in the assessment of heavy metal levels in estuaries and the formation of a pollution index. Helgolander Wissenschaftliche Meeresuntersuchungen, 33: 566 - 572.

[34]. Turner J.W.D., Sibbald R.R. and Hemens J. (1986). Chlorinated secondary domestic sewage effluent as a fertilizer for marine aquaculture. III. Assessment of bacterial and viral quality and accumulation of heavy metals and chlorinated pesticides in cultured fish and prawns. Aquaculture, 53(2): 157 - 168.

[35]. Ukoha P.O., Ekere N.R., Udeogu U.V. and Agbazue V.E. (2014). Potential health risk assessment of heavy metals [Cd, Cu And Fe] concentrations in some imported frozen fish species consumed in Nigeria. International Journal of Chemical Sciences, 12(2): 366-374.

[36]. USEPA IRIS (2006). United States, Environmental Protection Agency, *Integrated Risk Information System*. <http://www.epa. Gov/iris/subst>.

[37]. USEPA (2006). Partition Coefficient of metals in surface water, soil and waste, Office of the Research and Development, EPA/600/R-05/074, 2005.

[38]. WHO (2004). Guidelines for drinking water quality. Vol. 1:3rd ed., Geneva, World Health Organization.

[39]. WHO (World Health Organization), (1993). Guidelines for drinking water quality. Recommendations, vol. 1, 2nd ed., Geneva.

[40]. WHO/FAO (1993). Toxicological evaluation of certain food additives and contaminants . Geneva, World Health Organization (WHO Technical Report Series, No. 837).

[41]. WPCL (Water Pollution Control Legislation), (2004). Land-Based Water Quality Classification, Official journal, 25687, Turkey.

[42]. Wu B., Zhao D.Y., Jia H.Y., Zhang Y., Zhang X.X. and Cheng S.P. (2009). Preliminary risk assessment of trace metal pollution in surface water from Yangtze River in Nanjing section, China. Bulletin of Environmental Contamination Toxicology, 82: 405 - 409.

[43]. Wyse, E. J., Azemard, S., and Mora, S. J., (2003). Report on the World-wide Intercomparison Exercise for the Determination of Trace Elements and Methylmercury in Fish Homogenate IAEA-407, IAEA/AL/144 (IAEA/MEL/72), IAEA, Monaco.

[44]. Yang R.,Yao T., Xu B., Jiang G. and Xin X. (2007). Accumulation features of organochlorine pesticides and heavy metals in fish from high mountain lakes and Lhasa River in the Tibetan Plateau. Environmental International, 33: 151 - 156.

[45]. Zabetoglou, K., Voutsa, D. and Samara, C. (2002). Toxicity and heavy metal contamination of surficial Sediments from the Bay of Thessaloniki (Northwestern Aegean Sea) Greece. Chemosphere, 49, 17-26.

B.B Otene. " Human and Ecological Risk Assessment of Heavy Metals in Water and Sediment of Elechi Creek, Port Harcourt, Nigeria.." IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 13.3 (2019): 01-07.