Sky Journal of Biochemistry Research Vol. 5(4), pp. 031 – 047, September, 2016
Available online http://www.skyjournals.org/SJBR
ISSN 2315-8786 ©2016 Sky Journals

Full Length Research Paper

Heavy metal concentration in fishes from surface water in Nigeria: Potential sources of pollutants and mitigation measures

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Accepted 22 August, 2016

Waste management and surveillance in Nigeria is grossly inadequate, and of poor quality. Human activities typically release wastes into the environment causing pollution. This paper reviews the various sources of heavy metals in Nigerian environment, concentration of heavy metals in different fish body parts and potential health effects associated with consumption of fishes high in heavy metals. It can be stated that each sector including food processing, industrial, pharmaceutical, and dredging; also oil and gas, fertilizer production and pesticides could influence the release of heavy metal above the regulatory limit (i.e. Federal Environmental Protection Agency). These heavy metals could find their way to the aquatic ecosystem via runoff due to precipitation. Thereby accumulating in fisheries above the limit values recommended by various agencies including Food and Agricultural Organization/ World Health Organization, Median international standard, European Union, United State Environmental Protection Agency and Water Pollution Control Legislation. The incipient effect of heavy metal due to the bioaccumulation of heavy metals from aquatic organisms cannot be overemphasized; hence, the need for caution. This study concludes by suggesting and conducting Impacts Assessment on projects that could lead to environmental pollution and adhering to suggested mitigation measures as stipulated by Federal Environmental Protection Agency guideline.

Key words: Bioaccumulation, fisheries, health impacts, heavy metals, Nigeria, pollutants.

INTRODUCTION

Pollutants are substances that affect the physical, chemical and biological characteristics of biotic and abiotic components of the ecosystem, thereby, posing a threat to biodiversity. Environmental pollution occurs mainly by anthropogenic activities and to a lesser extent by natural effects. In recent times, natural effects appear to be triggered by the activities of humans. The anthropogenic based environmental pollution is majorly caused by industrialization and urbanization. According to Emere and Dibal (2013), industrialization is essential to the socioeconomic development of a nation. In developing nation, pollution is caused by inadequate or improper waste management strategies. Large chunks of wastes are generated in all sectors of any nation's economy.

Unsafe waste disposal poses a threat to the environment. Three wastes streams exist including; solid wastes (plastic, remnants from food processing, agricultural residues), liquid (effluents from industries, food sector etc.) and gaseous emissions (pollutant gases from processing or manufacturing sector). For instance, during oil palm processing, several wastes are generated including empty fruit bunch, palm press fibre, palm kernel shell and chaff (solid wastes), palm oil mill effluents (liquid wastes) and pollutant gases such as volatile organic compounds, suspended solid matters, carbon

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monoxide, hydrogen sulphide (Ohimain et al., 2013a). In the coastal region of the Niger Delta, oil spills into aquatic environment cause adverse degradation of aquatic life (especially fish), due to terminal operations (George et al., 2014), and export activities (Edem et al., 2009).

Toxic leachates of waste can be transported as runoffs into water bodies (Angaye et al., 2015), or suspended as sediment (Inyinbor et al., 2012). Direct sewage discharge into river has been reported in the Niger Delta (Agedah et al., 2015; Ogamba et al., 2015). Anim-Gyampo et al. (2013) enumerated the source of heavy metals in the environment to include weathering and dissolution (natural processes), agriculture through the use of fertilizers, pesticides (fungicides, herbicides, and insecticides) and industrial activities that releases gaseous, liquid and solid wastes. Unyimadu et al. (2008) also noted that exploration and exploitation of oil including spills, use drilling chemicals and combustion of fuel releases heavy metals into the environment. As such, heavy metal is a major pollutant in river because in large enough doses, it can prove lethal to organisms including humans (Inyinbor et al., 2012).

Generally, pollution of natural freshwater by heavy metals (iron, zinc, lead, nickel, manganese etc) is a worldwide problem (Abdullah et al., 2007). The Nigeria aquatic ecosystem is a home to several species of shelled and fin fish. Generally, fish species found in different location in Nigeria water ways have been widely studied by several authors (Odo et al. 2009; Abowei and Hart 2007; 2008; Abowei and Ogamba 2013; Abowei et al. 2007; 2008; Ezekiel et al. 2002; Ogamba et al 2013a; 2013b; Sikoki et al. (1998), Solomon et al. (2012), Badejo and Oriyomi (2015), Oyewo (2015), Davis (2009), Sikoki et al. (2008), (http://fish.mongabay.com/data/Nigeria.htm. Accessed August 2nd 2016). The availability of fish species depends on the type of the water body and prevailing water quality parameters. For instance, shell fish such as bivalve and periwinkle are found in brackish water or estuarine and sea/marine water; while different fish species are found in surface water including fresh, brackish and marine ecosystem. The water quality parameters such as salinity, ions vary significantly on three kinds of water bodies.

In aquatic ecosystem, three major constituents exists. These include water, sediment and aquatic life (i.e. planktons, fisheries etc). According to Titilayo and Olufemi (2014), fisheries are often found at the top of the aquatic food chain and can accumulate higher concentration more than the sediment and water. In a study conducted by Ogamba et al. (2015), a higher concentration of lead and cadmium was observed in muscle and bone of *Citharinus citharaus* and *Synodontis clarias* than in sediment and water were both fish species were obtained from. Fisheries typically bioaccumaulate metals in their body (tissue, liver, kidneys, bone, blood, and fin) through the metal laden contaminated water when ingested and absorbed. The uptake of the heavy metal by fisheries is mostly through epithelia surface, gill pores, water and ingested food. The adverse effect of heavy metal on fish is toxic and could lead to changes in the physiological and metabolic process of their body (Emere and Dibal, 2013). Heavy metal could cause lesion in the body and lead to haematological, histopathological and biochemical impairment.

Due to the apparent bioaccumulation and magnification of fish, as pathways to pollution from one trophic level to the other (Akan et al., 2012), which are capable of inducing toxic level of heavy metals in fisheries (Ekeanyanwu et al., 2011), biomonitoring of hazardous substance need to be checkmated in fisheries. Fisheries are used as bioindicators to monitor heavy metals levels in aquatic ecosystem (Uniyimadu et al., 2008). In Nigeria, most industries dispose their effluents without treatment into the environment (Idris et al., 2013). In this way, the various constituents of such wastes may end up in the aquatic food chain. Since fisheries is a major source of protein to several people in Nigeria, hence, this study reviews the concentration of heavy metals found in different commonly consumed fish assemblages from surface water in Nigeria. This paper concludes by suggesting ways of reducing heavy metals toxicity in the aquatic ecosystem.

