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Bioaccumulation of Heavy Metals in Fish Tissues from Selected Surface Water of the Niger Delta, Nigeria.

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Abstract

Environmental pollution by toxic heavy metals does not only elicit concern in the metropolitan cities but also in remote and rural communities where anthropogenic activities are taking place. Bioaccumulation of heavy metals (Pb, Cd, As, Hg, Ni, and Mn) was determined in the liver, heart and kidney of fish from Selected Surface Water of the Niger Delta, Nigeria. Samples were collected and analyzed using AAS under stringent laboratory protocols. The result revealed marked variations and non-uniform distribution of across the study areas. The levels of the heavy metals varied significantly ($p<0.05$) among fish species from the three Rivers. The kidneys possessed the lowest concentration of all the metals assayed. The results of the parameters were below the accepted limit (reference dose). Among the heavy metals assayed, only Manganese (Mn) was observed to be higher than the recommended reference dose (0.14) across the sampling sites. These levels might be due to anthropogenic inputs as there is no industrial activity around the Rivers. The presence of these heavy metals is a threat to public health. The evidence of pathological alterations in heart, livers and kidneys of fish samples appeared to be a useful bio-marker to assess the impact of metal pollution in water on the health of fish and the presence of Cr, Cd, Zn, Pb and Hg in the fish are worrying as it may cause health related problems in the consumers of fish in the study areas.

Keywords: Bioaccumulation, Heavy Metals, Fish, Tissues, Water, Niger Delta.

Introduction

Bioaccumulation is defined as the buildup of contaminant concentrations in aquatic organisms following uptake from the ambient environmental medium. Different sources of exposure contribute to contaminant bioaccumulation. Bioaccumulation describes the accumulation and enrichment of contaminants in organisms, relative to that in the environment. Bioaccumulation can be considered as a particular type of biosorption in which metals are incorporated inside living biomass.

In The Niger Delta, the problem of waterand sediment pollution has been of concern to all stakeholders, following the rate and extent of degeneration of the environment and water bodies by human activities, particularly from industrial and domestic source [1-2] Coastal waters and sediment systems are Vulnerable to pollution by organic, industrial and chemical pollutants/wastes from several industries and human habitats located by the banks and water front [3]. Increase in population has induced urbanization and industrialization withcorresponding discharge of wastes such as heavy metals into the environment.

The term ‘heavy metal’ refers to metals whose specific gravity is greater than 5 g/cm^3 in their standard state [4] and adversely affect the environment and living organisms [5]. According to the World Health Organization (WHO), heavy metals must be controlled in order to assure public safety [6]. Heavy metal pollution is one of the challenges of coastal waters as a result of human activities such as oil exploration and exploitation, construction and fabrication of marine boats, disposal of industrial and domestic wastes and sailing activities [7]. Pollution of aquatic ecosystems by heavy metals is an important environmental problem, as heavy metals constitute some of the most dangerous toxicants that can be bioaccumulated in living tissues [8]. Heavy metals find their way into the aquatic environment via wastes discharges of domestic, commercial, municipal and industrial origin and such wastes contain different concentrations of heavy metals. Fish are sensitive indicators of heavy metal pollution [9]. Hence, fish have been widely used as biological indicators of coastal water and in the determination and assessment of biological effects of contaminants on the marine environment [10].

Fish is important food sources for human body. It provides essential fatty acids like Omega 3, proteins, vitamins and minerals. Despite the nutritive values derived from consumption of these marine fish,it brings about many times a potential hazard concern for human consumers [11].Fish from natural aquatic environment are consumed everyday for nutritional requirements and this could expose such consumers of fish frompresumed polluted areas to health risks. [1] had stated that dietary intake of toxicelements is the main route of exposure for most people. Excess amount of these metals entering into the aquatic ecosystem may pollute the environment and also affect the food chain and ultimately pose serious human health risks to those who depend directly or indirectly on the water body for the supply of fish and water. Also found that fish raised in contaminated waters take up heavy metals in large quantities, enough to cause potential health risks tothe consumers. [12] stated that analysis of fish muscle helps to determine the direct transfer of heavy metals and other contaminates to human via fish consumption [13]. Heavy metals enter the aquatic environment mainly by anthropogenic sources. Fish is at the top of the aquatic food chain and during its life, can accumulate large amounts of toxic elements. Heavy metals are defined by their weight. To be classified as a heavy metal it must have a specific gravity of $2.7 g/cm^3$. Examples include lead (Pb), mercury (Hg), cadmium (Cd) chromium (Cr) and arsenic (As) . Any of these heavy metals can destroy life when they concentrate in the body above accepted levels. Heavy metals have the tendency to accumulate in various muscle tissues of aquatic animals. Contaminated fish enter the body through consumption and they result to health hazards. Heavy metals are commonly found in natural waters and some are essential to living organisms.

