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# Evaluation of Some Heavy Metals in Selected Sea Foods Directly from the Creeks in Rivers State, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author IE designed the study, performed the statistical analysis and wrote the protocol. Authors RBE and NFP wrote the first draft of the manuscript. Authors AMA and AEBC managed the analyses of the study. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aim:** To assess and compare the levels of arsenic, cadmium, mercury and lead, in common seafoods (mudskippers, periwinkle and Shrimp) consumed in Rivers state obtained from different creeks of Rivers State Nigeria.
**Study Design:** Commonly consumed seafoods in Rivers State: *Periopthalmus barbarous* (mudskipper), *Pandalus borealis* (shrimp) and *Tympanotonus fucatus* (periwinkle) were collected at 5 different occasions from each of the study location (creek): Eagle Island, Iwofe, Bodo and Borokiri creeks in Rivers State. Eagle Island and Iwofe creeks are in Obio/Apkor and Degema LGA respectively, Borokiri Creek is in Port Harcourt LGA while Bodo creek is located in Gokana LGA.
**Study Area:** The study was carried out in the Department of Medical Laboratory Science, Rivers State University between the periods of June, 2018 – March, 2019. Samples of seafoods were

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collected from Bodo, Eagle Island, Borokiri and Iwofe creeks of Rivers State for 5 times at interval of 30 days between the periods of June, 2018 – October, 2018 during the wet season.
**Methodology:** *Periopthalmus barbarous*, *Pandalus borealis,* and *Tympanotonus fucatus* were collected from Eagle Island, Iwofe, Bodo and Borokiri creeks. The samples were correctly labeled, dried in an oven at 80°C, ground to powdered form then sieved to attain homogenous particles. Each sample was weighed, recorded and the concentrations of metals in the samples were determined. Two (2) grams each of the ground samples were weighed and put into a beaker with 6mls of nitric acid ($HNO_3$) which was added as oxidizing acid to break the sample matrix and 2ml of perchloric acid as a reagent with 2 mls of de-ionized water was added to blend it. The sample was place on a heating mantle at 105°C until the sample volume reduced to two third of its original volume, the sample color clear and turns yellowish and its entire component was digested. The concentration of HMs: lead, arsenic, cadmium and mercury in the digested seafood samples were analysed using Atomic absorption spectrophotometer (AAS). The concentration of HMs from the sample were determined from the absorbance calibration in parts per million (ppm) or mg/kg dw.
**Results:** The bio-concentration mercury and arsenic in the selected seafoods from the creeks were below the World Health Organization permissible limits while levels of cadmium and lead in the seafoods in the order of periwinkle>mudskipper>shrimp collected from these creeks were above the FAO/WHO permissible limits of 0.5 1.0 mg/kg dw and 2.0 mg/kg dw respectively.
**Conclusion:** Mudskipper, periwinkle and shrimp were observed to bio-accumulate HMs beyond FAO/WHO permissible limits. Toxicities of these HMs in humans could induce several clinical derangements and eventually death if drastic measures are not put in place to stop or limit these anthropogenic activities.

*Keywords: Seafoods; heavy metals; creeks; Rivers State; Niger Delta.*

## ABBREVIATIONS

*dw : Dry Weight*
*FAO : Food and Agriculture Organization*
*HMs : Heavy Metals*
*WHO : World Health Organization*

## 1. INTRODUCTION

Rapid industrialization, technological, agricultural advancement, and urbanization has no doubt, improved our lifestyle and standards of living, but these advancements have also simultaneously polluted the natural environment [1]. Pollution is the introduction of contaminants into the environment leading to a reduction in the quality of the environment [1]. Industrial and domestic waste, municipal sewage, dust, smoke etcetera pollute air, land and sea. Pollutants like fertilization, HMs, pesticides, fungicides, emissions from automobile and others gets discharged and enter into water bodies and then directly or indirectly get into our food.

Heavy metals (HMs) are regarded as metallic or trace elements having relatively high densities with reference to the density of water [2,3]. The description of HMs have included metalloids (elements with metallic and non-metallic properties), because of the supposed inter-relationship between the concepts of heaviness and toxicity. Arsenic is a typical example of such metalloids as it can induce toxicity at low concentration of exposure [4,5]. HMs are naturally occurring metals from the earth crust having an atomic weight higher than 40.04 and they form part of the lithosphere and often get into the environment through volcanism, soil erosion, dissolution of water-soluble salts and so on [6,7]. The presences of large quantities are largely due to human activities such as coal burning, metal processing, plastics, textiles and petroleum combustion [8,9,10,11]. Other sources of HMs metals in the environment include agricultural, pharmaceutical, and domestic effluents [12]. HMs are an emerging class of human carcinogens [1,3]. They are toxic and harmful to human health even when ingested in little concentrations taken over time [13,14].