Possible sources of heavy metals in surface water in Nigeria

Nigeria is a diverse country with several economic activities. Agriculture is a notable activity that is a major source of livelihood to the inhabitants of the country. Nigeria has fertile and arable land that enhances the cultivation of crops. The Nigerian agricultural sectors include food processing, forestry, agro-allied, fisheries and other aquatic animals.

Nigeria is known globally for the production of certain food. For instance, Nigeria is the largest producer of cassava and fifth largest producer of oil palm in the world (Izah and Ohimain, 2015). Also, the country has several economic trees and this has been over exploited in some part of Nigeria. For instance, the activity of saw mill and lumbering is high in the coastal region of Bayelsa State, Niger Delta of Nigeria. Timbers are basically used in the production of several products including furniture (table, chair, bed), construction materials (building of houses, bridges etc.). Also, in plantation agriculture, several inputs are required including fertilizer, movement of machines (i.e. in terms of mechanized farming), use of pesticides (including herbicides, fungicides, insecticides). In recent time, the use of herbicides for weed control has also increased.

During these agricultural activities, especially food processing, several by-products/wastes are generated. Some of the waste contains heavy metal, while the processing equipment which is typically made up of iron and steel could leach some metals such as iron into the product which could manifest in the wastes. For instance, Ohimain et al. (2012, 2013b) have reported the occurrence of heavy metal from palm oil mill processing effluents. Table 1 presents agricultural activities that could lead to higher c ooncentrationf heavy metals into the environment. Again, Bello et al. (2014) also reported that heavy metals including manganese and copper concentration in soil increases while iron decreases with deposition of vegetable oil effluent. Obire et al. (2008) reported that fertilizer effluents specifically from National Fertilizer Company of Nigeria affect water physicochemistry including pH, free ammonia, urea, total dissolved solid and the conductivity. Generally, some of the effluents from agricultural wastes often exceed the Federal Environmental Protection Agency limit while some of these effluents are from food processing. Major heavy metals that exceed the limit include cadmium, chromium, lead, mercury, arsenic, zinc and nickel (Nwosu et al., 2014).

Heavy metals could also be generated from industrial sectors including construction of ports, power generation and transmission, railway, drainage system, dredging, housing and recreational system and waste treatment system. During these activities some of the materials used in production could contain traces of heavy metals.

For instance, during dredging, it was reported that the heavy metal in surface water increases above the normal concentration (Ohimain et al., 2008). Again, Nigeria is an oil and gas producing nation especially in the Niger Delta region. Nigeria also has other resources and minerals. Some of these resources are tin, iron ore, coal, lead, zinc, limestone, niobium (Izah and Srivastav, 2015). During the mining of these resources, heavy metals could be released into the environment. Table 2 presents concentration of heavy metal from industrial, manufacturing, construction activities in Nigeria. Agah et al. (2014) have reported metallic contaminations of Azuiyiokwu Creek resulting from infiltration of effluents from Ebonyi Fertilizer and Chemical Plant in Ebonyi state. Fertilizers specifically contaminate surface water indirectly. This is because they are not added to aquatic plant to enhance their growth. Generally, fertilizer and pesticides is a major cause of water contamination. This is because chemical fertilizers contain macro nutrients including nitrates, phosphates, potassium, calcium, magnesium, sulphur, boron, manganese, iron, molybdenum and copper (Agu et al., 2014). According to Agu et al. (2014), the use of chemicals in agriculture could cause pressure on the ecosystems and can directly or indirectly, positively or negatively affect the services of a functioning ecosystem.

However, the concentration of heavy metals in the industrial and fertilizer effluents often exceeds the limit values for all categories of industries in Nigeria. During runoff, fertilizer could be deposited in the aquatic ecosystem. The runoff could be transported along with domestic wastes, thereby causing pollution depending on the toxic constituents of the wastes.

Some of these waste streams are discharged into land and during rainfall, it could find its way into the aquatic ecosystem via runoff. The pollution level increases during the rainy season. During the dry season, the action of wind becomes more pronounced in the transport of hazardous substances which could bioaccumulate in aquatic ecosystem. Similarly, some of these wastes are also deposited directly on the aquatic ecosystem. For instance, Edward et al. (2015), Awotoye et al. (2011) reported that palm oil mill effluents are discharged in surface water in some locations in Nigeria. Beside heavy metals in palm oil mill effluents, other constituents of palm oil mill effluents and cassava mill effluents could cause acidification, eutrophication, depletion of oxygen, turning the water to smelly, which could affect the health of the biota in such environment. Olaniyi et al. (2013) reported that cassava processing effluents can alter haematological parameters (especially haemoglobin, red blood cells counts and packed cells volume) thereby leading to decrease in cellular iron resulting in low oxygen carrying capacity of the blood and biochemical indices of fish (*C. gariepinus*) (causing high asparate aminotransferase and alanine aminotransferase which is an indication of destruction hepatic cellular function while low alkaline phosphatase is an indication of liver disease and hypoproteinea and decline in cholesterol level could be due to destruction of liver cells resulting to decease synthesis within). Hence, cassava effluents are toxic fish life (Olaniyi et al., 2013; Olufayo and David, 2013).

Heavy metals could also enter the environment through waste. Generally, the management of wastes in Nigeria is generally challenging. Solid wastes are basically deposited in several areas including along the streets, gutters, drainage channels, rivers, abandoned plots of land etc. According to Ohimain (2013), Abah and Ohimain (2010), Oyoh and Evbuomwan (2008) poor wastes management causes obstruction of drainage systems thereby causing flood, poor aesthetics, release of foul odour and greenhouse gases, obstruction of traffic flow and pollution of surface and ground water. These waste are mainly from anthropogenic activities including hospitals, agriculture, market, workshops, food processing etc. (Angaye et al., 2015). In some locations, wastes from hospital environment are discharged into the environment without treatment (Abah and Ohimain, 2011). According to Al-Ghamdi (2011), Angaye et al. (2015), hospital wastes including pathological, hazardous chemicals, radioactive, stock cultures, blood and blood products, animal carcasses, pharmaceutical, pressurized containers, batteries, plastics, low level radioactive materials, disposable needles, syringes, scalpels, clinical bandages, gauze, cotton and other sharp items could be hazardous. These wastes could contain traces of heavy metals. Also, heavy metals have been reported in leachates aligning water bodies (Angaye et al., 2015).

Table 1. Concentration of heavy metals in effluents from agricultural processing activities in different regions of Nigeria.

