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Potentially Toxic Element Pollution Levels in *Clarias batracus* (Cat fish) and Sediments of Onu Asu River in Arochukwu, Abia State, Nigeria

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ABSTRACT

Pollution of water bodies with potentially toxic elements (PTEs) can be detrimental to man and animals that depend on aquatic resources such as fish for food. This study aimed to determine the status of PTEs (Ni, Pb, Cr and Cd) distribution in Clarias batracus and sediments samples collected from the upstream, middle stream, and downstream of Onu Asu River in Arochukwu local government area of Abia State, Nigeria. The fish and sediment samples were dried, grinded, sieved, and digest separately in the laboratory to determine the concentrations of Ni, Pb, Cr and Cd using Atomic Absorption Spectrometer. The highest concentration of Ni (0.02± 0.01 and 0.22±0.01 mg/kg), Pb (0.023±0.015 and 2.05±0.13 mg/kg), and Cr (0.020±0.010 and 1.12±0.14 mg/kg) were recorded in cat fish and sediments respectively from the downstream. Cadmium (0.16±0.02 mg/kg) was highest in sediments from the downstream. The concentration of Cd (0.01±0.00 mg/kg) in cat fish is above the maximum permissible limit set by WHO while Pb (2.05±0.13 mg/kg) in sediment is higher than the standard limit set by FEPA and DPR, Nigeria. Sustained consumption of fish from Onu Asu River may pose health risks to the people. Therefore, periodic monitoring of contaminants in the River is recommended.

1. INTRODUCTION

The importance of freshwater ecosystems to human survival and sustenance can never be discounted (Asare *et al*., 2018). Fish is an essential constituent of human diet because of its low cholesterol, high nutrient content, and palatability. It is the most affordable source of animal protein for poor households in urban and semi-urban areas and to rural communities as it provides minerals and nutrients like fat, and vitamins D and B complex (Bene and Heck, 2005).

In Nigeria, many rural dwellers suffer the burden of walking long distances in search of water for daily domestic use. However, where some water sources are available, its quality remains questionable with potential health risks (Okovido *et al.*, 2018). Potentially toxic elements such as heavy metals are naturally occurring from weathering of parent materials. Notwithstanding this, various human activities such as vehicular emissions (Ogbonna and Okezie, 2011), bone charring with vehicle tires (Ogbonna *et al.*, 2011), quarrying (Ogbonna *et al.*, 2011), coal mining (Ogbonna *et al.*, 2012, 2018a), agriculture (Ogbonna *et al.*, 2013), sewage irrigation (Pan *et al.*, 2018) releases heavy metals into the environment. Thus, potentially toxic element in sediments are mainly from natural sources and human activities (Pan *et al.*, 2018). Sediments are basic components of aquatic environment where it plays a vital role in elemental cycling and are responsible for transporting large quantity of contaminants and nutrients (Ayoade and Nathaniel, 2018).

The contamination of aquatic bodies is a serious challenge since increasing load of potential toxic elements in water bodies can disrupt the activities and lives of aquatic organisms (Ogbonna *et al.*, 2018b). Elevated concentrations of pollutants in aquatic bodies may result in bio-accumulation of heavy metals in various organs of fish. The level of heavy metal accumulation in fish depend on the ecological requirements, feeding pattern, metabolism, growth rate of a given fish species (Yilmaz *et al.*, 2005; 2010), the difference in life history patterns among species (including tropic and geographical distribution of life stages) that influence their exposure to heavy metal (Allen-Gil and Martynov, 1995). The consumption of fish may be a possible route of entry of heavy metals in human alimentary system since man depend on fish for protein and fish oil (Ogbonna *et al.*, 2018b). Human health challenges in recent times has been associated with consumption of food contaminated with potential toxic element (Ogbonna *et al.*, 2018c, Ogbonna *et al.*, 2020). Potentially toxic elements have proven to be a major threat and there are several health risks associated with them (Mathew *et al.*, 2014) which include cancer of the skin, bladder and lung (WHO, 2001), liver and kidney damage (Plunkett, 1987) and skeletal fluorosis (Finkelman, 2007).

Onu Asu River is the major source of water for over a century to several villages and or communities in Arochukwu, Abia State of Nigeria. Pollutants carried by runoff through agricultural lands and effluent discharge from cassava and oil processing mills are deposited in Onu Asu river. The rural communities pay less attention to the associated environmental hazards taken place in the river. They are more interested in harvesting fish for daily meals (e.g. for preparation of soup, stew, sauce among others) and making profit from sales of their harvest. Fish scavenges for food (i.e. zoo and phytoplankton) in sediments using their mouth but dermal contact and ingestion are two principal sources of heavy metal deposition in living organisms. Literature search show that no work has been carried out on potentially toxic element in fish and sediments from Onu Asu River, hence, the results of this study will serve as background information on potentially toxic element present in the river. This study, therefore, is aimed to investigate the potentially toxic elements in fish and sediments from Onu Asu River and the result obtained were compared to permissible limits set by World Health Organization, WHO (2008), Food and Agriculture Organization, FAO (1989) to confirm its health implications.

2. MATERIAL AND METHODS

2.1. Description of the Study Area

The study was conducted at Onu Asu River in Amasu village in Arochukwu Local Government Area of Abia State. Amasu lies at latitude 5° 22' 41" N and longitude 7° 54' 48" E. It is located in the tropical lowland rainforest of Nigeria (Keay, 1959) and has an average annual rainfall of about 2,000–3,000 mm per annum that is distributed over 8 months wet season (April to November) with peak in September. The relative humidity is 65–85% and annual temperature range of 23 ^{o}C to 26.7 ^{o}C. Amasu community is generally known as a fishing hub of Arochukwu and the launch pad for Christianity to the Aros. At some point in history, it was the gateway to Arochukwu through the Onuasu water way. Onu Asu River is the river that Mary Slessor used during her fight against the barbaric religion of Arochukwu people. This river connects Arochukwu and a village known as Ikpanja in Akwa Ibom State of Nigeria.

2.2. Collection of Fish and Sediment

A reconnaissance survey was carried prior to collection of samples. This was done in collaboration with fishermen to determine the fish species that is common in the river. The possible effluents and rainwater runoff path, upstream locations as well as other human-ecological interactions were taken into consideration in chosen the targeted sampling positions (Simpson *et al.*, 2005). Four (4) sampling positions were considered in this study which are upstream (i.e. where locals collect water for domestic uses), middle stream (i.e. where locals swim), and down-stream (i.e. where locals wash clothing, processing of fermented *Treculia africana* (African bread fruit) and *Manihot esculenta* (tapioca, "fufu" etc.) and the control points which is about 100 m ahead of the upstream where there was very minimal human activity. At each sampling position, three basket traps were set to catch fish of similar sizes and weight. Six (6) similar sizes of fish were harvested at each sampling point (e.g. upstream), put in small coolers containing river water (collected at each point where the fish are harvested). The coolers were labeled well and placed in a bigger cooler to avoid contamination from external sources. The fish samples were taken to the laboratory for pre-treatment and analysis of lead (Pb), cadmium (Cd), chromium (Cr) and nickel (Ni).

The sediments were collected at the points where the fish samples were harvested from Onu Asu River. The purpose of collecting the sediments was to determine the level of concentration of potentially toxic elements deposited at the bottom of the river. Fifty (50) g sediment samples (n =12) were collected randomly from a depth of 10 cm from the surface at each sampling positions, using a sediment collector with an acid-washed plastic scoop and transferred to aluminum foils and transported to the laboratory using Abia State Environmental Protection (ASEPA) polythene bags.