Human activities have caused levels of heavy metals in the environment to increase. Metal concentrations in biota are generally low, except in the vicinity of metals pollution [13]. Many aquatic organisms have the ability to accumulate and biomagnify pollutants like heavy metals, in the environment [11].In this study, pollutant such as chromium,lead, cadmium, mercury, nickel, manganese & arsenic will be considered which are capable of bioaccumulation in the tissues of aquatic organisms [13]. Any of these heavy metals can destroy life when they concentrate in the body above accepted levels. Heavy metals have the tendency to accumulate in various organisms and muscle tissues of aquatic animals. Heavy metals are commonly found in natural waters and some are essential to living organisms, examples iron, cobalt, zinc, ruthenium, silver and indium [14]. The heavy metals may become highly toxic when present in certain concentrations. These metals also gain access into ecosystem through anthropogenic activities and get distributed in the water body, tended solids and sediments during the cause of their mobility. The rate of bioaccumulation of heavy metals in aquatic organisms depends on ability of the organisms to digest the metals in rivers; it has to do with the concentration of heavy metals in surrounding soil sediments, as well as feeding habit of the organisms [14]. Though accidental losses of oil represent a relatively large proportion of total oil input to the environment, they are likely to be of most concern from the conservation point of view because the resulting slicks are particularly likely to coat aquatic organisms and emergent vegetation.

Heavy metals occur naturally in aquatic ecosystem, but deposit of anthropogenic origin increase their levels and create environmental problems in coastal zones and rivers [4]. Such metals have been described as non- biodegradable and persistent in the environment and known to cause deleterious effects on animal and human health [7].Excess amount of this metals entry into the aquatic ecosystem may pollute the environment and also affect the food chain and ultimately pose serious human health risk to those who depend directly or indirectly on water body for the supply of fish and water [15]. [3] also found that fish raised in contaminated waters take up heavy metals in large quantity enough cause potential health risk to the consumers.

Heavy metals are often major constituentes of wastes discharged into the aquatic system which ultimately deposit into the underlying sediment. Heavy metal pollution is one of the challenges of coastal water pollution due to human activities such as oil exploration and exploitation, construction and fabrication of marine boats, disposal of industrial and domestic wastes and water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support a human use, like serving as drinking water and/or undergoes a marked shift in its ability to support its constituent biotic communities such as fishes. [10] stated that improperly treated industrial wastes are discharged directly into nearby surface water bodies. Due to the ineffectiveness of purification system; waste may become seriously dangerous, leading to the accumulation of toxic product in receiving water bodies with potentially serious consequences on the ecosystem [16]. The interaction and impact of such wastes with the immediate environment creates pollution problems [13]. In recent times, the activities of oil bunkering and the practice of dumping domestic waste by the river/creek side has further worsened the contamination load of nearby surface water bodies in the Niger Delta. The ultimate discharge of effluent by industries and other anthropogenic activities in and around creeks and rivers constitute a major environmental challenge particularly in developing areas such as the Niger Delta in Nigeria [11].

There are numerous heavy metals, some of which are highly toxic like mercury, lead, arsenic and cadmium. Aquatic organisms accumulate toxic materials at various levels, depending on species, age, season and feeding pattern [17]. None of the metals are biodegradable though they can change forms from solid to liquid, to dust and gas [15]. The ones that are toxic even in minute amounts create instant cellular destruction in any of their forms. Aquatic animals such as fish readily absorb metals and their bodies regulate to accommodate their presence. They are easily stored in fatty tissue and will bioaccumulate if the organisms are exposed to further contamination. Because of high contamination, it is essential to study the fish and heavy metal load in them.