Activity/waste/effluents	Location	Season	Heavy metals (mg/l)											Reference
			Cd	Cu	Fe	Cr	Mn	Pb	Hg	As	Zn	Ni	Co	
POME	Rivers	-	0.0028 – 0.0231	0.00 - 1.6093	1.812-13.8127	0.00 - 1.6683	-	-	-	-	-	-	-	Ohimain et al., 2012
POME	Bayelsa	-	0.03	2.44	5.62	2.01	-	-	-	-	-	-	-	Ohimain et al., 2013b
Vegetable oil processing	Adamawa	-	-	1.41	5.5	-	2.81	0.00						Bello et al., 2014
Cassava mill effluents	Osun	-	-	-	0.34-1.92	-	-	-	-	-	0.18-0.8	-	-	Okunade and Adekalu, 2013
*Food processing industry	Anambra	Wet	**0.818-1.828	0.872-0.523	1.178 – 2.772	0.701-1.692	-	0.875-2.446	1.252-1.874	0.281-2.211	5.303-9.656	0.599-1.129	0.083-0.523	Nwosu et al., 2014
		Dry	**0.306-1.308	0.00	1.83-4.428	1.082-2.801		2.465-3.313	0.878-3.182	0.602-1.836	3.783-8.262	0.00	0.23-0.783	
Effluent guideline in Nigeria for all categories of industries	Limits	-	<1	<1	20	<1	5	<1	0.05	0.1	<1	<1	-	FEPA, 1991

*Industrial wastewater from different food processing industries namely some of the products include brandy, dark rum, Schnapps, Sachet and bottled water, drugs such as aspirin, syrup and paracetamol; Black Gold Wisky, Sir Peter dry gin and Ponche; POME (palm oil mill effluents)

Table 2. Concentration of heavy metals in effluents resulting from industrial, manufacturing, construction activities.

Activity/waste /effluents	State	Season	Heavy metals (mg/l)											Reference
			Mn	Cu	Fe	Cr	Zn	Pb	As	Co	Hg	Ni	Cd	
Ebonyi Fertilizer and Chemical Plant	Ebonyi	Dry	3.296	6.69	4.059	1.299	1.226	0.388	0.376	2.356	1.538	-	-	Agah et al., 2014
		Wet	2.007	5.007	2.110	1.01	1.21	0.29	0.239	0.911	1.031	-	-	
Industrial waste water	Oyo	-	-	1.9-6.7	-	1.9-3.9	-	0.3-0.7	-	-	-	1.4-4.4	0.1-0.9	Ayeni et al., 2014
*Brewery sludge	Lagos	-	-	79.67-100.75	-	29.33 – 47.92	-	9.89-34.42	-	5.98-7.00	-	-	0.59-1.84	Olowu et al., 2012
Surface water following dredging	Delta	-	14.30	15.36	229.5	0.27	9.56	2.57	-	-	-	-	0.39	Ohimain et al., 2008
Surface water following dredging	Imo	-	4.01	5.11	6.55	2.0	5.82	3.02	-	-	-	-	0.9	Udensi et al., 2014

Cement effluents point of discharge into the river	Kogi	-	0.05	0.02	-	-	0.06	0.05	-	-	-	-	-	Inyinbor et al., 2012
Surface water inside National Petroleum Corporation (NNPC) depot	Oyo	-	-	8.714	-	0.052	5.096	0.195	-	-	-	0.135	0.195	Adewuyi and Olowu, 2012
Effluent guideline in Nigeria for all categories of industries	Limits	-	5	<1	20	<1	<1	<1	0.1	-	0.05	<1	<1	FEPA, 1991

* Data is expressed as µg/l

Detailed review on the activities and wastes leading to the release of heavy metal has recently been reported by Izah et al. (2016). Anietie and Labunmi (2015) have also reported the occurrence of heavy metal in dumpsite.

Pharmaceutical effluents are typically generated by pharmaceutical industry during the process of drugs production (James et al., 2013). Most pharmaceutical effluents are known to contain varying concentrations of organic compounds and total solids including heavy metals (Anyakora et al., 2011; James et al., 2013) including mercury, cadmium, isomers of hexa-chlorocylohexane, 1,2-dichloroethane and other solvents (James et al., 2013). Furthermore, Anyakora et al. (2011) reported high presence of nickel, lead, cadmium and chromium in the effluents from the pharmaceutical companies in some location in Nigeria which could pose adverse consequences on health of the biota and environment. Table 3 presents the heavy metal concentration from pharmaceutical effluents.

The wastes streams/effluents resulting from use of pesticides, fertilizer, and some material used in construction work and some mining and industrial activities could emit traces of heavy metals into the environment. These trace metals could be deposited into the aquatic ecosystem via runoff during rainfall. On water bodies, heavy metal could go into solution and sink at the bottom of the water and found in sediment and bioaccumulate in aquatic organisms including macrophytes such as water hyacinths, shell fish (periwinkle and bivalve), fin fish (several species of fish that have swimming bladder, and different type of fins). During feeding by aquatic organisms such as fishes, they may incorporate heavy metals into their bodies, and may remain for a very long time and bioaccumulate (Akintujoye et al., 2013).

Concentration of heavy metals in tissues/organs of freshwater fishes in Nigeria

Heavy metals have been severally reported in fisheries from surface water sources in Nigeria. This section of the paper discusses the concentration of heavy metals commonly found in different parts of different fishes found in surface water in Nigeria with regard to their permissible/tolerable limits as recommended/ specified by Food and Agricultural Organization/ World Health Organization, Median international standard, European union, United State Environmental Protection Agency, Water Pollution Control Legislation and World Health Organization. Table 4 shows the concentration of heavy metals that have been reported in different parts of fishes from surface water in Nigeria. Furthermore, the heavy metals in the different fish part frequently exceed the limits recommended by Food and Agricultural Organization/ World Health Organization, Median international standard and European union and seldom exceed the limit recommended by United State Environmental Protection Agency, Water Pollution Control Legislation and World Health Organization (Table 5).

Several fish species have been studied for bioaccumulation including *Arius gigas, Chrysicthys furcatus, Chrisichthyes nigrodigitatus, Chrysicthys walker,* Catfish, *Cithrinus citharus, Clarias anguillaris, Clarias camerunensis, Clarias garepinus, Clarias lazera, Ethmalosa fimbriata, Hydrocynus forskahlii, Hyperopisus bebe occidentalis, Ilisha africana, Mugil cephalus, Oreochromics niloticus, Parachana obscura, Pseudotolithus elongates, Synodentis budgetti,*

Table 3. Concentration of heavy metals in effluents resulting from pharmaceutical effluents.