2.3. Digestion of Fish and Sediment Samples

Fish samples from each sampling points were dried separately at 50 ^{o}C in an air circulating oven to complete dryness for 4 days. The dried fish samples from each sampling point were bulked together and milled with Wiley milling machine and sieved with 0.5 mm sieve. One gram (1 g) of each sieved fish sample was weighed into a 100 cm^3 beaker. Thereafter, 10 ml of aqua regia was added in the beaker and the mixture was placed on a hot plate under fume cupboard and heated near dryness at 50 ^{o}C until the colour changes to white. The sample was allowed to cool before leaching the residue. After the samples had all cooled to room temperature; the mixtures were all filtered through a funnel containing Whatman filter paper no. 125 mm and finally made-up to 20 cm^3 with distilled water.

The procedure of Defew *et al.* (2005) with slight modification was adopted in the analyses of sediment samples. The sediments were sieve to remove any stones, pebbles and organic matter, then placed in an air circulating oven to dry at 50 ^{o}C for 5 days. The dried sediment samples were crushed to the finest possible fraction using an acid-washed pestle and mortar, and sieved with 0.5 mm sieve. One gram (1 g) of the sieved sediment from each sampling position was transferred separately to an acid-washed 100 cm^3 beaker, and 10 ml of aqua regia was added and covered. Aqua regia solution is prepared by the combination of hydrochloric acid and nitric acid in the ratio of 3:1. The samples were left overnight to digest completely at room temperature. Twenty (20 ml) of distilled water was added to the sample and the mixture was filtered through a funnel containing Whatman filter paper no. 125 mm and finally made-up to 20 cm^3 with distilled water. Potentially toxic elements were determined using Atomic Absorption Spectrometer Solar UN–969 (UNICAM).

2.4. Experimental Design and Data Analysis

A simple factorial experiment in randomized complete block design (RCBD) with replications. The data collected was subjected to one-way analysis of variance (ANOVA) with statistical package for social science (SPSS) v. 15 and means were separated by Duncan New Multiple Range Test (DNMRT) according to Steel and Torrie (1980)**.**

3. RESULTS AND DISCUSSION

3.1. Concentration of Potentially Toxic Elements in *Clarias batracus*

The result of the concentration of potentially toxic element in cat fish from Onu Asu River is presented in Table 1. The result indicate that the highest and lowest concentration of the potentially toxic elements were obtained in cat fish harvested at the points where human activities are been carried out (upstream, middle stream, and downstream) and control area. Human activities such as washing of clothing with detergents and soaps, bathing and swimming, processing of fermented *Treculia africana*, and *Manihot* esculenta among others might have contributed to the high concentration of potentially toxic element in cat fish at the upstream, middle stream and downstream unlike the control area. Processing of fermented cassava helps to remove or reduce the level of toxic cyanogenic glucosides and other toxic contaminants like heavy metals present in cassava root (Wyllie *et al.*, 1984) while laundry activities in streams or rivers releases metals in some tablets of soap used during washing (Ogbonna *et al.*, 2018b). The highest concentration of Ni (0.02± 0.01 mg/kg), Pb (0.023±0.015 mg/kg), and Cr (0.020±0.010 mg/kg) were recorded in cat fish harvested at the downstream and the values were significantly ($p<0.05$) higher than their corresponding values in cat fish obtained at the upstream (0.01±0.00, 0.00±0.00, and 0.007±0.006 mg/kg), middle stream (0.01±0.00, 0.00±0.00, and 0.003±0.006 mg/kg) and the control (0.00±0.00, 0.00±0.00, and 0.00±0.00 mg/kg). The high concentration of Ni, Pb and Cr in cat fish harvested at the downstream may be attributed to high concentration of these potentially toxic element in sediments in Onu Asu River (Table 3). Sediments form the major repository of heavy metals in aquatic body (Atta *et al.*, 1997; Adeniyi and Yusuf, 2007) and fish scavenges for food in sediments with the mouth and this might have enhanced the level of intake of potentially toxic element in their body. Saeed (2000) and Ogbonna *et al.* (2018b) opined that cat fish are mainly carnivorous, feeding on insect larvae, fish, molluscs, plankton organisms, seeds, worms and detritus that accumulate large amount of heavy metals.

The concentration of Ni increased from 0.01±0.00 (upstream/middle stream) to 0.02±0.01 (downstream) mg/kg and the values were well below 1.50±0.90 to 2.70±4.70 mg/kg (Ni) in soft tissue of fresh water mussels collected from River Kabul, Pakistan (Khan *et al.*, 2018), 1.56±0.04 to 1.59±0.01 mg/kg (Ni) reported in *Tilapia zilli* (Tilapia) from Ubeyi River in Afikpo south of Ebonyi State, Nigeria (Ogbonna *et al.*, 2018b), 0.01 to 0.38 mg/kg (Ni) in cat fish and 0.050 to 0.330 mg/kg (Ni) in Tilapia collected in Lake Njuwa, Adamawa State, Nigeria (Ibrahim *et al.*, 2018). In this study, the concentration of Ni (0.01±0.00 – 0.02±0.01 mg/kg) in cat fish is below the maximum permissible limit <0.10 (WHO, 2008). Nickel is essential in small doses but could be dangerous when the maximum tolerable amounts are exceeded resulting in lung, liver and kidney damage (Wuana and Okieimen). In high quantities, Ni could also cause cancer, respiratory failure, birth defects, allergies, dermatitis, eczema, nervous system, heart failure (Adelekan and Abegunde, 2011; Al Hagibi *et al.*, 2018), reproductive failures and growth problems (Kumar *et al.*, 2007).

The concentration of Pb increased from 0.00±0.00 (upstream/middle stream) to 0.023±0.015 (downstream) mg/kg and the values is well below 2.36±0.17 to 47.77±1.4 mg/kg (Pb) in *Oreochromis niloticus* and *Clarias anguillaris* in Rosetta branch of the River Nile, Egypt (Yehia and Sebaee, 2012), 10.1±10.7 to 31.9±11.9 mg/kg (Pb) in mussels from River Kabul, Pakistan (Khan *et al.*, 2018), 0.020±0.012 to 0.117±0.048 mg/kg (Pb) in fish from Al Delmaj Marshes, Iraq (Baker *et al.*, 2019), 0.50 to 2.50 mg/kg (Pb) in Tilapia and 0.99 to 1.40 mg/kg (Pb) in cat fish collected in Lake Njuwa, Adamawa State, Nigeria (Ibrahim *et al.*, 2018) (Table 2). In this study, the concentration of Pb (0.00±0.00 – 0.023±0.015 mg/kg) in cat fish is below the maximum permissible limit 0.05 (WHO, 2008). Notwithstanding this, low-level chronic exposure to Pb cause adverse health effects such as neurological and reproductive effects (Ogbonna *et al.*, 2018b). Exposure to Pb could lead to loss of memory, nausea, insomnia, anorexia, and weakness of the joints, irritation and producing tumour (Adelekan and Abegunde, 2011; Al Hagibi, 2018).