Materials and methods

The study was carried out in Nnembe Creek in Rivers state, Ikot Abasi, River in Akwa-Ibom State, Oguta Lake in Imo state and Onuiyi Ukwu stream, Akabor in Ahiazu Mbaise in Imo state areas of Niger Delta Nigeria. Control is to be taken from Onuiyi Ukwu stream Akabor in Ahiazu Mbaise in Imo state areas of Niger Delta.

Ethical clearance and Authorization letter were obtained from the Department of Health or EPA of the Local Government of the study area. The letter was given to the leaders or the heads of the community. Verbal consent was given to selected villagers to assist in collection of the samples.

Field Sampling

Twelve locations within the surface water systems in Niger Delta were sampled on monthly basis, fish samples were collected and composited on a monthly basis for a period of twelve months. Fish was obtained directly from fishermen using cast net methods.

Estimation of Bioaccumulation Factor of Heavy Metals In Fish Tissues.

Fish, caught in twelve locations for a period of 12 months were put into pre-cleaned polythene bag inside ice pack and transported to the laboratory. They were placed inside oven for drying in readiness for digestion process.

The composited samples were dried and digested using HCL/HNO_3 following the method of the American Society for Testing and Materials (1998). The total concentration of heavy metals were assessed using an Atomic Absorption spectrophotometer (GB Avanta PM AAS, S/N A6600).

Determination of Heavy Metals Concentration in Liver, Heart Andkidney

To assess heavy metals concentrations in liver, heart and kidney of fish caught for 12 months. The fish for analysis were dissected in order to obtain the liver, heart and kidney; and were dried in an oven in a room temperature. They were digested with Aqua Regia (mixture of HCL and HNO3), following the method of the American Society for Testing and Materials (1998). Analysis was done using Atomic Absorption spectrophotometer AAS (Model 210V GP BUCK Scientific (USA) to detect total concentration of heavy metals in liver, heart and kidney.

To Determine The Estimated Daily Intake (EDI) And Target Hazard Quotient (THQ).

Estimated daily intake (EDI): The exposure pathway of heavy metals to humans via intake of contaminated food estimated using the method of Copal *et al*., (2012). The estimated daily intake (EDI) of each metal in this study were determined by the equation:

$$EDI = \frac{E_F \times E_D \times F_{IR} \times C_F \times C_M \times 10^{-3}}{W_{AB} \times T_A}$$

E_F = Exposure frequency 365 days/year

E_D = Exposure duration, equivalent to verge lifetime (65 years)

E_{IR} = Fresh food ingestion rate (g/person/day)

C_F = Conversion factor = 0.208

C_M = Heavy metal concentration in food stuffs (mg/kg d-w)

W_{AB} = Average body weight (bw) was taken as 60kg

E_D = Average exposure of time for non-carcinogens (it is equal to E_F x E_D) as used by in previous studies. The public health risk is evaluated by using the Estimated Daily Intake (EDI) to determine the Target Hazard Quotient (THQ).

Target Hazard Quotient (THQ) is given by: $THQ = \frac{EDI}{RFD_O}$

Where EDI = Estimated daily intake

RFDO = the reference oral dose of individual metal (mg/kg/day)