Activity/waste/ effluents	State	Point source	Heavy metal (mg/l)									Reference
			Cd	Cu	Fe	Cr	Zn	Pb	Ni	Co	Mn	
Pharmaceutical effluents (1st – 3rd batch)	Lagos	-	0.00-0.280	0.0-0.337	-	0.0-0.513	0.0 – 1.407	0.0-0.644	0.0-0.132			Anyakora et al., 2011
Pharmaceutical	Niger state	*	0.06	0.15	9.28	-	2.25	0.09	0.22	0.0	1.20	Idris et al., 2013
		**	0.00	0.04	3.91	-	0.12	0.01	0.07	0.0	0.62	
Pharmaceutical (1st – 3rd batch)	Ogun state	-	0.008-0.081	0.115-0.227	-	0.019-0.52	-	0.00-0.028	0.30-0.935	0.00-0.043	-	James et al., 2013
Effluent guideline in Nigeria for all categories of industries	Limits	-	<1	<1	20	<1	<1	<1	<1	-	5	FEPA, 1991

* = point of discharge of waste water in to the drain, ** = point of discharge of waste water in to River.

Table 4. Bioaccumulation of heavy metal on fish species found in surface water in Nigeria.

Fish species	Fish part	Cadmium, mg/kg	Lead, mg/kg	Chromium, mg/kg	Mercury, mg/kg	Iron, mg/kg	Copper, mg/kg	Nickel, mg/kg	Zinc, mg/kg	Manganese, mg/kg	Cobalt, mg/kg	River	State	References
Arius gigas	Gill *	1.44	85.85	7.15	-	121.02	2.19	4.03	67.85	-	-	Warri river	Delta	Aghoghovwia et al., 2016
	Muscles*	1.25	39.83	3.80	-	55.00	2.14	3.58	37.10	-	-			
	Liver *	3.80	94.00	11.18	-	146.02	26.50	12.05	112.20	-	-			
	kidney *	1.87	110.95	11.34	-	157.59	3.96	6.56	97.29	-	-			
Catfish	Gill	0.14	<0.01	0.04	-	-	-	-	-	0.13	-	Okumeshi river	Delta	Ekeanyanwu *et al.,* 2011
	liver	0.28	0.01	0.14	-	-	-	-	-	0.43	-			
	Muscle	0.45	<0.01	0.04	-	-	-	-	-	1.89	-			
	Bone	0.09	<0.01	0.05	-	-	-	-	-	0.45	-			
Chrisichthyes nigrodigitatus	Tissue	0.00	0.21	7.41	-	48.31	4.84	3.69	17.40	-	-	Lower Sombreiro River	Niger Delta,	Wokoma, 2014
Chrysicthys furcatus	Gill *	1.24	15.28	1.90	-	67.25	3.10	6.30	117.02	-	-	Warri river	Delta	Aghoghovwia et al., 2016
	Muscles*	1.10	38.75	2.10	-	37.95	3.57	5.20	50.50	-	-			
	Liver *	3.35	20.25	5.93	-	116.20	10.00	14.45	152.20	-	-			
	kidney *	1.53	19.08	2.81	-	80.12	6.33	9.43	153.38	-	-			

Chrysicthys walkeri	Gill *	0.99	12.60	2.15	-	129.20	6.50	19.20	66.13	-	-			
	Muscles*	0.84	7.48	2.68	-	61.25	5.10	7.91	38.93	-	-			
	Liver *	2.58	16.50	7.23	-	176.20	14.04	18.25	110.02	-	-			
	kidney *	1.73	17.72	3.74	-	168.19	9.42	25.65	93.34	-	-			
Cithrinus citharus	Muscles	0.015-0.016	0.005-0.007	-	0.001-0.002	-	-	-	-	-	-	River Nun	Bayelsa	Ogamba et al., 2015
	Bones	0.024-0.030	0.024-0.028	-	001-0.002	-	-	-	-	-	-			
Clarias anguillaris	Tissue*	0.11-0.76	0.13-0.45	0.22-0.93		0.98-8.88	0.08-0.29	0.23-0.73	0.06-0.44	014-0.38	0.26-0.89	River Benue	Adamawa	Akan *et al.,* 2012
Clarias camerunensis	Bone	0.028	0.625	7.776	-	-	-	-	-	-	-	Ikoli Creek	Bayelsa	Ogamba et al., 2016a
	Tissue	0.018	0.218	0.793	-	-	-	-	-	-	-			
Clarias garepinus	Head	0.02-0.39	-	0.06-1.21	-	-	-	1.7-4.59	-	-	-	River Galma, Kubanni	Kaduna	Udiba et al., 2014
	Gills	0.55-1.72	-	0.21-0.75	-	-	-	0.6-6.61	-	-	-			
	Liver	0.91-16.33	-	0.95-8.12	-	-	-	2.01-13.90	-	-	-			
	Muscles	0.06-0.39	-	0.26-0.54	-	-	-	0.17-2.87	-	-	-			
	Gill	0.071	0.023	-	0.005	-	-	-	-	-	-	River Nun	Bayelsa	Ogamba et al., 2016b
	Liver	0.045	0.049	-	0.006	-	-	-	-	-	-			
	Muscles*	0.00 – 0.00	3.41-53.01	13.0-113.1	-	12.12-333.41	72.56-302.02	27.02-152.21	30.03-76.13	62.11-475.23	34.14-114.12	Yah, Arula and Rara streams and associated fish pond	Osun	Titilayo and Olufemi (2014)
	Gills*	0.00 – 0.00	1.03-11.2	29.51-101.01	-	27.13-271.11	44.0-446.0	7.71-47.31	14.22-45.11	73.42-373.12	10.88-103.1			
	fins*	0.00 – 0.00	1.14-2.34	7.01-42.0	-	10.10-112.12	11.21-457.03	3.02-53.17	10.18-69.13	46.01-746.02	9.01-19.11			
	livers*	0.00 – 0.00	1.34-6.01	72.33-89.22	-	97.12-410.53	83.62-703.01	43.34-573.34	11.1-72.22	245.11-399.51	44.17-97.12			
	Gill	0.325	1.28	32.2	-	49.0	2.07	-	7.05	1.73	-	River Benue	Benue	Eneji et al., 2011
	Intestine	0.333	0.678	28.1	-	34.0	2.26	-	6.86	1.17	-			
	Tissue	0.269	0.801	28.2	-	30.1	1.56	-	3.85	0.607	-			
	Gill	-	0.60	-	-	3.58	0.61	-	1.2	-	-	Yobe River	Yobe	El-Ishaq et al., 2016
	Tissue	-	0.92	-	-	2.34	0.60	-	0.28	-	-			
	Muscle	-	1.18	-	-	2.03	0.58	-	2.14	-	-			
	Tissue	-	0.30-0.90	-	-	5.27-6.84	1.0-1.68	-	2.0-2.84	-	-	River Ogbese	Ondo	Olawusi-Peters et al., 2014
	Gill	-	0.1-1.4	-	-	4.23-6.7	1.1-1.44	-	0.27-1.44	-	-			