Table 1: Heavy metal concentration (mg/kg) in *Clarias batracus*

Sampling points	Nickel (Ni)	Lead (Pb)	Chromium (Cr)	Cadmium (Cd)
Upstream	0.01^b ± 0.00	0.00^b ± 0.00	0.007^b ± 0.006	0.00^a ± 0.00
Middle stream	0.01^b ± 0.00	0.00^b ± 0.00	0.003^b ± 0.006	0.00^a ± 0.00
Down stream	0.02^a ± 0.01	0.023^a ± 0.015	0.020^a ± 0.010	0.01^a ± 0.00
Control	0.00^c ± 0.00	0.00^b ± 0.00	0.00^b ± 0.00	0.00^a ± 0.00

Values are mean ± standard deviation of three replicates; Means in a column with different superscripts are significantly different (P<0.05)

Table 2: Comparison with international standards and similar studies

Source	Ni	Pb	Cr	Cd
This study	0.01±0.00 – 0.02±0.01	0.00±0.00 – 0.023±0.015	0.003±0.006 – 0.020±0.010	0.00±0.00 – 0.01±0.00
Ogbonna *et al.* (2018)	1.55±0.08 – 1.59±0.01	0.00±0.00 - 0.00015±0.00	2.90±0.01 – 2.95±0.04	0.00±0,00 – 0.00015±0.00
Khan *et al.* (2018)	1.50±0.90 – 2.70±4.70	10.1±10.7 – 31.9±11.9	1.1±0.9 – 1.8±0.9	1.1±0.9 – 1.8±0.9
Yehia and Sebaee, (2012)	NA	2.36±0.17 – 47.77±1.4	NA	0.90±0.07 – 18.3±0.32
Ibrahim *et al.* (2018)	0.01 – 0.38	0.50 – 2.50	0.05 – 0.86	0.020 – 0.10
Baker *et al.* (2019)	NA	0.020±0.012 – 0.117±0.048	NA	0.860±0.566 – 5.101±1.455
Funtua *et al.* (2016)	NA	1.099±0.0019 – 1.832±0.0004	NA	NA
WHO 2008	<0.1	0.05	0.05	0.01
EC 2005	NA	0.2	0.05	NA
FAO 1989	NA	0.5	0.5	NA

The concentration of Cr increased from 0.003±0.006 (middle stream) to 0.020±0.010 (downstream) and the values is well below 1.1±0.9 to 1.8±0.9 mg/kg (Cr) recorded in soft tissues of fresh water mussels (Khan *et al.*, 2018), 0.69 to 0.86 mg/kg (Cr) in cat fish and 0.05 to 0.70 mg/kg (Cr) in Tilapia collected from Lake Njuwa, Adamawa State, Nigeria (Ibrahim *et al.*, 2018). In this study, the concentration of Cr (0.003±0.006 – 0.020±0.010 mg/kg) in cat fish is relatively lower than the maximum permissible limit <0.05 (WHO, 2008). The concentration of Cr over time may pose a health risk to the people of Amasu that depend on fish as their source of livelihood. Chromium is essential for carbohydrate metabolism in animals (Hardy *et al.*, 2008) but Cr and its compounds are known to cause serious developmental effects (ATSDR, 1999), cancer of the lung, nasal cavity (ATSDR, 2002). Exposure to Cr could lead to allergic dermatitis in humans, bleeding of the gastrointestinal tract, cancer of the respiratory tract and ulcers of the skin, liver and kidney damage (Bhagure and Mirgane, 2010). The highest concentration of Cd (0.01±0.00 mg/kg) is obtained at the downstream but the value is statistically ($p>0.05$) not different from its corresponding values in cat fish harvested from upstream (0.00±0.00 mg/kg), middle stream (0.00±0.00 mg/kg) and control (0.00±0.00 mg/kg). The value of Cd recorded at the downstream is relatively higher than the maximum permissible limit <0.01 (WHO, 2008). Cadmium is toxic even at low concentrations (Jain *et al.*, 2007) causing high blood pressure, adverse changes in the arteries of human kidney, kidney damage, replaces zinc biochemically (Feng *et al.*, 2011), interferes with enzymes and causes Itai-itai (Sperotto *et al.*, 2014). Itai-itai is a pollution related disease induced by cadmium (Cd) that was first reported in the Cd-polluted Jinzu River basin of Toyama Prefecture, Japan, starting around 1912 but the main characteristics of the disease are osteomalacia and osteo-porosis with a propensity for fractures accompanied by severe bone pain and renal tubular dysfunction (Friberg *et al.*, 1974; Nogawa, 1981; WHO, 1992; Aoshima, 2016). Consequently, consumption of cat fish from Onu Asu River will constitute a serious health risks to man and carnivorous animals such as Pel's fishing owl (*Scotopelia peli*), Lanner falcon (*Falco biarmicus*) and Black kite (*Milvus migrans*) within the area. For example, consumption of food stuff contaminated with Cd and Pb in Copsa Mica and Bala Mare, Romania decrease human life expectancy by 9 to 10 years (Lacatusu *et al.*, 1996). The source of potentially toxic elements in Onu Asu River may be attributed to contamination from erosion of natural deposits and effluents discharged from cassava and oil processing mills. Effluents of oil mill (Ohimain *et al.*, 2012) and cassava waste water (Ariyomo *et al.*, 2017) which contains heavy metals as well as cyanides for cassava effluents (Oviasogie and Ofomaja, 2007; Iwegbue *et al.*, 2013) are discharged into water bodies that cause certain alterations in the naturally occurring chemical composition of the water bodies, aquatic phase and consequently affects the behaviour, biochemistry, haematology and general physiology of aquatic faunas (Arguedes and Cooke, 1982; Ehiagbonare *et al.*, 2009; Olaniyi *et al.*, 2013).

3.2. Concentration of Potentially Toxic Element in Sediments

The result of the concentration of potentially toxic elements in sediments collected from Onu Asu River, Arochukwu is summarized in Table 3 The results show that the highest and lowest concentration of potential toxic elements were obtained in sediments collected from the points of human activities (upstream, middle stream, and downstream) and control area. The highest concentration of Ni (0.22±0.01 mg/kg), Pb (2.05±0.13 mg/kg), Cr (1.12±0.14 mg/kg) and Cd (0.16±0.02 mg/kg) were obtained in sediments collected from the downstream and these values are significantly ($p<0.05$) higher than their corresponding values in sediments collected from middle stream (0.15±0.01, 0.82±0.11, 0.68±0.06 and 0.09±0.01 mg/kg), upstream (0.08±0.01, 0.22±0.09, 0.24±0.06 and 0.04±0.02 mg/kg) and control (0.02±0.01, 0.06±0.01, 0.04±0.02 and 0.01±0.01 mg/kg), respectively for Ni, Pb, Cr and Cd. The high concentration of potentially toxic element (Ni, Pb, Cr and Cd) in sediments collected from the downstream may be attributed to influence of human activities like collection of water for drinking at the upstream and swimming by the locals at middle stream that displaced metal contaminated organic material and deposits to the downstream. In addition, the processing of fermented *Manihot esculenta* (cassava) and *Treculia africana* (African breadfruit) at the downstream may have deposited metal contaminated organic material in sediments at the downstream. Plants growing on heavy metal contaminated soil absorb metals via the roots and translocate to stems and leaves (Ogbonna *et al.*, 2018d) resulting in bioaccumulation of the elements in plant tissues (Amusan *et al.*, 2005). The harvest of such plants and subsequent processing will result to release of heavy metals (Ogbonna *et al.*, 2018d) in form of organic material that are deposited as sediments in the aquatic body. Sediments is a reservoir of numerous chemicals and it has influence in water contamination (Sakan *et al.*, 2009; Yang *et al.*, 2009; Mil-Homens *et al.*, 2013). The concentration of Ni in sediment increased from 0.08±0.01 (upstream) to 0.22±0.01 mg/kg (downstream) and the values is well below 50 to 141 mg/kg in sediment of surface water from Ore and Okitipupa southwest, Nigeria (Ediagbonya and Ayedu, 2018), 68.5±13.3 to 85.1±3.6 mg/kg in sediment of River Kabul, Pakistan (Khan *et al.*, 2018), 8.08 to 36.5 mg/kg in sediment collected from Mashavera River, Republic of Georgia (Withanachchi *et al.*, 2018), 12.4 to 30.9 mg/kg reported in sediments samples collected from Kumasi area of Ghana (Kodom *et al*., 2012), and 0.31 mg/L in sediment of Ndibe River, Ebonyi State, Nigeria (Nwani *et al*., 2010) (Table 4). The concentration of Ni (0.08±0.01 - 0.22±0.01 mg/kg) in this study is well below the Hungarian regulatory limit 40 mg/kg for (Ni) in the sediment (Hungarian Ministry for Health and Environment, 1999; 2000). The concentration of Pb in sediment increased from 0.22±0.09 (upstream) to 2.05±0.13 mg/kg (downstream) and the values is well below 11.1 to 94.9 mg/kg in sediment collected from Mashavera River, Republic of Georgia (Withanachchi *et al*., 2018), 32.8±18.2 to 54.6±4.3 mg/kg in sediment of River Kabul, Pakistan (Khan *et al*., 2018), 37.90±5.727 µg/kg in sediment of Al Delmaj Marshes, Iraq (Baker *et al*., 2019), 41.22±3.33 to 56.88±4.89 ppm in sediment collected in Rosetta branch of the River Nile, Egypt (Yehia and Sebaee, 2012), 0.00 to 698.34 mg/kg in sediment of a tropical man-made lake southwestern, Nigeria (Ayoade and Nathaniel, 2018) and 0.06 to 8.75 mg/kg (Ugbomeh *et al*., 2019) but higher than 0.992±0.0008 mg/kg (Pb) in sediment of Kpata River Lokoja, Kogi State, Nigeria (Funtua *et al*., 2016) (Table 4). The concentration of Pb (0.22±0.09 – 2.05±0.13 mg/kg) in this study is higher than the standard limit 0.5 mg/kg (Pb) set by the Federal Ministry of Environment, Nigeria (FMEnv 2011) and Department of Petroleum Resources (DPR, 2002). The concentration of Pb in sediment of Onu Asu River may affect the life and activities of smaller aquatic organisms such as phytoplankton and zooplankton. Lead (Pb) is a non-essential element and can be toxic even at low concentration (Awofolu *et al*., 2005; Ogbonna *et al*., 2013).