Results

Bioaccumulation of heavy metals in fish organs

Bioaccumulation of heavy metal contents in fish organs collected at Oguta Lake, Nembee River, Ochen River and Onuiyi stream is presented in Table 15. Results obtained Oguta Lake showed that the mean concentration of Lead (Pb) in liver, heart and kidney ranged from 0.91-1.51, 1.0-1.54, and 1.1-1.60. At Nembee River mean value of Pb ranged from 2.98-4.00, 2.37-4.11, 3.14-1.12; whereas Ochen river recorded 1.97-2.49, 2.00-2.92 and 1.99-2.43. No value of Pb was found in fish organs at the Onuiyi stream (control). Mean concentration of Cadmium (Cd) in fish organs (Liver, Heart, and Kidney) at Oguta Lake ranged between 0.14-0.38, 0.17-0.35, 0.13-0.24; at Nembee River: 0.19-0.51, 0.26-0.42, 0.29-0.50. At Ochen River: 0.18-0.47, 0.21-0.39, 0.27-0.46 while at the control site no value of Cd was obtained. Oguta Lake ranged between 0.24-0.37, 0.17-0.32, 0.13-0.48. in Nembee river, concentration of As in Liver, Heart, Kidney ranged as follows: 0.13-0.39, 0.08-0.16, 0.21-0.29; at Ochen river: 0.28-0.47, 0.20-0.28, 0.19-0.31 while at the control site no value of As was obtained in fish organs. No value of Mercury was obtained in fish organs at Oguta lake, Ochen River and the control site, however, at Nembee river mean levels of Hg ranged between 0.008-0.02, 0.007-0.02, and 0.008-0.02 respectively. Mean levels of Nickel in fish samples in Liver, Heart and Kidney at Oguta Lake ranged between 0.07-0.34, 0.03-0.08, 0.21-0.28. At Nembee river: 0.11-0.49, 0.21-0.32, 0.22-0.34. At Ochen river: 0.08-0.39, 0.10-0.21, 0.17-0.26 while no value was gotten from the control site. From Oguta lake, value of Manganese in fish organs ranged as follows: 0.38-0.95, 0.54-0.70, 0.77-0.87; at Nembee: 0.57-0.63, 0.55-0.68, 0.61-0.69; at Ochen river: 0.61-0.70, 0.60-0.71, 0.62-0.73 while at the control site: 0.007-0.02, 0.08-0.02, 0.007-0.02.

Bioaccumulation of heavy metal contents in fish organs collected at Oguta lake, Nembee river, Ochen river and Onuiyi stream

	Heavy metals	**Pb, µg/g**		**Cd, µg/g**		**As, µg/g**		**Hg, µg/g**		**Ni, µg/g**		**Mn, µg/g**	
Locations	WHO Permissible Limit/ Organs	5.0	Range	1.0	Range	2.0	Range	0.3	Range	0.5	Range	1.0	Range
Oguta lake	Liver	1.41^{c} ±0.01	0.91-1.51	0.25^{b} ±0.07	0.14-0.38	0.26^{b} ±0.06	0.24-0.37	ND	-	0.30^{a} ±0.05	0.07-0.34	0.82^{a} ±0.11	0.38-0.95
	Heart	1.33^{c} ±0.12	1.0-1.54	0.21^{b} ±0.06	0.17-0.35	0.25b ±0.07	0.17-0.32	ND	-	0.06^{e} ±0.02	0.03-0.08	0.67^{c} ±0.08	0.54-0.70
	Kidney	1.37^{c} ±0.14	1.1-1.60	0.18^{c} ±0.04	0.13-0.24	0.26^{b} ±0.06	0.13-0.48	ND	-	0.24^{c} ±0.08	0.21-0.28	0.75^{b} ±0.10	0.77-0.87
Nembee river	Liver	3.54^{a}± 0.41	2.98-4.00	0.41^{a} ±0.09	0.19-0.51	0.32^{a} ±0.08	0.13-0.39	0.01^{a}±0.001	0.008-0.02	0.35^{a} ±0.11	0.11-0.49	0.68^{c} ±0.07	0.57-0.63
	Heart	3.42^{a} ±0.32	2.37-4.11	0.36^{a} ±0.06	0.26-0.42	0.27^{b} ±0.06	0.08-0.16	0.1^{a}±0.001	0.007-0.02	0.27^{b} ±0.09	0.21-0.32	0.63^{c} ±0.06	0.55-0.68
	Kidney	3.53^{a}±0.49	3.14-1.12	0.38^{a} ±0.11	0.29-0.50	0.26^{b} ±0.06	0.21-0.29	0.01^{a}±0.001	0.008-0.02	0.29^{a} ±0.10	0.22-0.34	0.66^{c} ±0.07	0.61-0.69
Ochen river	Liver	2.42^{b}±0.34	1.97-2.49	0.36^{a} ±0.10	0.18-0.47	0.33^{a} ±0.09	0.28-0.47	ND	-	0.31^{a} ±0.09	0.08-0.39	0.67^{c} ±0.07	0.61-0.70
	Heart	2.21^{b}±0.23	2.00-2.92	0.28^{b} ±0.08	0.21-0.39	0.25^{b} ±0.07	0.20-0.28	ND	-	0.12^{d} ±0.06	0.10-0.21	0.67^{c} ±0.08	0.60-0.71
	Kidney	2.34^{b}±0.28	1.99-2.43	0.32^{a} ±0.12	0.27-0.46	0.27^{b} ±0.06	0.19-0.31	ND	-	0.21^{c} ±0.07	0.17-0.26	0.69^{c} ±0.09	0.62-0.73
Onuiyi stream (control)	Liver	ND	-	ND	-	ND	-	ND	-	ND	-	0.01^{d} ±0.001	0.007-0.02
	Heart	ND	-	ND	-	ND	-	ND	-	ND	-	0.1^{d} ±0.01	0.08-0.02
	Kidney	ND	-	ND	-	ND	-	ND	-	ND	-	0.01^{d} ±0.001	0.007-0.02