	Operculum ***	0.13	0.09	1.76	-	-	-	2.67	-	-	0.46	Ogun Estuary	Ogun	Murtala et al., 2012
	Gills***	0.29	0.01	2.54	-	-	-	1.30	-	-	0.06			
	Kidney***	0.41	0.03	2.61	-	-	-	3.43	-	-	0.46			
	Heart***	0.26	0.01	1.73	-	-	-	1.86	-	-	0.55			
	Muscles***	0.00	0.03	1.36	-	-	-	1.37	-	-	0.00			
	Vertebrae* **	0.28	0.02	1.70	-	-	-	2.44	-	-	1.16			
	Liver	0.08	-	0.11	0.00	6.48	-	-	-	0.298	-	Calabar river	Cross River	Joseph et al., 2016
	Gill	0.065	-	0.115	0.00	5.843	-	-	-	0.345	-			
	Muscle	0.045	-	0.115	0.00	5.15	-	-	-	0.187	-			
	Head**	0.005	0.031	-	ND	0.13	0.05	-	0.17	0.22	-	UKE Stream	Nasara wa	Opaluwa *et al.,* 2012
	Gill**	0.016	0.021	-	ND	1.63	1.31	-	2.35	0.12	-			
	Intestine**	0.026	0.012	-	ND	0.26	0.31	-	0.26	0.21	-			
	Flesh**	0.001	0.013	-	ND	0.13	0.15	-	0.18	0.11	-			
Clarias lazera	Gill *	0.73	5.85	1.10	-	25.25	1.59	6.70	26.48	-	-	Warri river	Delta	Aghoghovwia et al.,2016
	Muscles*	0.58	0.91	0.91	-	18.13	0.90	3.65	15.18	-	-			
	Liver *	1.63	11.85	4.63	-	43.43	2.54	10.63	33.50	-	-			
	kidney *	1.05	9.64	1.14	-	50.61	2.45	12.50	35.99	-	-			
Ethmalosa fimbriata	Gill *	0.65	42.08	2.88	-	78.75	3.85	7.61	173.02	-	-			
	Muscles*	0.43	3.40	2.27	-	28.00	2.68	2.90	58.25	-	-			
	Liver *	3.00	111.02	6.93	-	88.53	10.03	9.25	160.02	-	-			
	kidney *	1.00	65.10	4.11	-	102.20	6.36	10.72	210.20	-	-			
Hydrocynus forskahlii	Operculum ***	0.41	0.07	0.37	-	-	-	2.74	-	-	0.73	Ogun Estuary	Ogun	Murtala et al., 2012
	Gills***	0.39	0.25	1.35	-	-	-	3.00	-	-	0.48			
	Kidney***	0.00	0.03	5.64	-	-	-	6.33	-	-	1.17			
	Heart***	0.15	0.04	2.47	-	-	-	2.45	-	-	0.00			
	Muscles***	0.26	0.05	1.36	-	-	-	2.56	-	-	0.43			
	Vertebrae* **	0.45	0.02	1.33	-	-	-	0.00	-	-	0.42			
Hyperopisus bebe occidentalis	Operculum ***	0.32	0.04	0.79	-	-	-	0.02	-	-	1.66			
	Gills***	0.25	0.03	1.95	-	-	-	5.00	-	-	1.23			
	Kidney***	0.00	0.02	4.95	-	-	-	3.66	-	-	0.00			

	Heart***	0.15	0.02	0.68	-	-	-	3.72	-	-	2.32			
	Muscles***	0.13	0.01	1.30	-	-	-	0.00	-	-	0.37			
	Vertebrae***	0.13	0.01	0.98	-	-	-	0.02	-	-	1.12			
Ilisha africana	Gill *	1.64	97.15	6.90	-	64.25	3.68	4.78	75.63	-	-	Warri river	Delta	Aghoghovwia et al.,2016
	Muscles*	1.18	4.10	4.10	-	29.73	2.70	3.30	42.15	-	-			
	Liver *	2.90	108.2	11.30	-	90.25	8.53	9.18	121.20	-	-			
	kidney *	2.29	130.22	9.07	-	88.01	5.36	8.07	89.51	-	-			
Mugil cephalus	Tissue	0.00	0.17	9.91	-	67.43	2.7	4.17	21.37	-	-	Lower Sombreiro River	Niger Delta,	Wokoma (2014)
Oreochromics niloticus	Flesh	-	0.27	2.27	-	-	0.30	-	0.87	-	-	Adamu Lake	Jigawa	Sambo *et al.,* 2014
	Bone	0.044	0.525	3.628	-	-	-	-	-	-	-	Ikoli Creek	Bayelsa	Ogamba et al., 2016a
	Tissue	0.016	0.486	2.52	-	-	-	-	-	-	-			
	Gill *	4.39	15.10	2.38	-	104.02	2.63	16.50	106.02	-	-	Warri river	Delta	Aghoghovwia et al.,2016
	Muscles*	3.73	7.14	2.35	-	34.50	1.53	5.84	60.13	-	-			
	Liver *	12.08	17.50	6.78	-	122.02	3.23	16.00	163.02	-	-			
	kidney *	6.57	20.27	3.76	-	149.86	4.03	26.60	136.22	-	-			
	Gill	-	0.68	-	-	2.74	0.52	-	1.40	-	-	Yobe River	Yobe	El-Ishaq et al., 2016
	Tissue	-	0.92	-	-	1.17	0.7	-	0.34	-	-			
	Muscle	-	0.61	-	-	0.46	0.74	-	1.99	-	-			
	Tissue	-	0.1-1.0	-	-	4.27-5.83	0.51-4.46	-	0.54-2.45	-	-	River Ogbese	Ondo	Olawusi-Peters et al., 2014
	Gill	-	0.9-1.5	-	-	1.89-6.7	1.2-2.86	-	0.4-1.87	-	-			
	Bones***	0.019	0.067-0.069	-	ND	-	-	-	0.10-0.103	-	-	Henshaw town beach market	Cross Rivers	Edem *et al.,* 2009
	Gill***	0.038-0.044	0.133-0.153	-	ND	-	-	-	0.198-0.227	-	-			
	Livers***	0.019-0.049	0.067-0.173	-	ND	-	-	-	0.099-0.257	-	-			
	Muscles***	0.015-0.017	0.053-0.062	-	ND	-	-	-	0.079-0.095	-	-			
	Tissue*	0.18-0.85	0.12-0.61	0.33-0.85	-	0.68-8.92	0.14-0.38	0.23-0.95	0.08-0.21	0.11-0.38	0.06-0.48	River Benue	Adamawa	Akan *et al.,* 2012
Parachana obscura	Gill *	1.20	16.83	2.06	-	75.75	1.80	12.50	66.75	-	-	Warri river	Delta	Aghoghovwia et al.,2016
	Muscles*	0.43	11.52	0.91	-	39.00	1.94	4.68	13.28	-	-			

Table 4 Cont.