Based on whether some HMs play beneficial physiological roles in living organism, especially man, they have been classified into essential and non-essential HMs. Examples of essential HMs are cobalt (Co), copper (Cu), Iron (Fe), Magnesium (Mg), Manganese (Mn), Nickel (Ni), selenium (Se) and Zinc (Zn), which are elements required for different biochemical and physiological functions of the body, although only needed in minute quantities [9,12]. However, the non-essential HMs are non-degradable, having no known beneficial effects in humans and no homeostasis mechanism [15]. Examples of non-essential HMs include lead (Pb), mercury (Hg), cadmium (Cd), arsenic (As) and chromium (Cr) [12,15,16,17]. These HMs are used in industries for production of car batteries, lead based paints, thermometers, plastics, textiles, microelectronics, barometer and lead pipes as well as in medicine for tooth filling using the silver-mercury tooth amalgam, they are also present in fungicides and pesticides used in agriculture. Arsenic is used as a pigment, which is a major constituent of many consumer products (toys, candle and fabric) but its use in wallpaper. Cd is produced alongside Zn in different commercial forms. In automobile industries, cadmium is used as alloy for electroplating. It is also used for the production of various pigments including cadmium sulphate, and cadmium selenide. More so, it is required for stabilization for the production of polyvinyl plastic, and in rechargeable nickel – cadmium batteries [18]. Exposure to inorganic Hg causes lung damage, a chronic exposure is characterized by tremor, anxiety, restlessness, sleep disturbance and depression. Exposure to elemental Hg is associated with kidney damage and as allergen may cause contact eczema [3]. Pb is used in the production of car batteries, lead based paints, and lead pipes. In the human body, the greatest percentage of Pb is taken into the kidney, followed by the liver and the other soft tissues such as heart and brain [19]. The nervous system is the most vulnerable target of Pb poisoning [3,14].

The contamination of water bodies with HMs is a consequent of many anthropogenic activities. In the Niger Delta, south-south of Nigeria, crude oil has been a major pollutant of the marine environment, it occurs during shipping, spills, and leakages from pipelines [20,21]. The coastal marine environment has also been exposed to pollution caused by polycyclic aromatic hydrocarbon (PAH), resulting from incomplete combustion of coal, fossil oil and wood, and petroleum seeps [2,22,23]. Contamination of water bodies had led to their bioaccumulation in the tissue of some fishes and seafoods. Seafoods considered in this study include mudskipper, shrimp and periwinkle. These Seafoods were considered because they are popular around the world and highly consumed because of its high protein content, low saturated fatty acid and high Omega-3 fatty acid content in Rivers State [24].

Mudskippers are the largest amphibious fish that are uniquely adapted to living on mudflats having a distinct ability to transition from aqueous life to terrestrial living [25]. *Periophthalmus* specie is one of the most predominant seafood in Rivers State, Nigeria. The Mudskippers are typical recipients of HMs when pollution occurs in the coastal ecosystem as they are capable of accumulating and tolerating HMs in their tissues [26,27,28]. Being amphibious, mudskippers migrate to deep water and to the mangrove daily [28,29], thus, having direct contact with the different pollutants that enter into coastal water via any route – industrial, agricultural and domestic activities [27,30]. The plasma enzyme levels in mudskippers of polluted water have been reported to be higher, consequently leading to a change in their ability to metabolize protein [31]. A study by Akinrotimi et al. [23], carried out in Buguma and Ekerekana Creeks in Niger Delta showed that the level of Pb in mudskipper were above the WHO permissible limit.

Shrimp (*Pandalus borealis)* is found in cold parts of the Atlantic and Pacific Ocean and it is commonly called 'pink shrimp' but locally called 'crayfish'. It lives on soft muddy bottoms at depths of 20-1,330m. While crayfish are a valuable food source, they are also useful in bio-monitoring of HMs contamination in water bodies as they can tolerate polluted environment, bio-accumulate toxins in their tissues and bio-magnify these HMs at concentration greater than those in the water and sediments of the same coastal area [32,33]. In 2005, Asaolu and Olaofe [32], reported the presence of essential (Fe, Zn, and Cu) and toxic (Pb, Cd, Cr, and Mn) of which the highest concentrations were found in sediment, followed by crayfish, fishes *(Oreorchromis niloticus*, synodontis *spp*, and *Clarias gariepinus*) and water in Ondo costal region of Niger Delta, Nigeria.

In a similar manner, periwinkles have also been found to bio-accumulate toxic metals in their bodies when they are exposed to occasions of coastal pollution [34,35]. Periwinkles are deposit feeders, that is, they feed on sediments benthic dweller which implies that they have the ability to bio-accumulate metals in their tissue and so integrate the environmental conditions and sediments of the water making them good bio-indicators of metals [36]. According to Daka et al. [37], periwinkles satisfy a number of the criteria listed for the selection of an ideal bio-indicator. Research by Moslen et al. [36], showed a value of lead (Pb) to be lower than WHO permissible limit, but confirmed the presence of HMs in this seafood. In another related researches by Nwaichi et al. [19] and Davies et al. [35], they reported in their separate studies the presence of lead, chromium and cadmium in periwinkle further confirming the presence of HMs in this aquatic animal. Therefore, in this study, HMs levels (Lead, Cadmium, Arsenic and Mercury) in some seafoods (mudskipper, Periwinkle and crayfish) obtained from Bodo, Eagle Island, Borokiri and Iwofe creeks which are major creeks in which seafoods were caught and supplied to most areas in Port Harcourt Metropolis and Rivers state will be analysed.

## 2. MATERIALS AND METHODS

### 2.1 Materials

Materials used in this study include measuring cylinder, weighing balance (Ohaus), local grinder, beaker, filter paper, petri dish (fisher scientific, USA), de-ionized water, nitric acid ($HNO_3$) and sulphuric acid ($H_2SO_4$), (Sigma-Aidrich, Germany) hot air oven (memment, Germany), heating mantle, Solar thermo elemental atomic absorption spectrophotometer (AAS) Model SE-71906.

### 2.2 Sampling and Sampling Locations

Commonly consumed seafoods such as mudskipper, crayfish and periwinkle were collected directly from Eagle Island, Iwofe, Bodo and Borokiri Creeks with the help of fishermen. Sampling was done for 5 times at interval of 30 days between the periods of June, 2018 – October, 2018 during the wet season.