Mean along the column having different superscript of alphabets differ significantly at P ≥ 0.01 according to Duncan Multiple Range Test, ND = Not detected.

Table 4.18: Two way ANOVA showing variation in metals between locations and organ of different species

Heavy metals	Source	df	F	P
Pb	site	3	14.045	≥ 0.01
	species	36	15.083	≥ 0.01
	organ	2	243.034	≥ 0.01
Cd	site	3	34.217	
	species	36	27.892	≥ 0.01
	organ	2	212.678	
				≥ 0.01
				≥0.01
As	site	3	17.903	≥ 0.01
	species	36	14.781	
	organ	2	123.564	≥ 0.01
	site	3	19.678	
				≥ 0.01
Hg				
				≥ 0.01
	species	36	15.732	≥ 0.01
	organ	2	178.346	
				≥ 0.01
Ni	Site	3	87.435	≥ 0.01

	species	36	46.738	≥ 0.01
	organ	2	342.023	
	site			≥ 0.01
Mn	species	3	56.893	
	organ			≥ 0.01
		36	34.784	
				≥ 0.01
		2	367.935	
				≥ 0.01

Estimation of heavy metal daily intake and target cancer risk in the study locations

Table 18 displays the results of the estimated daily intake (EDI), Target hazard quotient, Hazardous index (HI), Target cancer risk and Reference dose (RfDo) of heavy metals through the ingestion of fishes from the study locations: Oguta, Nembee Ochen and Onuiyi rivers. The results of these parameters that were above accepted limit (reference dose) are indicated in bold fonts. Among the heavy metals assayed, only Manganese (Mn) was observed to be higher than the recommended reference dose (0.14) across the sampling sites.

Estimation of heavy metal daily intake and target cancer risk in the study locations

Heavy metals	locations	EDI	THQ	HI	TR	RfDo
Pb	Oguta river	0.66x10^{-3}	0.183	79.45	1.97x10^{-3}	3.6x10^{-3}
	Nembee river	0.81x10^{-3}	0.225		3.08x10^{-3}	
	Ochen river	0.77x10^{-3}	0.214		2.86x10^{-3}	
	Onuiyi stream	-	-		-	
Cd	Oguta river	0.05x10^{-3}	0.050	42.84	0.25x10^{-3}	1.00x10^{-3}
	Nembee river	0.062x10^{-3}	0.062		0.86x10^{-3}	
	Ochen river	0.059x10^{-3}	0.059		0.67x10^{-3}	
	Onuiyi stream	-	-		-	
As	Oguta river	0.16x10^{-3}	0.053	63.71	0.99x10^{-3}	3.00x10^{-3}
	Nembee river	0.27x10^{-3}	0.090		2.47x10^{-3}	
	Ochen river	0.21x10^{-3}	0.070		1.41x10^{-3}	
	Onuiyi stream	-	-		-	
Hg	Oguta river	0.034x10^{-3}	0.021	0.078	1.02x10^{-3}	1.60x10^{-3}
	Nembee river	0.059x10^{-3}	0.037		1.31x10^{-3}	
	Ochen river	0.038x10^{-3}	0.024		1.26x10^{-3}	
	Onuiyi stream	-	-		-	
Ni	Oguta river	0.010	0.500	0.473	0.03	0.02
	Nembee river	0.017	0.850		0.05	
	Ochen river	0.014	0.700		0.04	
	Onuiyi stream	-	-		-	
Mn	Oguta river	0.152	1.086	71.88	0.21	**0.14**
	Nembee river	0.164	1.171		0.34	
	Ochen river	0.158	1.129		0.27	
	Onuiyi stream	0.013	0.093		0.11	