	Liver *	1.23	11.68	2.85	-	108.02	3.80	11.18	43.80	-	-			
	kidney *	2.10	25.91	3.34	-	115.89	3.29	17.52	82.88	-	-			
Pseudotolithus elongates	Tissue	0.00	0.23	6.3	-	59.63	5.31	2.89	11.61	-	-	Lower Sombreiro River	Niger Delta,	Wokoma (2014)
Synodentis budgetti	Tissue*	0.13-1.03	0.04-0.38	0.19-0.57		1.86-12.65	0.11-0.31	0.12-0.78	0.23-2.86	0.21-2.33	0.08-0.34	River Benue	Adamawa	Akan *et al.,* 2012
Synodontis clarias	Muscles	0.014 - 0.015	0.005-0.007	-	0.001	-	-	-	-	-	-	River Nun	Bayelsa	Ogamba et al., 2015
	Bones	0.017-0.020	0.015-0.019	-	0.001	-	-	-	-	-	-			
	Head**	0.005	0.021	-	ND	0.12	0.06	-	0.19	0.24	-	UKE Stream	Nasarawa	Opaluwa *et al.,* 2012
	Gill **	0.015	0.014	-	ND	1.52	1.35	-	3.25	0.11	-			
	Intestine**	0.026	0.011	-	ND	0.31	0.25	-	0.21	0.18	-			
	Flesh**	0.001	0.012	-	ND	0.16	0.15	-	0.71	0.11	-			
Tilapia	Gill	0.21	<0.01	0.06	-	-	-	0.11	-	0.17	-	Okumeshi river	Delta	Ekeanyanwu *et al.,* 2011
	Liver	0.31	0.01	0.17	-	-	-	0.14	-	0.49	-			
	Muscle	0.62	<0.01	0.06	-	-	-	0.17	-	1.97	-			
	Bone	0.04	<0.01	0.04	-	-	-	0.07	-	1.48	-			
Tilapia zilli	Gill *	0.81	11.56	1.60	-	87.90	3.76	0.72	69.28	0.09	-	Warri river	Delta	Aghoghovwia et al.,2016
	Muscles*	2.44	13.28	1.61	-	53.50	2.19	11.75	43.15	-	-			
	Liver *	7.40	39.50	4.23	-	187.02	6.23	37.25	130.02	-	-			
	kidney *	1.98	14.93	2.37	-	121.85	7.02	1.18	88.58	-	-			
	Gill	0.351	1.00	31.6	-	53.6	2.98	-	7.15	6.18	-	River Benue	Benue	Eneji et al., 2011
	Intestine	0.337	1.40	31.5	-	7.07	5.36	-	5.66	0.703	-			
	Tissue	0.306	1.18	29.8	-	8.01	1.65	-	5.24	0.935	-			
	Tissue*	0.11-0.96	0.16-0.31	0.05-0.32	-	1.08-9.23	0.12-0.39	0.11-0.69	0.33-3.45	0.11-0.44	0.15-0.82	River Benue	Adamawa	Akan *et al.,* 2012

*Data expressed in μg g^{-1}; ** in mg/g; *** in ppm.

geopolitical zones of Nigeria (i.e. South-South, South-East, South-West, North-Central, North-East and North-West). Most of the studies were carried out in the South-South including Delta and Bayelsa state. Among the various study, Aghoghovwia et al. (2016) reported the highest number of fisheries in the surface water (Warri River) and the heavy metal concentration from this study exceeded the limit of Food and Agricultural Organization/ World Health Organization, Median international standard and European union for cadmium, lead, chromium, copper, and zinc and frequently exceed the limit of cadmium, and lead and rarely exceed iron, copper and Zinc concentration as recommended by United State Environmental Protection Agency, Water Pollution Control Legislation and World Health Organization (Table 5).

Besides the study of Aghoghovwia et al. (2016) from Warri River, the various heavy metals such as cadmium, lead, iron often exceed the various limits, while chromium, copper, zinc, manganese hardly exceed the limit. No limits for cobalt, nickel, and mercury. Their concentration in the fish parts followed the trend of other metals; hence, caution should be exercised on fishes with these metals to avoid possible health effects. Mercury has adverse effect and are essential metal, its presence in consumable food indicate toxicity.

The trend of heavy metal accumulation with regard to various fishes and their part showed non-linear manner. Various authors have reported this trend in fisheries. Based on different part, Aghoghovwia et al. (2016) reported heavy metal trend in eight different fishes as Fe>Zn>Pb>Ni>Cr>Cu>Cd (gills), Fe>Zn>Pb>Ni>Cu>Cr>Cd (muscle, liver and kidney) Ekeanyanwu et al. (2011) reported trend of Cd>Mn>Ni>Cr>Pb (gills), Mn>Cd>Cr>Ni>Pb (liver), Mn>Cd>Ni>Cr>Pb (muscle) for catfish and Tilapia fish) and Mn>Ni>Cr>Cd>Pb (bone) of only Tilapia fish and Mn>Cd>Ni>Cr>Pb (bones) of catfish. Wokoma (2014) also reported heavy trend in tissues of fishes in the order of Fe>Zn>Cr>Cu>Ni>Co>Pb>Cd (*Pseudotolithus elongates* and *Chrisichthyes nigrodigitatus,* Fe>Zn>Cr>Ni>Cu>Co>Pb>Cd (*Mugil cephalus*). Manganese and chromium is mostly controlled by fish through several metabolic pathways (Ekeanyanwu et al., 2011)

The sources of the heavy metal pollutant are mainly from anthropogenic activities and to lesser extent natural effects. Generally, when industrial wastes with toxic heavy metals find its way into the aquatic ecosystem it could have an impact on the biotic composition of such water including fisheries. Hence, the occurrence of heavy metals in aquatic ecosystem is a major concern because of its toxicity potentials (Ntiforo et al., 2012). The bioaccumulation of heavy metals in aquatic biota is mainly dependent on the capacity of the organisms to digest the metals as well as the concentration of such metal in the water body, sediment and surrounding soil feeding habits of such organism (Eneji et al., 2011).