### 2.3 Description of Sampling Locations

Iwofe creek is located at the coordinates 4°49'4"N, and 6° 57'24"E in Degema Local Government Area of Rivers State. It is characterized by red mangrove – Rhizophora mangle and other species. More so, the Eagle Island creek is located at the coordinates 4°49'4"N, and 6° 57'24"E in Obio/Apkor Local Government Area of Rivers State. The Borokiri creek is mainly made up of Okirika Island and Aboturu Creeks. Borokiri is within the City of Port Harcourt, Rivers State, Nigeria. It lies at 4.740°N and 7.023°E. The creeks as described by Ogolo et al. [38] are characterized by mangrove species like Avicima species, Rhizophora, Nepa palm and host of other plant and animal species. The Iwofe, Eagle Island and Borokiri creeks are reaches of the new Calabar River. Finally, Bodo creek is the upper reach of the Andoni-Bonny estuarine system and it is a collection of networks of brackish waters, mangrove swamps and pockets of island located at $4^0 36'$N and $7^0 21'$E. Bodo is in Gokana Local Government area of Rivers State. The main human activities here are artisanal fishing with canoes, drift nets and the use of hook and lines. However, this community has been hit by one of the major crude oil spill in the Niger Delta for which Royal Dutch Shell has accepted been responsible.

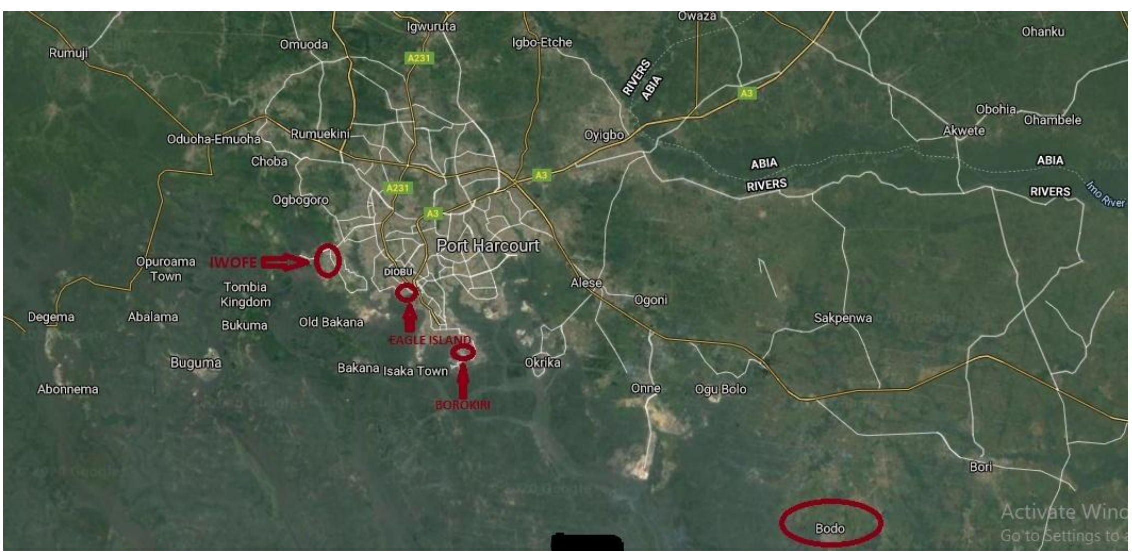


**Fig. 1. Map showing the sampling areas (in red) around in Rivers State**

## 2.4 Experimental Design

Mudskipper, Shrimp, and periwinkle were collected from 4 different locations in Rivers State. The seafoods were collected at 5 different occasions from Eagle Island, Iwofe, Bodo and Borokiri Creeks. The samples were labeled and dried in an oven. The dried samples were ground and the concentrations of heavy metal in the samples were determined.

## 2.5 Sample Preparation

The periwinkles were removed from their shells using acid-sterilized needle. The other seafoods as well as the removed periwinkle were strapped in aluminum foil, and labeled according to the area of collection. They were dried in oven at a temperature of $80^0$C. The dried samples were ground to powdered form in a local blender, then sieved to attain homogenous particles and weighed in a weighing balance. Their respective weights were recorded.

### 2.5.1 Acid digestion of ground samples

Two (2) grams each of the ground samples were weighed and put into a beaker with 6mls of nitric acid ($HNO_3$) which was added as oxidizing acid to break the sample matrix and 2ml of perchloric acid as a reagent with 2mls of de-ionized water was added to blend it. The sample was place on a heating mantle at $105^0$C until the sample volume reduced to two third of its original volume, the sample color clear and turns yellowish and its entire component was digested. The sample was filtered with a filter paper and filtrate was made to a known mark with a de-ionized water ($D/H_2O$).

### 2.5.2 Quality control and validation of the digestion method

Possible contamination of the procedure was avoided during the analysis of arsenic in the sample by ensuring that all pipette tips, cork and glassware were washed with acid (10% nitric acid). Validation of the digestion method and instrument used was done by carrying out recovery experiment and precision analysis.

## 2.6 Sample Analysis for Heavy Metals

The concentration of Pb, As, Cd and Hg in the digested seafood samples were analysed using Solar Thermo Elemental Atomic absorption spectrophotometer (AAS) Model SE-71906. The principle of measurement was based on Beer-Lambert's law which states that the amount of light absorbed by a coloured solution is directly proportional to the concentration of the solution. The concentration of HMs from the sample were determined from the absorbance calibration in parts per million (ppm).