EDI = Estimated daily intake, THQ = Target hazard quotient, HI = Hazardous index, TR = Target cancer risk (Carcinogenic potency slope, oral mg/k body weight day^{-1}, RfDo = Reference dose

Discussion

Findings in this study showed that there were variations in ability of fish species to bioaccumulate heavy metals in their organs (Liver, Heart and Kidney). Fish can take up heavy metals in their diets and bioaccumulate them at different rates in their organs. The concentrations of the metals in the organs were in the order of liver > kidney > heart. The result indicated higher bioaccumulation in the liver across the sampling areas. The higher bioaccumulation of metals in liver may be linked to its function of metabolism. According to [18] the Liver serves as storehouse for metals, redistribution, and detoxification .This might be the yardstick for which liver organs are regarded as an indicator of water pollution than any organ in fishes [19].

Similar results of high heavy metals in liver had been reported by recorded by other researchers [20-25]. In comparison with standard permissible level [26] of the assayed heavy metals in the organs of the fishes investigated from the study areas including those from the control are safe for consumption. However, if bioaccumulation of heavy metals continues, this may lead to biological risk [27] health risk [28] and carcinogenic risk [29]. Generally, more heavy metals were detected at the study sites than the control.

The estimated daily intake of heavy metals from the mean concentration values of heavy metals via ingestion of water and fish were used to determine the hazard quotient, cancer risk, total hazard index and cancer risk index. The hazard quotient of the heavy metals in fish samples showed that Manganese poses threat to the user of the water in the study areas with reference to dose exceeding permissible limit of 0.14. Though other heavy metals (Pb, Cd, As, Hg, and Ni) showed concentration values that were below set limit and therefore showed hazard quotient that were below reference dose, its concentration values in fish is a major source of concern. The consumption of these metals in excess could impact health hazards to human. Results of this study are in agreement with report of [30-36].

Conclusion

The study has been able to clearly show that the concentration of heavy metals in the water, sediment and fish organs are of moderate risk but begging for immediate attention, therefore good hygiene, measures against indiscriminate dumping of waste in the vicinity of water bodies as well as burning of tyres, organic and petroleum products that are the major sources of heavy metals be ensured with the creation and implementation of stiffer laws to regulate indiscriminate refuse disposal. Although, the levels of heavy metals were found to be within permissible limits, bioaccumulation and magnification is capable of leading to toxic level of these metals in fish, water and sediment. Results obtained from the estimation of daily intake and target cancer risk in the study locations showed that all sampling points had low risk. Constant routine monitoring should be ensured in order to guide against ignorant consumption of excess pollutants (heavy metals) should the level of the heavy metals in the media increase to intolerable limit.