The concentration of Cr in sediment increased from 0.24±0.06 (upstream) to 1.12±0.14 mg/kg (downstream) and the values is well below 75.5±24.8 to 92.5±12.8 mg/kg in sediment of Kabul River, Pakistan (Khan *et al*., 2018), 4.93 to 47.4 mg/kg in sediment collected from Mashavera River, Republic of Georgia (Withanachchi *et al*., 2018), 5.0 to 34.0 mg/kg in sediment of surface water in Ore and Okitipupa, southwestern Nigeria (Ediagbonya and Ayedu, 2018), 0.00 to 26.10 mg/kg in sediment of a tropical man-made lake southwestern, Nigeria (Ayoade and Nathaniel, 2018) but higher than 0.305±0.0007 mg/kg in sediment of Kpata River Lokoja, Kogi State, Nigeria (Funtua *et al*., 2016). The inhabitant of Amasu village will be exposed to chromium in the Onu Asu River by drinking, bathing and consumption of fish. Chromium (VI) is changed to chromium (III) in the body but most of the chromium leaves the body in the urine within a week, although some may remain in cells for several years or longer (ATSDR, 1999). The most common health problem associated with exposure to chromium involves the respiratory tract (cause breathing problems), stomach and small intestine (cause irritation and ulcer), male reproductive system (cause sperm damage) and cancer (ATSDR, 1999).

The concentration of Cd in sediment increased from 0.04±0.02 (upstream) to 0.16±0.02 mg/kg (downstream) and the values is well below 28.66±3.11 to 39.22±4.45 ppm (Yehia and Sebaee, 2012), 3.96 to 37.14 mg/kg in sediment of Owudu Creek (Obunwo *et al*., 2004), 12.80 mg/kg from sediment of the lower reaches of the New Calabar River in Niger Delta (Horsfall and Spiff, 2002), 0.105 to 8.35 mg/kg in sediment collected from Mashavera River, Republic of Georgia (Withanachchi *et al*., 2018), 4.4±±2.6 to 7.1±1.8 mg/kg (Khan *et al*., 2018), 0.01 to 4.18 mg/kg (Ugbomeh *et al*., 2019), 0.00 to 9.00 mg/kg (Ayoade and Nathaniel, 2018) and 1.910±0.361 mg/kg (Baker *et al*., 2019) but higher than 0.050±0.0001 mg/kg (Funtua *et al*., 2016). The concentration of Cd (0.04±0.02 – 0.16±0.02 mg/kg) in this study falls within the range of the standard limit 0.03 – 0.3 mg/kg (Cd) set by Federal Ministry of Environment, Nigeria (FMEnv, 2011) and Department of Petroleum Resources (DPR, 2002). The order of abundance of potentially toxic elements is: Pb>Cr>Ni>Cd.

Table 3: Heavy metal concentration (mg/kg) in sediments

Sampling points	Nickel (Ni)	Lead (Pb)	Chromium (Cr)	Cadmium (Cd)
Upstream	$0.08^{c} \pm 0.01$	$0.22^{c} \pm 0.09$	$0.24^{c} \pm 0.06$	$0.04^{c} \pm 0.02$
Middle stream	$0.15^{b} \pm 0.01$	$0.82^{b} \pm 0.11$	$0.68^{b} \pm 0.06$	$0.09^{b} \pm 0.01$
Down stream	$0.22^{a} \pm 0.01$	$2.05^{a} \pm 0.13$	$1.12^{a} \pm 0.14$	$0.16^{a} \pm 0.02$
Control	$0.02^{d} \pm 0.01$	$0.06^{c} \pm 0.01$	$0.04^{d} \pm 0.02$	$0.01^{d} \pm 0.01$

Values are mean ± standard deviation of three replicates; Means in a column with different superscripts are significantly different (P<0.05)

Table 4: Comparison with similar studies of sediments from rivers in Nigeria and other countries of the world