## 2.7 Statistical Analysis

Statistical software used for data analysis was Graphpad Prism 8.02 (California, USA). Statistical tools used were mean, standard deviation and inferential statistics using one Way ANOVA with post-hoc done with turkeys multiple tests. Statistical significance was set at $P$=.05.

# 3. RESULTS

## 3.1 Heavy Metals Concentration in Sea Foods in Some Selected Creeks of Rivers State

In Table 1, one Way ANOVA of arsenic concentrations among the three different sea foods collected from different creeks in Rivers State. Iwofe Creek, showed highest significant concentration of arsenic in shrimps>periwinkle> mudskipper. However, in Eagle Island, Borokiri and Bodo Creek, the results obtained showed that the significant highest concentration of arsenic level was seen in periwinkle> mudskipper>shrimps (Table 1).

In addition when Cadmium was considered, Iwofe, Eagle Island and Borokiri creeks indicated the highest concentration was seen in periwinkle>mudskipper>shrimps (Table 2). However, in Bodo Creek, again, the concentration was in the order of periwinkle> shrimps>mudskipper (Table 2).

Furthermore, when mercury was considered, iwofe creek, the concentration of mercury concentration did not differ significantly the seafoods considered. However, the mercury level was in the order of periwinkle> shrimp>mudskipper. In Eagle Island, mudskipper and periwinkle showed no significant differences with the highest concentration but significant lower values were seen shrimps. In Borokiri and Bodo creeks, mudskipper had the significant highest concentration in the order of mudskipper>periwinkle>shrimps (Table 3).

Finally, when Lead was considered, Iwofe, Eagle Island and Borokiri creek indicated significant highest level of Lead concentration in the order of periwinkle>Mudskippers>shrimps. However, in Bodo creek, it was in the order of periwinkle>shrimps>Mudskipper (Table 4).

**Table 1. Arsenic concentration (ppm) in commonly consumed sea foods in some selected creeks in Rivers State**

| Creeks | Net conc. | Mudskipper | Shrimps | Periwinkle | *P* value | F value | Remark |
|---|---|---|---|---|---|---|---|
| Iwofe (n=5) | 0.19±0.0005 | $0.03±0.0002^{a}$ | $0.11±0.0002^{bc}$ | $0.05±0.0001^{bd}$ | <0.0001 | 1678 | S |
| Eagle (n=5) | 0.24±0.0002 | $0.11±0.0001^{a}$ | $0.01±0.0001^{bc}$ | $0.12±5.7×10^{-5bd}$ | <0.0001 | 9227 | S |
| Borokiri (n=5) | 0.08±0.0003 | $0.03±0.0002^{a}$ | $0.01±5.7×10^{-5bc}$ | $0.04±0.0001^{bd}$ | <0.0001 | 5460 | S |
| Bodo (n=5) | 0.24±0.0004 | $0.10±0.0001^{a}$ | $0.02±0.0001^{bc}$ | $0.14±0.0002^{bd}$ | <0.0001 | 6584 | S |

*Values in same column with different superscript (a, b) differ significantly when comparing Arsenic in Mudskipper to other sea foods. Values in same column with different superscript (c, d) differ significantly when comparing Arsenic in Shrimps to Periwinkle. S=significant, n=no of sampling*

**Table 2. Cadmium concentration (ppm) in commonly consumed sea foods in some selected creeks in Rivers State**

| Creeks | Net Conc. | Mudskipper | Shrimps | Periwinkle | P value | F value | Remark |
|---|---|---|---|---|---|---|---|
| Iwofe (n=5) | 7.75±0.0005 | $2.64±0.0001^{a}$ | $1.61±0.0002^{bc}$ | $3.32±0.0002^{bd}$ | <0.0001 | $8.81x10^{7}$ | S |
| Eagle (n=5) | 3.72±0.0006 | $1.29±0.0002^{a}$ | $0.17±0.0002^{bc}$ | $2.26±0.0002^{bd}$ | <0.0001 | $9.37x10^{7}$ | S |
| Borokiri(n=5) | 12.29±0.0005 | $3.30±0.0002^{a}$ | $1.94±0.0002^{bc}$ | $3.33±0.0001^{bd}$ | <0.0001 | $9.95x10^{7}$ | S |
| Bodo (n=5) | 5.54±0.0004 | $0.56±0.0001^{a}$ | $1.67±0.0001^{bc}$ | $3.31±0.0002^{bd}$ | <0.0001 | $3.75x10^{8}$ | S |

*Values in same column with different superscript (a, b) differ significantly when comparing Cadmium in Mudskipper to other sea foods. Values in same column with different superscript (c, d) differ significantly when comparing Cadmium in Shrimps to Periwinkle. S=significant. n=no of sampling*

**Table 3. Mercury concentration (ppm) in commonly consumed sea foods in some selected creeks of Rivers State**

| Creeks | Net Conc. | Mudskipper | Shrimps | Periwinkle | P value | F value | Remark |
|---|---|---|---|---|---|---|---|
| Iwofe (n=5) | 0.015±0.0010 | $0. 0012±0.006^{a}$ | $0.0022±0.0002^{ab}$ | $0.011±0.0002^{ab}$ | 0.0691 | 4.309 | NS |
| Eagle (n=5) | 0.008±0.0006 | $0.0034±0.0003^{a}$ | $0.0014±0.0001^{bc}$ | $0.003±0.0002^{ac}$ | <0.0001 | 146.2 | S |
| Borokiri (n=5) | 0.022±0.0006 | $0.012±0.0004^{a}$ | $0.004±0.0001^{bc}$ | $0.006±0.0001^{bd}$ | <0.0001 | 1161 | S |
| Bodo (n=5) | 0.13±0.0004 | $0.110±5.7×10^{-5a}$ | $0.004±0.0001^{bc}$ | $0.012±0.0002^{bd}$ | <0.0001 | 9127 | S |