References

1. Akporido, S.O. & Onianwa, P.C.(2015).Heavy Metals and Total Petroleum Hydrocarbon Concentrations in Surface Water of ESI River, Western Niger Delta.*Res. J. Environ. Sci.* 9: 88–100.
2. Alatise, O.I.&Schrauzer, G.N.(2010). Lead exposure: A contributing cause of the current breast cancer epidemic in Nigerian women. *Biol. Trace Elem. Res.* 136: 127–139.
3. Alexander, P. & Evans, R. (1970). Cooperation of immune Lymphoid cells with Macrophages in tumor immunity, mature 228 (5272) Pp 620-622.
4. Ali, H. & Khan, E. (2018). Bioaccumulation of non-essential hazardous heavy metals and metalloids in freshwater fish. Risk to human health. *Environmental Chemistry Letters.* 2018; 16:903–917.
5. Ali Mohammad (2018). The cholera outbreak in Yemen: lessons learned and way forward *BMC Public Health* volume 18, Article number: 1338
6. Almeida,J. ANoveli, E.L.B.Silva, M.D. &Alves, R. (2001).Environmental cadmium exposure and metallic responses of the Nile tilapia, *Oreoechromisniloticus. Environ Pollution* 114 (2): 169 — 175.
7. Amadi, C.N. Orisakwe, O.E. &Roberts, I.I.(2012).Elemental impurities in registered herbal supplements in Nigeria.A look at Mercury, Antimony and Tin.*Rasayan J. Chem.* 5: 220–228.
8. Amadi, C.N. & Orisakwe, O.E (2018). Herb-induced liver injuries in developing nations: An update. *Toxics* 6: 24.
9. Ampiah-Bonney,R.J.Tyson, J.F. & Lanza, G.R. (2007). "Phytoextraction of arsenic from soil by *Leersia oryzoides*," *International Journal of Phytoremediation*, vol. 9, no. 1, Pp. 31–40,
10. Anders, M.W.Lash, L. Dekant, W.Elfarra, A.A.Dohn, D.R. & Reed, D.J. (1988).Biosynthesis and biotransformation of glutathione S-conjugates to toxic metabolites.CRC Crit. *Rev. Toxicol*. 1: 311–341.
11. Andrianisa, H.A.Ito, A. Sasaki, J. Aizawa, H. &Umita, T. (2008)."Biotransformation of arsenic species by activated sludge and removal of bio-oxidised arsenate from wastewater by coagulation with ferric chloride," *Water Research*, vol. 42, no. 19, Pp. 4809–4817.
12. Antonini, J.M. Santamaria, A.B. Jenkins, N.T. Albini, E. & Lucchini, R. (2006). Fate of manganese associated with the inhalation of welding fumes potential neurological effects *Neurotoxicology* 27(3) Pp 304-310.
13. Ankley, G.T. Bennett, R.S. Erickson, R.J. Hoff, D.J.Hornung, M.W. Johnson, R.D. & Serrrano, J.A. (2010). Adverse outcome pathways: A conceptual framework to support ecotoxicology research and risk assessment. *Environ. Toxicol.Chem*. 29: 730–741.
14. Ansari, T.M.Marr, I.L. & Tariq, N. (2004). Heavy metals in marine pollution perspective—Amini review. *J. Appl. Sci.* 4:1–20.
15. Armah, F.A.Quansah, R.& Luginaah, I. (2014).A systematic review of heavy metals of anthropogenic origin in environmental media and biota in the context of gold mining in Ghana.*Int. Sch. Res. Not.* 252148.
16. Arnot, J.A.&Gobas,F.A.P.C(2006). A review of bioconcentration factor (BCF) and bioaccumulation factor (BAF) assessment for organic chemicals *in*aquatic organisms. *Environ. Rev*. 14 (4): 257 — 297.)