Location		Pb	Cd	Cr	Ni	Reference
Onu Asu River in Abia State, Nigeria		0.22-2.05	0.04-0.16	0.24-1.12	0.08-0.22	This study
Red Sea coast of Yemen	Al-Salif	7.73	0.18	19.05	21.93	Al Hagibi *et al.* (2018)
	Al-Urj	8.73	0.35	24.85	24.70	
	Al-Hodeidah	14.25	0.53	33.10	31.73	
	Yakhtol	6.70	0.12	18.05	17.08	
	Ghorairah	11.50	0.43	24.93	24.93	
Saudi Arabia	Shuaiba	0.53	0.02	8.74	27.42	Abohassan (2013)
	Yanbu	3.84	0.20	11.51	24.80	
	Farasan Island	ND	ND-1.04	8.1-14.9	.37-4.0	Usman *et al.* (2013)
Egypt	Abu-Minqar Island	12.80	0.40	-	-	Dar and El-Saharty (2006)
	Safaga Island	28.40	0.40	-	-	
United Arab Emirates		20.4-37.3	4.5-5.1	10.2-14.1	8.0-76.	Shriadah (1999)
Iran	Qeshm Island	43.61	-	-	54.12	Einollahipeer *et al.* (2013)
	Sirik Azini creek	32.31	18.93	-	99.41	Parvaresh *et al.* (2011)
	Booshehr	94.80	-	-	64.14	Davari *et al.* (2012)
India	Kannur	28.00	2.00	-	-	Badarudeen *et al.* (2014)
	Gulf of Mannar	16.00	0.16	177.00	24.00	Jonathan *et al.* (2009)
	Cuddalore	8.00	0.10	22.00	5.00	Kathiresan *et al.* (2014)
	Godavari	55.80	10.90	2.20	25.70	Ray *et al.* (2006)
Thailand	Pattani Bay	47.30	0.20	58.30	16.90	Kaewtubtim *et al.* (2016)
Singapore	Khatib Bongsu	30.98	0.26	32.07	11.65	Cuong *et al.* (2005)
Sanglades	Sundarbans	25.61	0.09	52.87	207.31	Kumar *et al.* (2016)
	Sundarbans	19.30	0.55	15.70	76.10	Awal *et al.* (2009)
China	Futian	133.30	0.98	30.28	-	Li *et al.* (2008)
	Maowei Gulf	18.31	0.34	30.02	9.24	Huang *et al.* (2015)
	Quanzhou Bay	61.60	-	21.90	8.19	Yu *et al.* (2015)
Panama	Punta Mala Bay	78.20	<10	23.30	27.30	Defew *et al.* (2005)
Colombia	Cienaga Grande	12.60	1.92	13.20	32.50	Perdomo *et al.* (1999)
Brazil	Jequia	160.80	1.32	-	-	Kehrig *et al.* (2003)
	Antonina	-	-	-	-	Madi *et al.* (2015)
Australia	Hawksbury	26.40	-	-	-	Macfarlane *et al.* (2002)
	Queensland	36.00	0.60	1-72	9.00	Preda and Cox (2002)
France	Sinnamary	26.94	-	59.80	35.20	Marchand *et al.* (2006)
Nigeria	Okitipupa Southwest Nigeria	-	-	5.0-34.0	26.1-128.0	Ediagbonya and Ayedu (2018)
	Ebonyi State	-	-	-	0.31	Nwani *et al.* (2010)
	Southwest Nigeria	0.00-698.34	0.00-9.00	0.00-26.1	-	Ayoade and Nathaniel (2018)
	Niger Delta	0.06-8.75	0.01-4.18	-	-	Ugbomeh *et al.* (2019)
	Lokoja, Kogi State	0.992	0.050	0.305	-	Funtua *et al.* (2016)
Marine Sediments		4-17	0.1-0.3	7-13	9.9	Buchman (2008)

ND = Not detected

3.3. Pearson Correlation between PTE in Fish and Sediments

The result of the Pearson correlation analysis of potentially toxic elements in fish and sediments is presented in Table 5. The result show very strong positive relationship between heavy metals in fish and sediments; very strong positive relationship between heavy metals in sediments as well as cat fish. Indeed, very strong positive relationship occur between Ni in fish and sediment ($r=0.826$, $p<0.01$), Pb in fish and sediment ($r=0.824$, $p<0.01$) and Cd in fish and sediment ($r=0.853$, $p<0.01$) and this suggest that increase in Ni, Pb and Cd in sediments resulted to their (Ni, Pb and Cd) increase in cat fish. Furthermore, very strong positive relationship exists between Pb and Ni in fish ($r=0.774$, $p<0.01$), Cd and Cr in fish ($r=0.781$, $p<0.01$). Very strong positive relationship also exists between Ni in sediment and Cd in fish ($r=0.785$, $p<0.01$), Pb in sediment and Cr in fish ($r=0.732$, $p<0.01$), Pb in sediment and Cd in fish ($r=0.927$, $p<0.01$). Similarly, very strong positive relationship exists between Pb and Ni in sediment ($r=0.939$, $p<0.01$), Cr and Ni in sediment ($r=0.973$, $p<0.01$) as well as Cd and Ni in sediment ($r=0.969$, $p<0.01$). However, there was strong positive relationship between Cr in fish and sediment ($r=0.662$, $p<0.05$).

Table 5: Pearson correlation coefficient showing the relationship between heavy metal concentrations in *Clarias batracus* and sediments

	Catfish				Sediments			
	Ni	Pb	Cr	Cd	Ni ()	Pb	Cr	Cd
Ni (Catfish)	1							
Pb (Catfish)	.774**	1						
Cr (Catfish)	.442	.513	1					
Cd (Catfish)	.707*	.851**	.781**	1				
Ni (Sediments)	.826**	.659*	.649*	.785**	1			
Pb (Sediments)	.803**	.824**	.732**	.927**	.939**	1		
Cr (Sediments)	.777**	.744**	.662*	.819**	.973**	.960**	1	
Cd (Sediments)	.879**	.774**	.656*	.853**	.969**	.967**	.961**	1

***. Correlation is significant at 1% ($P<0.01$); *. Correlation is significant at 5% ($P<0.05$)*

4. CONCLUSION

The concentration of Cd in fish is above the maximum permissible limit set by Codex Alimentarius Commission (FAO/WHO) which make the fish unsafe for consumption by man and carnivores. Heavy metals in the sediment were within Food and Agricultural Organization FAO/WHO (2008) limit. Similarly, the concentration of Pb in the sediments is above the standard set by the Federal Environmental Protection Agency (FEPA) and Department of Petroleum Resources (DPR). Hence, these heavy metal (Cd and Pb) may pose serious health threat on the consumers of fish and fish products from Onu Asu River. Prolong consumption of the cat fish from Onu Asu River will likely have adverse effects on the people of Amasu community. Thus, we recommend periodic monitoring of potentially toxic element in Onu Asu River since the river serves as a source of drinking water and fish for the people.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Abohassan, R.A. (2013). Heavy metal pollution in *Avicennia marina* mangrove systems on the Red Sea coast of Saudi Arabia. JKAU: *Meteorology, Environment and Arid Land Agriculture Sciences*, 24(1), pp. 35-53.

Adelekan, B.A. and Abegunde, K.D. (2011). Heavy Metals Contamination of Soil and Groundwater at Automobile Mechanic Villages in Ibadan, Nigeria. *International Journal of Physical Sciences*, 6(5), pp. 1045-1058.

Adeniyi, A.A. and Yusuf, K.A. (2007). Determination of heavy metals in fish tissues, water and bottom sediments from Epe and Badagry Lagoons, Lagos, Nigeria. *Environmental Monitoring and Assessment*, 37, pp. 451-458.

Agency for Toxic Substances and Disease Registry, ATSDR (1999). Division of Toxicology and Human Health Sciences (proposed) Environmental Toxicology Branch (proposed) 1600 Clifton Road NE Mailstop F-62 Atlanta, Georgia 30333.

Agency for Toxic Substances and Disease Registry, ATSDR (2002). Toxicological profile for chromium. Depart Health and Human Services, Public Health Service, Atlanta, Georgia, pp. 502.

Al Hagibi, H.A., Al-Selwi K.M., Nagi H.M. and Al-Shwafi, N.A. (2018). Study of heavy metals contamination in mangrove sediments of the Red Sea coast of Yemen from Al-Salif to Bab-el-Mandeb Strait. *Journal of Ecology and Natural Resources*, 2(1), p. 121.

Allen-Gil, S.M. and Martynov, V.G. (1995). Heavy metal burdens in nine species of freshwater and anadromous fish from the Pechora River, northern Russia. *The Science of the Total Environment*, 160/161, pp. 653–659.

Amusan, A.A., Ige, D. V. and Olawale, R. (2005). Characteristics of soils and crops uptake of metals in municipal waste dumpsites in Nigeria. *Journal of Human Ecology*, 17(3), pp. 167-171.

Aoshima, K. (2016). Itai-itai disease: Renal tubular osteomalacia induced by environmental exposure to cadmium—historical review and perspectives. *Soil Science and Plant Nutrition*, 62(4), pp. 319-326.

Arguedes, P. and Cooke, R.D. (1982). Cyanaide concentrations during extraction of cassava starch. *Food Technology*, 17, pp. 251-262.