*Values in same column with different superscript (a, b) differ significantly when comparing Mercury in Mudskipper to other sea foods. Values in same column with different superscript (c, d) differ significantly when comparing Mercury in Shrimps to Periwinkle. S=significant, NS= Not significant. n=no of sampling*

**Table 4. Lead concentration (ppm) in commonly consumed sea foods in some selected creeks of Rivers State**

| Parameters | Net conc | Mudskipper | Shrimps | Periwinkle | P value | F value | Remark |
|---|---|---|---|---|---|---|---|
| Iwofe (n=5) | 7.84±0.0005 | $2.74±0.0001^{a}$ | $1.69±0.0002^{bc}$ | $3.41±0.0002^{bd}$ | <0.0001 | $8.81x10^{7}$ | S |
| Eagle (n=5) | 3.99±0.0006 | $1.37±0.0002^{a}$ | $0.27±0.0002^{bc}$ | $2.35±0.0002^{bd}$ | <0.0001 | $9.367x10^{7}$ | S |
| Borokiri (n=5) | 8.85±0.0005 | $3.40±0.0002^{a}$ | $2.04±0.0002^{bc}$ | $3.41±0.0001^{bd}$ | <0.0001 | $9.951x10^{7}$ | S |
| Bodo (n=5) | 5.77±0.0004 | $0.63±0.0001^{a}$ | $1.74±0.0001^{bc}$ | $3.40±0.0002^{bd}$ | <0.0001 | $3.745x10^{8}$ | S |

*Values in same column with different superscript (a, b) differ significantly when comparing Lead in Mudskipper to other sea foods. Values in same column with different superscript (c, d) differ significantly when comparing Lead in Shrimps to Periwinkle. S=significant, NS= Not significant. n=no of sampling*

When the net concentration of HMs in the different sea foods were considered in the different sampling sites, it was observed that Bodo and Eagle island had the highest level of Arsenic in the seafoods considered (Table 1). More so, when cadmium was considered, Borokiri creek had the highest concentration of cadmium, followed by Iwofe creek (Table 2). In addition, Bodo creek had the highest concentration of mercury in the seafoods considered followed by Borokiri creek (Table 3). In case of lead, again, Borokiri creek had the highest concentration of Lead in the seafoods, followed by Iwofe creek. Bodo creek has the third highest concentration of Lead in the seafoods while Eagle Island had the least concentration of Lead (Table 4).

## 4. DISCUSSION

Regions of high industrial activities are potential areas of heavy metal pollution. Rivers State having several oil companies has been a potential site for the analysis of HMs as most of the industrial effluents are discharged into the sea. In this study the concentrations of cadmium, arsenic, mercury and lead in mudskipper, shrimps and periwinkle collected from Iwofe, Eagle Island, Borokiri and Bodo Creeks of Rivers State were determined and compared.

When Arsenic (As) concentrations in the seafoods were considered, shrimp had the highest concentration of As at Iwofe creek while periwinkles had the highest concentration of arsenic in Eagle island, Borokiri and Bodo creeks. The total bio-accumulated concentration of arsenic in these seafoods in the different locations is in descending order of Bodo>Eagle Island>Iwofe>Borokiri with the highest concentration of 0.24±0.0004ppm seen in Bodo creek. The concentration of arsenic in the seafoods observed in our work is within the established permissible limit of as in seafoods, fishes and fishery products of 1.41mg/kg (ppm) as reported by FAO/WHO [39]. Usese et al. [40] also reported that the concentration of HMs seen in fleshy fishes were below the FAO/WHO acceptable limits in Lagos Lagoon which is in line with the results as seen in Mudskipper but contrary to our findings in periwinkle. They [40] reported that arsenic in periwinkle was above the FAO/WHO acceptable limit with a value of 2.31±0.24 mg/kg. More so, the results seen in our study is in line with the findings of Kuplulu et al. [41]. They [41] also reported that As levels in seafoods in turkey were below FAO/WHO acceptable limits but the highest concentrations were seen in Shrimps. The concentration of As seen in the seafoods and Bodo creek having the highest level of As in these seafoods, though below the FAO/WHO acceptable limits is clearly an indication of anthropogenic activities especially due to oil drilling and bunkering. Bodo, has been hit by one of the major oil spillage in the Niger Delta coastal region of Nigeria.

In addition, when cadmium (Cd) concentrations in seafoods were considered, periwinkle had the highest level of bio-accumulated cadmium from Iwofe, Eagle Island and Borokiri, and Bodo creeks. The total bio-accumulated concentration of Cd is in descending order of Borokiri>Iwofe>Bodo>Eagle Island, with the highest concentration of 12.29±0.0005 ppm seen in Borokiri creeks. Kakulu et al. reported [33] that, the FAO/WHO maximum limit for Cd in seafoods is 0.5 – 1.0 mg/kg dw. In our study, it was observed all the seafoods collected from the different locations had Cd levels above the FAO/WHO maximum limit except in Bodo were Mudskipper and in Eagle Island were shrimps had value below the FAO/WHO maximum limit. The concentration of Cd exceeding the FAO/WHO permissible limit as seen in our result concurs with the findings of Abu et al. [42]. They [42] also found Cd concentrations in the blue crab *Calllinectus amnicola* and sediments obtained from Bodo creek exceeding the FAO/WHO permissible limit of 0.5 -1.0mg/kg dw. Nwaichi et al. [19] reported the highest level of Cd in shell fish like periwinkle from Abonnema waters in Rivers state, Niger Delta, Nigeria and their values were above FAO/WHO acceptable limits in seafoods. This report is also in line with our findings which indicated that periwinkle had the highest level of Cd in all the sites of collection. In a related study, Shovon et al. [43], reported that Cd level in seafoods obtained from Bangladesh River fell within the FAO/WHO acceptable limit. This result is also in line with our findings with respect to the level of Cd in Mudskipper and Shrimps in Bodo and Eagle Island respectively in our study but contrary to the level of Cd level in periwinkle and other seafoods. The high level of Cd seen in Borokiri could be related to the high level of industrial activities (waste) of Trans-Amadi industrial layout linked to the creeks through the various channels and drainages, illegal bunkering activities as well as spilled petroleum products flowing from the new Calabar River. Trans-Amadi industrial Layout is an area mapped out by the Rivers State Government for industrial activities in the