17. Askari, S.A. Khodadadi,M. & Mohammadi,M. (2010).Concentration of heavy metal (Cd,Pb,Ni, Hg) in muscle, gill and liver tissues of *Barbusxanthopterus* in Karoon River, Iranian *Scientific Fisheries Journal* 9(4) :97-106.
18. Asonye, C.C.Okolie, N.P. Okenwa, E.E. &Iwuanyanwu, U.G.(2007).Some physico-chemical characteristics and heavy metal profiles of Nigerian rivers, streams and waterways.*Afr. J. Biotechnol*. 6:617–624.
19. ATSDR Agency for Toxic Substances and Disease Registry. (2008). Toxicological Profile for Cadmium; Agency for Toxic Substances Disease Registry: Atlanta, GA, USA,
20. ATSDR (Agency for Toxic Substances and Disease Registry). (2015). Toxicologial Profiles, Toxic Substances Portal; ATSDR: Atlanta, GA, USA,
21. Authier, F.J. Cherin, P. Creange, A.Bonnotte, B. Ferrer, X.Abdelmoumni, A. & Maisonobe, T. (2001).Central nervous system disease in patients with macrophagic myofasciitis.*Brain,* 124,Pp 974–983.
22. Authman, M.M. Zaki, M.S. Khallaf, E.A. & Abbas, H.H. (2015). Use of fish as bio-indicator of the effects of heavy met- also pollution. *Journal of Aquaculture Research & Development.* 2015; 6:1–13.
23. Avenant-Oldewage, A.& Marx, H.M. (2000).Bioaccumulation of chromium, copper and iron in the organs and tissues of Clarias gariepinus in the Olifants River, Kruger National Park. *Water SA* 26: 569–582.
24. Aykin-Burns, N.Laegeler, A.Kellogg, G.& Ercal,N. (2003).Oxidative effects of lead in young and adult Fisher 344 rats.*Arch. Environ. Contam. Toxicol*.44:417–420.
25. Azaman, F. Juahir, H. Yunus, K. Azid, A. Kamarudin, M.K.A. & Toriman, M.E. (2013). Heavy metal in fish: Analy- sis and human health-a review. *Jurnal Teknologi.* 77:61–69.
26. Baboli, M.J. &velayatzadeh, M. (2013).Determination of heavy metals and trace elements in the muscles of marine shrimps, *Fenneropenaeusmerguesnsis*from Persian gulf. *Iran. J. Anim. Plant. Sci*. 23(3):786.
27. Bagchi, D.Stohs, S.J.Downs, B.W.Bagchi, M. &Preuss,H.G. (2002).Cytotoxicity and oxidative mechanisms of different forms of chromium.*Toxicology*.180:5–22.
28. Bagchi, D.Vuchetich, P.J. Bagchi, M.Hassoun, E.A. Tran, M.X.Tang, L. &Stohs,S.J.(1997).Induction of oxidative stress by chronic administration of sodium dichromate [chromium VI] and cadmium chloride [cadmium II] to rats.*Free Radic. Biol. Med*. 22:471–478.
29. Bassey, F.I. Oguntunde, F.C. Iwegbue, C.M.A.Osabor, V.N.&Edem, C.A. (2014). Effect of processing on the proximate and metal contents in three fish species from Nigeria coastal waters.*Food Science and Nutrition* 2 (3): 272 — 281.
30. Bayen, S. Wurl, O. Karuppiah, S. Sivasothi, N. Lee, H.K. & Obbard, J.P. (2005). Persistent organic pollutants in man-grove food webs in Singapore. *Chemosphere.* 61:303–313.
31. Bawaskar, H.S. Himmatrao, S. Bawaskar, P.Himmatrao,S.& Bawaskar, P.(2010).Chronic renal failure associated with heavy metal contamination of drinking water: A clinical report from a small village in Maharashtra. *Clin.Toxicol*.48, 768.
32. Beg, MU. Al-Muzaini, S. Saeed, T. Jacob, PG. Beg, KR. Al-Bahloul, M. Al-Matrouk, K. Al-Obaid, T. & Kurian, A. (2001). Chemical contamination and toxicity of sediment from a coastal area receiving industrial effluents Kuwait.*Arch.of Environ. Contam.andToxicol.* 41: 289-297.
33. Beg, MU. Saeed, T. Al- Muzaini, S. Beg, KR. & AL-Baloul, M. (2003). Distribution of petroleum hydrocarbon in sediment from coastal area receiving industrial effluents in Kuwait *Ecoloxical. Environ. Saf.* 5: 47-55.
34. Bellinger, D.C. (2013). Inorganic arsenic exposure and children’s neurodevelopment: A review of the evidence. *Toxics* 1: 2–17.
35. Bernard, A. & Lauwerys, R.(1984).Cadmium in human populations, *Experientia*. 40: 143-152.
36. Bernard, A. (2008).Cadmium & its adverse effects on human health.*Indian J. Med. Res.*128:557–564.