Ariyomo, T.O., Jegede, T., Adeniran, A.F. and Omobepade, B.P. (2017). Toxicity of cassava effluents to catfish, *Clarias gariepinus* and the effect on some target organs. *Annals of Aquaculture Research*, 4(2), pp. 1034.

Asare, M.L., Cobbina, S.J., Akpabey, F.J., Duwiejuah A.B. and Abuntori Z.N. (2018). Heavy metal concentration in water, sediment and fish species in the Bontanga Reservoir, Ghana. *Toxicology and Environmental Health Sciences*, 10(1), pp. 49-58.

Atta, M.B., Sabaie, L.A., Noaman, M.A. and Kassab, H.E. (1997). The effect of cooking on the content of heavy metals in fish *(Tilapia nilotica*). *Food Chemistry*, 58, pp. 1-4.

Awal, M.A., Hale, W.H. and Stern, B. (2009). Trace element concentrations in mangrove sediments in the Sundarbans, Bangladesh. *Marine Pollution Bulletin*, 58(12), pp. 1922-1958.

Awofolu, O.R., Mbolekwa, Z., Mtshemla, V. and Fatoki, O.S. (2005). Levels of trace metals in water and sediment from Tyume River and its effects on an irrigated farmland. Water SA 31(1), pp. 87-94.

Ayoade, A, A. and Nathaniel, O. G. (2018). Assessment of heavy metals contamination of surface water and sediment of a tropical man-made lake southwestern Nigeria. *International Journal of Environment and Pollution Research*, 6(3), pp. 1-16.

Badarudeen, A., Sajan, K., Srinivas, R., Maya, K. and Padmalal, D. (2014). Environmental significance of heavy metals in leaves and stems of Karala mangroves, SW coast of India. *Indian Journal of Marine Sciences*, 43(6), pp. 1027-1035.

Baker, A.J., Hiba S.A., Hussain J. A., and Sultan A.M. (2019). Determination of heavy metals arsenic, cadmium and lead in water, sediments and fish from Al Delmaj Marshes, Iraq. The 7th International Conference on Applied Science and Technology (ICAST 2019), AIP Conference Proceedings 2144, pp. 1-9.

Bene, C. and Heck, S. (2005). Distribution of metals in tissues of common carp (cyprinus carpio). *Acta Veterinaria Brno*, 76, p. 93 – 100.

Bhagure, G.R. and Mirgane, S.R. (2010). Heavy metals contaminations in groundwater and soils of Thane Region of Maharashtra, India. *Environmental Monitoring and Assessment*, 173(1-4), pp. 643-652.

Buchman, M.F. (2008). Screening Quick Reference Tables, NOAA OR&R Report 08-1, Seattle WA, Office of Response and Restoration Div, NOAA: 34.

Cuong, D.T., Bayen, S., Wurl, O., Subramanian, K., Wong, K.K.S., Sivasothi, N. and Obbard, J.P. (2005). Heavy metal contamination in mangrove habitats of Singapore. *Marine Pollution Bulletin*, 50(12), pp. 1732-1738.

Dar, M.A. and El-Saharty, A.A. (2006). Recycling and retention of some heavy metals in the mangrove sediments Red Sea, Egypt. *Egyptian Journal of Aquatic Research*, 32(2), pp. 34-47.

Davari, A., Danekar, A., Khorasani, N. and Javanshir, A. (2012). Determination of heavy metals in mangrove forests of Booshehr. *Journal of Environment*, 38(3), pp. 27-36.

Defew, L.H., Mair, J.M. and Guzman, H.M. (2005). An assessment of metal contamination in mangrove sediments and leaves from Punta Mala Bay, Pacific Panama. *Marine Pollution Bulletin*, 50(5), pp. 547-552.

Department of Petroleum Resources (DPR) (2002). Environmental guidelines and standards for the petroleum industry in Nigeria (EGASPIN).

Ediagbonya, T.F. and Ayedun, H. (2018). Geochemistry of terrigenous sediments in surface water from ore and okitipupa southwest, Nigeria. *Bangladesh Journal of Scientific and Industrial Research*, 53(2), pp. 145-154.

Ehiagbonare, J.E., Adjarhore, R.Y. and Enabulele, S.A. (2009). Effect of cassava effluent on Okada natural water. *African Journal of Biotechnology*, 8, pp. 2816-2818.

Einollahipeer, F., Khammar, S. and Sabaghzadeh, A. (2013). A study of the heavy metal concentration in sediment and mangrove (*Avicenia marina*) Tissues in Qeshm Island, Persian Gulf. *Journal of Novel Applied Sciences*, 2(10), pp. 498-504.

European Commission, (EC) (2001). Commission Regulation 466/2001/EC of 8 March 2001 setting maximum levels for certain contaminants in foodstuffs. *Official Journal of European Community*, 2001, pp. 77:1–13.

European Commission, (EC) (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.

FAO/WHO (1989). WHO technical report series No 505, Evaluation of certain food additives and the contaminants, mercury, lead and cadmium for environment monitory report No 52 Center for environment. Tech. Rep., Fisheries and Aquaculture Science Lowest Tofit, UK.

Feng, H., Jiang, H.Y., Gao, W.S., Weinstein, M.P., Zhang, Q.F., Zhang, W.G., Yu, L.Z., Yuan, D.K. and Tao, J.H. (2011). Metal contamination in sediments of the western Bohai Bay and adjacent estuaries, China. *Journal of Environmental Management*, 92(4), pp. 1185-1197.

Finkelman, R.B. (2007). Health impacts of coal: facts and fallacies. Royal Swedish Academy of Sciences. *Ambio*, 36, pp. 103-105.

Federal Ministry of Environment (FMEnv) (2011). National Guidelines and standards for water quality in Nigeria. Publication Federal Ministry of Environment (FMENV), Lagos, Nigeria. Pp: 114.

Friberg, L., Piscator, M., Nordberg, G.F. and Kjellstrom, T. (1974). Health effects of cadmium in the general environment in Japan. In Cadmium in the Environment, 2nd ed. (Eds. Friberg, L., Piscator, M., Nordberg, G.F. and,Kjellstrom, T.). Chemical Rubber Press, Cleaveland pp. 137–227.

Funtua, M.A., Aminah, H.L., Dailami, S.A. and Onakpa, S.A. (2016). Heavy metal contents of water, sediment and fish from Kpatariver Lokoja, Kogi State-Nigeria. *International Journal of Environmental Science and Toxicology Research*, 4(9) pp. 162-168.

Hardy, D.H., Myers, J. and Stokes, C. (2008) Heavy metals in North Carolina soils: occurrence and significance. North Carolina Department of Agriculture and Consumer Services, pp. 1-2.

Horsfall, M. and Spiff, A.L. (2002). Distribution and partitioning of trace metals in sediments of the lower reaches of the New Calabar River, Port Harcourt, Nigeria. *Environmental Monitoring and Assessment*, 78, pp. 309-326.

Hungarian Ministry for Environment (2000). Order No. 10/2000 (VI. 2), on the limit values for the protection of quality of groundwater resources and soils (in Hungarian).

Hungarian Ministry of Health (1999). Order No. 17/1999 (VI. 16), on the limit values on the allowed concentration of chemical in food (in Hungarian).

Ibrahim, D., Ibrahim, A.S., Paul, E.D., Umar, M. and Zannah, U.A.S. (2018). Determination of some heavy metal content in Tilapia and Cat fish species in Lake Njuwa, Adamawa State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 22(8), pp. 1159 –1165.