Port Harcourt metropolis. More so, the level of Cd exceeding the FAO/WHO permissible limit could also be due to oil spillage which had obviously destroyed the flora and fauna of Bodo Creeks as reported by United Nations Environmental Programme, 2009. Abu et al. [42], reported an association between higher concentrations of Cd in seafoods (shrimps) obtained from a spill site than those obtained from areas far away from the site of spillage.

Furthermore, when mercury (Hg) concentrations in seafoods were considered, periwinkle had the highest concentration of Hg from Iwofe Creek while mudskipper had the highest leves of Hg from Eagle Island, Borokiri and Bodo Creeks. The total bio-accumulated concentration of Hg in these seafoods in the different locations is in the descending order of Bodo>Borokiri>Iwofe>Eagle Island creek, with the highest concentration of 0.13±0.0004 seen in Bodo creeks. As reported by Nwaichi et al. [19], Kakulu et al. [33], the FAO/WHO maximum limit for Hg in seafoods is 0.5 mg/kg dw. In our study, it was observed all the seafoods collected from the different locations had Hg level below the FAO/WHO maximum limit of 0.5mg/kg dw in seafoods. The result of Hg level seen in the seafoods agrees with the reports of Nwaichi et al. [19]. They reported that Hg levels were within the FAO/WHO acceptable limits when HMs in seafoods from Abonnema waters in Rivers State, Niger Delta were analysed. The high level of Hg seen in Bodo could be related to the high level of crude spillage and an indication of anthropogenic activities. The highest concentration of HMs seen in could be due to their habitats and feeding habits which are mostly in the mud flats which unarguably contain more sediment. Sediments have been reported to accumulate the highest concentration of HMs. In 2006, Davies et al. [35], reported *that* that sediments accumulated highest concentrations of HMs>periwinkle>water in Elechi Creek of Port Harcourt.

Finally, when Lead (Pb) was considered, periwinkle had the highest level of Pb from Iwofe, Eagle Island, Borokiri, and Bodo creeks. The total bio-accumulated concentration of Pb in these seafoods in the different locations is in descending order of Borokiri>Iwofe> Bodo>Eagle Island with the highest concentration of 8.85±0.0005 seen in Borokiri creeks. According to FAO/WHO [39], the maximum limit for Pb in seafoods is 2.0 mg/kg dw. In our study, it was observed all the seafoods collected from the different locations had Pb level above the FAO/WHO maximum limit of 2.0mg/kg dw in seafoods. The high level of Pb above FAO/WHO permissible limit seen in the periwinkles agrees with the reports of Nwaichi et al. [19]. They [19] also reported high level of Pb above FAO/WHO permissible limits in periwinkles from Abonnema waters in Rivers State, Niger Delta. More so, the level of Pb above the permissive limit seen in periwinkle concurs with the reports of Abu et al. [42]. They also reported the presence of Pb above 2.0mg/kg dw blue crab (*Callinectus amnicola*) obtained from Bodo creeks. However, our result contradicts the findings of Moslen et al. [36], who reported that the values of Pb were below WHO permissible limit. More so, Mudskippers selected from Iwofe and Borokiri creeks as well as Shrimps collected from Borokiri creek had high levels of Pb above FAO/WHO permissible limits of 2.0mg/kg dw. The high level of Pb seen in Borokiri and Iwofe creeks could be related to the high level of crude drilling and industrial waste been released into the water body. Iwofe (in Rumuolumeni) is home to over 20 Oil and Gas companies involved in crude drilling and transportation. There are also activities of illegal bunkering that has made spillage possible. On the other hand, Borokiri is closely associated to the Okrika oil field and activities of crude oil business at Marine base, Port Harcourt. In addition, Borkiri is also connected with industrial activities (waste) of Trans-Amadi industrial layout through the various channels and drainages. Trans-Amadi industrial Layout is an area mapped out by the Rivers State Government for industrial activities in the Port Harcourt metropolis. The difference in the level of HMs in the different species of seafood can attributed to their life cycle, behavioral patterns, habitat and feeding habits of the specie [44]. The highest levels of Lead in Periwinkle and Mudskipper could be attributed mainly to feeding habit. These species of fishes, feed from sediment and particular matters thereby are more exposed or tend to bio-accumulate HMs.