The variations that exist among the various heavy metals on the fishes are very compounding. Basically, it could be due to variation in the level of contaminant in the water bodies. Other authors have variously reported that heavy metal accumulation is influenced by external factors including dissolved metals, physicochemistry, dissolved oxygen, interactions between metals, sediment, food, seasonal effects, geographical differences and internal (individual variability, body size and development stage, sex, breeding condition, brooding, moulting and growth, behavior) (Olgunoğlu et al., 2015; Gokoglu et al., 2008; Çoğun et al., 2006), physicochemical properties of the contaminants, its distribution pattern in the aquatic ecosystem, the feeding mode, lipid content in the tissue and metabolism of the aquatic organism (Ezemonye et al., 2009; Ada et al., 2012; Eneji et al., 2011; Aghoghovwia et al., 2016), type of tissue/organ, age, size of the fish, exposure period, mechanisms of uptake, intrinsic factors and environmental conditions of the habitat of fisheries (Perera et al., 2015; Aghoghovwia et al., 2016).

Among the fishes under the same environmental condition, bioaccumulation level differs according to the location. This could be attributed according to the level of contaminant present in the particular river. Generally, the heavy metals in the different tissues/organs showed irregularly pattern with regards to bioaccumulation and bioavailability. Eneji et al. (2011) attributed this variation to bioavailability, intrinsic fish processes, and trophic structure of the ecosystem as well as variation in thresholds (i.e. concentration of the metal in which it begins to influence the physiology of the fisheries in such manner that once a specific level of the metal has been sequestered in the body) of metals which are a function of homeostasis.

Of all the tissues and organs of fisheries, the gill is the major route through which dissolved metals enter the fish. This could be due to their sensitivity to variations in the water and the ability of gill filaments and lamellae to get in contact with the contaminants in water (Olgunoğlu et al., 2015). The gills of the fish are one of the major sites that play active role in heavy metal accumulation (Eneji et al., 2011; Ekeanyanwu et al., 2011). This could be due to the fact that this (gill) (i.e. gill lamellae) organ is used for respiration.

Potential health effects resulting from consumption of heavy metals

Heavy metals have biological functions. Heavy metals are toxic to life once the concentration exceed the tolerate limit over a long period of exposure. Also, extreme low concentration could also cause adverse effect on the organisms. Izah et al. (2016) have recently reviewed the function of some essential heavy metal that are needed by human bodies and also listed some non-essential heavy metals. For example, iron has an important role as a constituent of enzymes, such as cytochromes and catalase, and of oxygen transporting proteins, such as haemoglobin and myoglobin (Agu et al., 2014). The deficiency of iron could cause various types of diseases (Adesuyi et al., 2015). Eneji et al. (2011) noted that lead is toxic and has many health implications; some other heavy metal also has beneficial properties including copper (which enhance the activity of certain enzyme systems in the body), iron (an active ingredient of the haemoglobin which is responsible for the transportation of oxygen in the body). When heavy metals are transported into the environment, it becomes

Table 5. Permissible limit for heavy metal in fisheries.

Fish species	Level	Cadmium, μgg^{-1}	Lead, μgg^{-1}	Chromium, μgg^{-1}	Mercury, μgg^{-1}	Iron, μgg^{-1}	Copper, μgg^{-1}	Nickel, μgg^{-1}	Zinc, μgg^{-1}	Manganese, μgg^{-1}	references
European Union	Maximum allowable	0.05	0.2	-	-	-	-	-	-	-	European Union (2002) cited in Senarathne and Pathiratne (2007), Senarathne *et al.* (2006)
Median International Standard	Tolerable levels	0.3	2.0	1.0	-	-	20.0	-	45.0	-	Philips (1993) cited in Senarathne and Pathiratne (2007), Senarathne *et al.* (2006)
FAO/WHO	maximum allowable	0.5	0.5	-	-	-	30.0	-	40.0	-	FAO/WHO (1989) cited in Elnabris *et al.* (2013)
*USEPA	-	0.01	0.11	-	-	0.5	2.25	-	5.0	0.02	USEPA, 1998; cited in Anim-Gyampo et al., 2013
*WHO	-	0.01	0.01	-	-	0.30	2.25	-	5.0	0.50	WHO, 2003; cited in Anim-Gyampo et al., 2013
*WPCL	-	0.03	0.05	-	-	0.45	2.00	-	4.25	0.02	WPCL, 2004; cited in Anim-Gyampo et al., 2013

*****Data expressed in mg/kg; FAO/WHO (Food and Agricultural Organization/ World Health Organization); USEPA (United State Environmental Protection Agency); WPCL (Water Pollution Control Legislation); and WHO (World Health Organization).

Table 6. An activity that requires Environmental Impact Assessment (EIA) studies and their impact could indirectly affect aquatic organisms including fisheries.

Activities	Contingencies
Agriculture/Agro-Allied	Ensuring adequate measures for agricultural activities such as wood and timber processing and saw milling requiring about 500 hectares of land
Fisheries	Carrying out EIA studies and applying adequate mitigation measures for fisheries activities involving 50% expansion and covering about 50 hectares of land
Forestry	Carrying out EIA studies on forest resources including logging and conversion of forest land requiring over 50 hectares of land for industrial, housing and agricultural activities
Manufacturing	Carrying out EIA studies on the use of chemical to produce product >100 100 tonnes/day; Petrochemicals; Non-ferrous (i.e. Aluminum, Copper), Non-metallic (Cement requiring 30 tonnes/hour), lime (100 tonnes/day and with burnt lime rotary kiln or 50 tonnes/day and above vertical kiln); Iron and steel (requiring iron ore for production of over 100 tonnes/day); Shipyards (with dead weight tonnage of over than 5,000tonnes) pulp and paper (with production capacity of >50 tonnes/day)
Food, beverages and tobacco processing	Carrying out EIA studies on the construction of different food processing plants. Some of these may include large scale processing of oil palm cassava etc.
Infrastructure including housing	Carrying out EIA studies on infrastructure such as housing, hospital, recreational centre covering over 50 hectares of land, road construction
Ports construction and expansion	Carrying out EIA studies on port construction and/or expansion with about 50% increase (port) and airport having about > 2,500 metres airstrip
Drainage and Irrigation	EIA should be carried out in dams and man-made lakes with surface areas of 200 hectares, drainage of area covering 100 hectares and irrigation area covering an area of 5000 hectares
Railways	Carrying out EIA studies on new and new branch of railway lines
Resort and recreational development	Carrying out EIA studies on establishment of coastal resort and hotels, tourist and recreational centres with about 80 rooms, with over 50 hectares of land
Power generation and transmission	EIA should be carried out for power generation with capacity of about 10 mega-watts, dam and hydroelectric power with about 15 metres high and ancillary structures covering about 40 hectares of land; reservoirs with surface area of about 400 hectares and establishment of both combined cycle and nuclear-fuelled power stations.
Petroleum	EIA should be carried out on oil and gas development including processing, pipeline and storage facilities and depots close to commercial, industrial or residential areas
Mining	EIA should be carried out in mining lease area covering 250 hectares; Ore processing (including concentrating for aluminum, copper, gold or tantalum) and sand dredging area covering 50 hectares.
Quarries	EIA should be carried out prior to establishment of quarrying of aggregate limestone, silica quartzite, sandstone, marble and decorative building stone within 3 (three) kilometers of any existing residential, commercial or industrial area, or any area for which a license, permit approval has been granted for residential, commercial or industrial development.
Waste treatment and disposal system	EIA should be carried out in the construction of Toxic and Hazardous waste system (i.e. incineration, recovery, waste treatment, composting, landfill facility and storage plant.
Water supply	EIA should be carried out in the construction of dams with surface area of about 200 hectares, groundwater that could bring water volume of 4,500 cubic meters per day.
Land reclamation	EIA should be carried out during reclamation of area covering about 50 hectares of land
Brewery	EIA should be carried out during the construction of brewery plant