Iwegbue, C.M.A., Bassey, F.I., Tesi, G.O., Nwajei, G.E. and Tsafe, A.I. (2013). Assessment of heavy metal contamination in soils around cassava processing mills in sub-urban areas of Delta State, Southern Nigeria. *Nigerian Journal of Basic and Applied Science*, 21(2), pp. 96-104.

Jain, M., Pal, M., Gupta, P. and Gadre, R. (2007). Effect of cadmium on chlorophyll biosynthesis and enzymes of nitrogen assimilation in greening maize leaf segments: role of 2-oxoglutarate. *Indian Journal of Experimental Biology*, 45(4), pp. 385-389.

Jonathan, S.G., Bawo, D.D.S., Adejoye, D.O. and Briyai, O.F. (2009). Studies on biomass production in *Auricularia polytricha* collected from Wilberforce Island, Bayelsa State, Nigeria. *American Journal of Applied Sciences*, 6(1), pp. 182-186.

Kaewtubtim, P., Meeinkuirt, W., Seepom, S. and Pichtel, J. (2016). Heavy metal phytoremediation potential of plants species in a mangrove ecosystem in Pattani Bay, Thailand. *Applied Ecology and Environmental Research*, 14(1), pp. 367-382.

Kathiresan, K., Saravanakumar, K. and Mullai, M. (2014). Bioaccumulation of trace elements by *Avicennia marina*. *Journal of Coastal Life Medicine*, 2(11), pp. 888-894.

Keay, R.W.J., (1959). *An outlines of Nigeria vegetation*, Government Printer, Lagos, Nigeria.

Kehrig, H.A., Pinto, F.N., Moreira, I. and Malm, O. (2003). Heavy metals and methylmercury in a tropical coastal estuary and a mangrove in Brazil. *Organic Geochemistry*, 34(5), pp. 661-669.

Khan, M.I., Khisroon, M., Khan, A., Gulfam, N., Siraj, M., Zaidi, F., Abidullah, A., Syeda Hira Fatima, S.H., Noreen, S.H., Shah, Z.A. and Qadir, F. (2018). Bioaccumulation of heavy metals in water, sediments, and tissues and their histopathological effects on *Anodonta cygnea* (Linea, 1876) in Kabul River, Khyber Pakhtunkhwa, Pakistan. *Biomed Research International*, 2018, pp. 1-10.

Kodom, K., Preko, K. and Boamah, D. (2012). X-ray fluorescence (XRF) analysis of heavy metal pollution from an industrial area in Kumasi, Ghana. *International Journal of Soil and Sediment Contamination*, 21(8), pp. 1006-1021.

Kumar, A., Ramanathan, A., Prasad, M.B., Datta, D., Kumar, M. and Sappal, S.M. (2016). Distribution, enrichment, and potential toxicity of trace metals in the surface sediments of sundarbans mangrove ecosystem, Bangladesh: a baseline before Sundarbans oil spill of December, 2014. *Environmental Science and Pollution Research*, 23(9), pp. 8985-8999.

Kumar, N., Soni, H. and Kumar, R.N. (2007). Characterization of heavy metals in vegetables using inductive coupled plasma analyzer (ICPA). *Journal of Applied Sciences and Environmental Management*, 11(3), pp. 75–79.

Lacatusu, R., Rauta, C., Carstea, S. and Ghelase, I. (1996). Soil-plant-man relationships in heavy metal polluted areas in Romania. *Applied Geochemistry*, 11, pp. 105 – 107.

Li, L., Ding, Z. and Liu, J. (2008). Distribution of heavy metals in surficial sediments from main mangrove wetlands of china and their influence factors. *Acta Oceanologica Sinica*, 30(5), pp. 160-164.

MacFarlane, G.R. (2002). Leaf biochemical parameters in *Avcienna marina* (Forsk.) Vierh as potential biomarkers of heavy metals stress in estuarine ecosystems. *Marine Pollution Bulletin*, 44(3), pp. 244-256.

Madi, L.M., Boeger, M. and Reissmann, C. (2015). Distribution of Cu, Fe, Mn, and Zn in two mangroves of Southern Brazil. *Brazilian Archives of Biology and Technology*, 58(6), pp. 970-976.

Marchand, C., Lallier-Verges, E., Baltzer, F. and Alberic, P. (2006). Heavy metals distribution in mangrove sediments along the mobile coastline of French Guiana. *Marine Chemistry*, 98(1), pp.1-17.

Mathew, B.B., Jaishankar, M., Tseten, T., Anbalagan, N. and Beeregowda, K.N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, 7(2), pp. 60–72.

Mil-Homens, M., Costa, A.M., Fonseca, S., Trancoso, M.A., Lopes, C., Serrano, R. and Sousa, R. (2013), Natural heavy metal and metalloid concentration in sediments of the Minho River estuary Portugal): baseline values for environmental studies, *Environmental Monitoring and Assessment*, 185(7), pp. 5937-5950.

Nogawa, K. (1981). *Itai-itaidisease and follow-up studies*. In: Cadmium in the Environment, Part II. Nriagu, J.O. (Ed.). John Wiley & Sons,New York, pp. 643–689.

Nwani, C. D., Nwachi, D.A., Okogwu, O.I., Ude, E.F. and Odoh, G.E. (2010). Heavy metals in fish species from lotic freshwater ecosystem at Afikpo, Nigeria. *Journal of Environmental Biology*, 31(5), pp. 595-601.

Obunwo, C.C., Braide, S.A. and Chindah, A.C. (2004). Influence of urban activities on the water quality of a fresh water stream in the Niger Delta, Nigeria. *Journal of Nigerian Environmental Society*, 2, pp. 196-209.

Ogbonna, P.C. and Okezie, N. (2011). Heavy metal and macronutrient content of roadside soil and vegetation in Umuahia, Nigeria. *Journal of Terrestrial and Aquatic Environmental Toxicol*ogy, 5(1), pp. 35-39.

Ogbonna, P.C., Emea, R. and Teixeira da Silva, J.A. (2011). Heavy metal concentration in soil and woody plants in a quarry. *Toxicology and Environmental Chemistry*, 93(5), pp.895-903.

Ogbonna, P.C., Anigor, T.O. and Teixeira da Silva, J.A. (2012). Bioaccumulation of nutrients and heavy metals in plants at a coal mine. *Terrestrial and Aquatic Environmental Toxicology*, 6(2), pp. 127-131.

Ogbonna, P.C., Odukaesieme, C. and Teixeira da Silva, J.A. (2013). Distribution of heavy metals in soil and accumulation in plants at an agricultural area of Umudike, Nigeria. *Chemistry and Ecology*, 29(7), pp. 595-603.

Ogbonna, P.C., Nzegbule, E.C. and Okorie, P.E. (2018a). Soil chemical characteristics in wet and dry season at Iva long wall underground mined site, Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 2(1), pp. 96-107.

Ogbonna, P.C., Ukpai, N and Obasi, K.O. (2018b). Assessment of metal contamination in Ubeyi River and accumulation in fish and sediment. *Journal of Applied Sciences and Environmental Management*, 22(8), pp. 1151–1157.

Ogbonna, P.C., Nzegbule, E.C. and Okorie, P.E. (2018c). Seasonal variation in heavy metal accumulation in plants at coal mine sites and possible health risk. *Nigerian Journal of Environmental Sciences and Technology*, 2(2), pp. 196-207.

Ogbonna, P.C., Kalu, E.N. and Nwankwo, O.U. (2018d). Determination of heavy metals in sawdust particles, distribution in soil and accumulation in plants at Ahiaeke timber market in Umuahia, Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 2(2), pp. 160-170.