The high levels of HMs seen in our study could also be affected by the season. These seafoods were collected around the start of rainy season between June and July. Therefore, the increase seen in these HMs in the seafoods may also be attributed to the leaching from pesticides sprayed on agricultural products, improper disposal of materials that contain these HMs which find their way into the water bodies thereby contaminating them. The ogoni and Ikwerre people of Rivers State are also farmers and they do participate actively in farming activities. From the findings it is implicit to say that bottom dwellers such as mudskipper, shrimp and periwinkle which showed variations in their accumulation levels are good bio-indicators of HMs, as a result of their feeding patterns leading to its bio-magnification and bioaccumulation as they make their way up the food chain to be taken by humans. Cd and Pb being non-essential HMs above the FAO/WHO permissive limits in seafoods might eventually pose a health hazards to the inhabitants of Rivers State as consumers due to their bio-accumulative tendencies over a prolong period.

## 5. CONCLUSION

The levels of As and Hg were within the FAO/WHO permissible limits for seafoods such as periwinkle, shrimps, and mudskippers in selected creeks in Rivers State. However, Pb and Cd had values above the FAO/WHO permissible limits in these seafoods. It is quite obvious that crude oil spills, illegal bunkering activities and industrial wastes released in these water bodies have severely affected common seafoods consumed by Rivers people of Nigeria and in turn might present a serious threat not only to the aquatic organisms or environment but also to humans who are frequent consumers these seafoods in Rivers state.

## 6. RECOMMENDATION

It is advised that novel policies and programs should be formulated and enforced by Rivers State Government even at the local level to reduce all forms of pollution into the coastal environment. It is also important to establish public/industrial educational and awareness programs on of the health risks associated with indiscriminate dumping of domestic, municipal waste, industrial effluents and illegal disruption of pipelines viz-a-viz HMs toxicity of the coastal environment and humans at large.

## 7. LIMITATION OF THE STUDY

The study was not design to cover wet and dry seasons in order to put into consideration possibly variations in HMs due to change in season.

## CONSENT

It is not applicable.

## ETHICAL APPROVAL

It is not applicable.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Bharti PK. Heavy metals in the environment. Environmental Science & Technology. 2014;16:243-256.
2. Ekpo EA, Asia IO, Amayo KO, Jegede DA. Determination of lead, cadmium & mercury in surrounding water & organs of some species of fish from Ikpoba River in Benin City, Nigeria. International Journal of Physics Sciences. 2008;3(11):289-292.
3. Jarup L. Hazards of heavy metal contamination. British Medical Bulletin. 2013;68(1):167-182.
4. Arif TJ, Mudssar A, Kehkashan S, Arif A, Inho C, Quazi MRH. Heavy metals & human health: Mechanistic insight into toxicology & counter defense system of antioxidants. International Journal of Molecular Sciences. 2015;16:29596-29630.
5. Duffus JH. Heavy metals-a meaningless term? Pure and Applied Chemistry. 2002;74(5):793–807.
6. Ming-OH Y. Biological & health effects of pollutants. Journal of Environmental Toxicology. 2005;16(5):55-72.
7. Fergosson JE. The heavy elements: Chemistry, environmental impact and health effects. Environmental Chemistry &Toxicology. 1990;4(6):16-87.
8. Obaroah IO, Abubaka U, Haruna MA, Elinge MC. Determination of heavy in River Argungu. Journal of Fisheries and Aquatic Science. 2015;10(6):581-586.

9. Tchounwou PB, Yedjou CG, Sutton DJ. Heavy metals toxicity & the environment. Molecular Clinical & Environmental Toxicology. 2012;101:133-164.
10. Pizent A, Tariba B, Zivkovic T. Reproductive toxicity of metals in men. Achieves of Industrial Hygiene and Toxicology. 2012;63:35–46.
11. Chandel M, Chand JG. Toxic effects of transition metals on male reproductive system: A review. Journal of Environmental and Occupational Science. 2014;3(1):204–213.
12. Obot O, Isangedighi AI, David SG. Heavy metals concentration in some commercial fishes in the lower cross river estuary, Nigeria. Nigerian Journal of Agriculture, Food, and Environment. 2016;12(4):218-224.
13. Mohammadi M, Askay S, Khodadadi M. Accumulation variation of selected heavy metals in *Barbus xanthopterus* in Karoon & Dez River of Khuzestan, Iran. Iranian Journal of Fisheries. 2011;11(2):372-382.
14. Andem AB, Ekpo PB. Proximate and mineral compositions of mudskipper fish (*Periophthalmus Babarus)* in the mangrove swamp of Calabar river, southern Nigeria. The International Journal of Science & Technology. 2014;2(3):72-76.
15. Vieria C, Morais S, Ramos S, Delerue-Matos C, Oliveira MBPP. Mercury, lead, cadmium & arsenic levels in three pelagic fishes from the Atlanta Ocean: Inter & intra-specific variability & human health risk of consumption. Food & Chemical Toxicology. 2011;49:932-932.
16. Rani A, Kumar A, Lal A, Pant M. Cellular mechanisms of cadmium-induced toxicity: A review. International Journal of Environmental Health and Research. 2014;24(1):378-399.
17. Ololade LA, Lajide L, Amoo IA. Seasonal variation in Ondo coastal sediment. Journal of Applied Science & Environmental Science. 2008;12(4):11-18.
18. Cobb AB. The elements cadmium. 1st ed. New York: Marshall Cavendish Corporation. 2008;8–10.
19. Nwaichi EO, Belonwu DC, Nkomadu CJ. Distribution of heavy metal in selected sea food & shell food from Abonnema water in Rivers State, Nigeria. International Journal of Pure & Applied Bioscience. 2013;1(4):63-66.
20. WHO. World Health Organization. Report on Heavy Metal; 1992.
21. Scott P, Nenibarini Z. Oil and water: The Bodo spills and the destruction of traditional livelihood structures in the Niger Delta. Community Development Journal. 2018;48(3):391-405.
22. Chimezie A, Ogbechea A, Palmerb P, Cokera H. Determination of polynuclear aromatic hydrocarbons in marine samples of Sikolo Fishing Settlement. Journal of Chromatography. 2005;10(73):323–330.
23. Akinrotimi OA, Makinde OO, Edun OM. Seasonal variations of heavy metals in selected sea foods from Buguma & Ekerekana Creek Niger Delta. International Journal of Innovative Studies of Aquatic Biology & Fishes (IJISABF). 2015;1(1):46-55.
24. He Y, Chen Z, Mo F, Huang L, Xu L, Wu Y, Xue Z, Fu F. Species characteristics of lead in sea foods collected from coastal water of Fujian, Southeastern of China. Scientific Reports. 2016;6:33294
DOI: 10.1038/srep33294
25. Moslen M, Miebaka CA. Temporate variation of heavy metal concentration in *Periophthalmus* spp. obtained from Azuabie Creek in the upper Bonny Estuary, Nigeria. Current Studies in Education, Science & Technology. 2016;3(2):136-147.
26. Polgar G, Saccahetti A, Galli P. Differentiation and adaptive radiation in amphibious gobies (Gobiidae oxudercinae) in semi-terrestrial habitats. Journal of Fish Biology. 2010;77(7):1645-1664.
27. Vincent A, Babatunde BB. Trace metals in water, fish and sediments from Elechi creek, Port Harcourt, Rivers State, Nigeria. Tropical Freshwater Biology. 2015;22:13-21.
28. Ahmed K, Yousu M, Haqu R, Pulakesh M. Heavy metal concentration in some macro-benthic fauna of the sundarbans mangrove forest, south west coast of Bangladesh. Journal of Environmental Monitoring and Assessment. 2011;177(1):505-514.
29. Sinaei M, Mashinchian A. Polycyclic aromatic hydrocarbons in the coastal sea water, the surface sediment and mudskipper *Boleophthalmus dussumieri* from coastal areas of the Persian Gulf: source investigation, composition pattern and special distribution. Journal of Environmental Health Science and Engineering. 2014;12(1):59.
DOI: 10.1186/2052-336X-12-59