Source: FEPA (1992).

bioavailable and bioaccumulate. The bioavailability and bioaccumulation process or route varies according to the biodiversity. And on the aquatic organisms such as fisheries they bioacummulate and bio-magnify. Typically, most heavy metals are toxic and some of these include cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc, and when they are released into the environment in large quantities, they become problematic to humans (Idris et al., 2013).

Heavy metals are very hazardous because they are recalcitrant to degradable and have long biological half-lives (James et al., 2013; Olgunoğlu et al., 2015). Most fish farmers harvest fish in their natural habitat especially individuals residing in coastal region of Nigeria. However, in Bayelsa state, fish farming including harvesting from the stock is a major source of livelihood. The incipient effects of consuming contaminated fish could manifest, and could cause health challenges. This is because heavy metals have the potential to accumulate in different body parts (James et al., 2013). Similarly, Akporido and Ipeaiyeda (2014) reported that cadmium and mercury compete with and displace a number of Zn containing metalloenzymes by irreversibly binding to active sites thereby destructing normal metabolism.

Diseases caused by heavy metal are usually severe. According to Akporido and Ipeaiyeda (2014), in zinc mine located in Japan, a rheumatic ailment known as ittai-ittai, killed many people in just one catastrophic episode of cadmium poisoning. Chronic exposure to heavy metal via consumption of food could cause different type of disease. Chronic exposure to cadmium has been found to cause serious damage to kidney, liver, bone. Other diseases that could be caused by heavy metals on exposure include cancer, abdominal pain and skin lesions (arsenic), kidney damage and hypertension (cadmium), development of autoimmunity in which a person's immune system attacks its own cells, thereby leading to joint diseases, kidney and circulatory system and neurons diseases and at high concentration could cause brain damage (mercury and lead) (Akan et al., 2010). However, detailed review on potential disease condition caused by heavy metals including arsenic have been documented by Izah and Srivastav (2015) and other heavy metals such as mercury, lead, cadmium, iron, cobalt, manganese, chromium, nickel, zinc and copper as also been comprehensively documented by Izah et al. (2016). Other authors have listed the adverse effects of heavy metal on humans including lead (Idris et al., 2013; Dabai et al., 2013; Nwaichi and James, 2012; Muhammad et al., 2014), cadmium (Erah et al., 2002; Dabai et al., 2013; Muhammad et al., 2014), copper (Chinedu et al., 2011; Muhammad et al., 2014), iron, chromium and mercury (Muhammad et al., 2014).

Means of mitigating high heavy metals in surface water in Nigeria

Environmental monitory of effluents and other solid waste with potential adverse effect to both the environment and its biotic composition is inadequate in Nigeria. Similarly, surveillance of the wastes management generated in Nigeria is grossly inadequate. However, regulations exist for managing various types of wastes stream in Nigeria. But most producers, manufactures, often ignore some of these rules. Hence, in other to mitigate the eco-toxic effects of heavy metal in aquatic ecosystem, the threshold limits of the various toxic effluent are not to be exceeded, this means that developers and manufacturers must adhere to regulatory instructions.

Nearly all the activities of human that could release heavy metal and/or other toxic materials into the environmental affecting its biota have been comprehensively listed by FEPA (1992) (Table 6). As such, the environmental protection agency has mandated that compulsory Environmental Impact Assessment be carried out for work in these categories. These regulations were aimed to provide less pollution to the environment. But unfortunately, most producers/manufacturers do not carry out Environmental Impact Assessment studies prior to the work of this magnitude as stipulated by FEPA (1992). However, it appears that Environmental Impact Assessment attention is mostly focused on oil and gas and power generation activities in Nigeria neglecting other areas like large scale agricultural practices. As a matter of fact, the agricultural waste generate the largest wastes stream in Nigeria. Therefore to avert the current trend of environmental pollution, Environmental Impact Assessment studies need to be conducted as required by law. Also, potential negative impacts and suggested mitigation measures should be adhered to.

Conclusion and the way forward

In Nigeria, fish from the wild is consumed as fresh or smoked fish. Heavy metals are accumulated in the different body part of fishes (including intestine, gills, fin, intestine, muscles/tissues, kidney, heart, bones). However, the heavy metals including lead, chromium, cadmium, manganese and iron often exceed the permissible limit recommended by Food and Agricultural Organization/ World Health Organization, Median international standard and European union for cadmium, lead, chromium, copper and frequently exceed the limit of cadmium, and lead and rarely exceed iron, copper and zinc concentration as recommended by United State Environmental Protection Agency and Water Pollution Control Legislation. The consumption of fisheries high in heavy metals over a long period of time could cause health related effects. The health effect depends on the particular metals. Detail effects of heavy metal have recently been documented by Izah et al. (2016). Based on the high heavy metal in different body parts of Nigeria fishes, we recommend that detailed Environmental Impact Assessment be carried out on anthropogenic activities for different categories of industry as prescribed by FEPA (1992) and the identified negative impacts be carried out as suggested in the potential mitigation measures.

Acknowledgement

The authors wish to thank the two anonymous reviewers of this publication and the Editor of Sky Journal of Biochemistry Research for their valuable suggestions and comments.

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