Ogbonna P.C., Osim, O.O. and Biose, E. (2020). Determination of heavy metal contamination in soil and accumulation in cassava (*Manihot Esculenta*) in automobile waste dumpsite at Ohiya mechanic village. *Nigerian Journal of Environmental Sciences and Technology*, 4(1), pp. 54-69.

Ohimain, E.I., Seiyaboh, E.I., Izah, S.C., Oghenegueke, E.V. and Perewarebo, G.T. (2012). Some selected physico-chemical and heavy metal properties of palm oil mill effluents. *Greener Journal of Physical Sciences*, 2(4), pp. 131-137.

Okovido, J.O., Owen-Egharevba, U. and Akhigbe, L.O. (2018). Rainwater harvesting system for water supply in a rural community in Edo State, Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 2(2), pp. 266-274.

Olaniyi, Christianah O, Adewoye SO, Ismail MO, Adeseun FM. (2013). Effect of cassava mill effluents on haematological and biochemical characteristics of adult African catfish (*Clarias gariepinus*). *Journal of Biotechnology, Agriculture and Healthcare*, 3, pp. 191-196.

Oviasogie., P.O and Ofomaja, A. (2007). Available Mn, Fe, Pb and physicochemical changes associated with soil receiving cassava mill effluent. *Journal of Chemical Society of Nigeria,* 32(1), pp. 69-73.

Pan, L., Fang, G., Wang, Y., Wang, L., Su, B., Li, D. and Xiang, B. (2018). Potentially toxic element pollution levels and risk assessment of soils and sediments in the upstream river, Miyun Reservoir, China. *International Journal of Environmental Research and Public Health*, 15, pp. 2-17.

Parvaresh, H., Abedi, Z., Farshchi, P., Karami, M., Khorasani, N, and Karbassi, A. (2011). Bioavailability and concentration of heavy metals in the sediments and leaves of grey mangrove, *Avicennia marina* (Forsk.) Vierh, in SirikAzini Creek, Iran. *Biological Trace Elements Research*, 14 (2), pp. 1121-1130.

Perdomo, L., Ensminger, I., Espinos, L.F., Elsters, C., Wallner-Kersanach, M. and Schnetters, M.L. (1998). The mangrove ecosystem of the Cie´naga Grande de Santa Marta (Colombia): Observations on regeneration and trace metals in sediment. *Marine Pollution Bulletin*, 37, pp. 393–403.

Plunkett, E.R., (1987). *Handbook of industrial toxicology*. Edward Arnold Chemical Publishing Co. Inc. USA, pp. 148-151.

Preda, M. and Cox, M.E. (2002). Trace metal occurrence and distribution in sediments and mangroves, Pumicestone region, SE Queensland, Australia. *Environment International*, 28(5), pp. 433-449.

Ray, A., Tripathy, S., Patra, S. and Sarma, V. (2006). Assessment of Godavari Estuarine mangrove ecosystem through trace metal studies. *Environment International*, 32(2), pp. 219-223.

Saeed, S.M. (2000). A study on factors affecting fish production from certain fish farms in the Delta. M. Sc. Thesis. Faculty of Science, Ain Shams University, Egypt.

Sakan, S.M., Dordević, D.S., Manojlović, D.D. and Predrag, P.S. (2009). Assessment of heavy metal pollutants accumulation in the Tisza river sediments, *Journal of Environmental Management*, 90(11), pp. 3382-3390.

Shriadah, M. (1999). Heavy metals in mangrove sediments of the United Arab Emirates shoreline (Arabian Gulf). *Water Air Soil Pollution*, 116(3), pp. 523-534.

Simpson, S.L., Batley, G.E., Chariton, A.A., Stauber, J.L., King, C.K., Chapman, J.C., Hyne, R.V., Gale, S.A., Roach, A.C. and Maher, W.A. (2005). Handbook for Sediment Quality Assessment (CSIRO:Bangor, NSW). Published by Centre for Environmental Contaminants Research CSIRO Energy Technology, Lucas Heights NSW.

Sperotto, R.A., Ricachenevsky, F.K., Williams, L.E., Vasconcelos, M.W. and Menguer, P.K (2014). From soil to seed: micronutrient movement into and within the plant. *Front Plant Sciences*, 5, pp. 438-441.

Steel, R.G.D. and Torrie, J.H. (1980). *Principles and procedures of statistics: A biometric approach*, McGraw-Hill, New York, p. 633.

Ugbomeh, A.P., Olu, U., Bob Manuel, K.N.O. and Ekweozor, I.K.E. (2019) Levels of selected heavy metals in water and sediment of the Soku oil field area of the Niger Delta, Nigeria. *Journal of Aquatic Pollution and Toxicology*, 3(1), pp. 25-34.

Usman, A.R., Alkredaa, R.S., and Al-Wabel, M.I. (2013). Heavy metal contamination in sediments and mangroves from the coast of Red Sea: *Avicennia marina* as potential metal bioaccumulator. *Ecotoxicology and Environmental Safety*, 97, pp. 263-270.

Withanachchi, S.S., Ghambashidze, G., Kunchulia, I., Urushadze, T. and Ploeger, A. (2018). Water quality in surface water: a preliminary assessment of heavy metal contamination of the Mashavera River, Georgia. *International Journal of Environmental Research and Public Health*, 2018, pp. 1-25.

World Health Organization, WHO (1985). Guidelines for drinking water quality (ii): Health criteria and supporting information. Geneva: WHO. p. 130.

World Health Organization, WHO (1992). Environmental Health Criteria 134. Cadmium, WHO, Geneva.

World Health Organization, FAO/WHO (2001). Managing water in the home: Accelerated health gains from improved water supply, Geneva.

World Health Organization, WHO (2008) Guidelines for drinking water quality, World health organization, Geneva.

Huang, L., Wu, Z. and Geng, J. (2015). Heavy metal contamination in sediments and mangroves from Maowei Gulf, South China. *Fresenius Environmental Bulletin*, 24, pp. 1091-1097.

Wuana, R.A. and Okieimen, F.E. (2011). Heavy metals in contaminated soils: A Review of sources, chemistry, risks and best available strategies for remediation. *Communications in Soil Science and Plant Analysis*, 42, pp. 111-122.

Wyllie, D., Mtui, M., Oloya, J.D. and Kategile, J.A. (1984). The processing of cassava meal for chicks. Nutrition Reports International 30(5), pp. 1127-1136.

Yang, Z., Wang, Y., Shen, Z., Niu, J. and Tang, Z. (2009), Distribution and speciation of elements in sediments from the mainstream, tributaries, and lakes of the Yangtze River catchment of Wuhan, China. *Journal of Hazardous Materials*, 30, 166(2-3), pp. 1186-1194.

Yehia, H.M. and Sebaee, E.S. (2012). Bioaccumulation of heavy metals in water, sediment and fish (*Oreochromis niloticus* and *Clarias anguillaris*), in Rosetta branch of the River Nile, Egypt. *African Journal of Biotechnology*, 11(77), pp. 14204-14216.

Yilmaz, F., Nozdemir, N., Demirak, A. and Tuna, A.L. (2005). Heavy metal levels in two fish species *Leuciscus cephalus* and *Lepomis gibbosus*. *Food Chemistry*, 100, pp. 830–835.

Yilmaz, A.B., Sangün, M.K., Yağlıoğlu, D. and Turan, C. (2010). Metals (major, essential to non-essential) composition of the different tissues of three demersal fish species from İskenderun Bay, Turkey. *Food Chemistry*, 123(2), pp. 410–415.

Yu, R., Hu, G., Zhang, W. and Liu, B. (2015). Accumulation and transfer of heavy metals in the mangrove from Quanzhou Bay Wetland, SE Coast of China. *Journal of Residuals Science and Technology*, 12(1), pp. 79-83.