30. Luoma SN, Rainbow PS. Why is heavy metal bioaccumulation so variable? Bio-dynamics as a unifying concept. Environmental Science Technology. 2005; 39(7):1921–1931.
31. Nkpaa WK, Wegwu OM, Essien BE. Heavy metal concentratios in four selected seafood from crude oil polluted waters of Ogoniland, Rivers State, Nigeria. Archieves of Applied Science Research. 2013;5(4):97–104.
32. Asaolu SS, Olaofe O. Bio-magnification of some heavy and essential metals in sediments, fishes and crayfish from Ondo State coastal region, Nigeria. Pakistan Journal of Scientific and Industrial Research. 2005;48(2):96–102.
33. Kakulu SE, Osibanjo O, Ajaji SO. Trace Metal Content of Fish and Shellfishes of the Niger Delta Area of Nigeria. Environment International. 1987;13(3): 247–251.
34. Schmitt JC, Brumbaugh WG, Linder GL, Hinck JE. A screening-level assessment of lead, cadmium and zinc in fish and crayfish from Northeast Oklahoma, USA. Environmental Geochemistry and Health. 2006;28(5):445-471.
35. Davies OA, Allison ME, Uyi HS. Bioaccumulation of heavy metals in water, sediment & periwinkle (*Tympanotonous fuscatus var. radula*) from the Elechi Creek, Niger Delta. African Journal of Biotechnology. 2006;5:968-973.
36. Moslen M, Ekweozor KEI, Nwoka N-D. Assessment of heavy metals and Bio-accumulation in periwinkle (*Tympanotonus fuscatus var. radula* (L)) obtained from the upper reaches of Bonny Estuary, Nigeria. Journal of Heavy Metal Toxicology & Diseases. 2017;2(2:3):1-5.
37. Daka ER, Ifidi I, Braide, SA. Accumulation of heavy metals from single and mixed metal solutions by the gastropod mosllusk *Tympanotonus fuscatus* Linnaeus from a Niger Delta estuary: Implications of bio-monitoring. African Journal of Biotechnology. 2006;5:1964-1962.
38. Ogolo SG, Ugbomeh AP, Isitor GN. Physico-chemical parameters of Iwofe and Bakana Rivers, tributaries of the New Calabar River, Niger Delta, Nigeria. Research Journal of Pure Science and Technology. 2017;1(2):1- 22.
39. FAO/WHO. Compilation of legal limit for hazardous substances in Fish and fishery products. FAO Fishery Circular. 1983;464: 5-100.
40. Usese IA, Chukwu OL, Rahman MM, Naidu R. Concentrations of arsenic in water and fish in a tropical open lagoon, Southwest-Nigeria: Health risk assessment, Part 1. Environmental Technology & Innovation. 2017;8:164-171.
41. Kuplulu O, Iplikcioglu CG, Korkmaz S, Aykut O, Ozansoy G. Determination of metal contamination in seafood from the black, Marmara, Aegean and Mediterranean sea metal contamination in seafood. Journal of the Hellenic Veterinary Medical Society. 2018;69(1): 749-758.
42. Abu O, Monica G, Nwokoma G. Bioaccummulation of selected heavy metals in water, sediments and blue crab *Callinectes arcuatus* from Bodo Creek, Niger Delta, Nigeria. Journal of Fisheries Sciences. 2016;4(2):231-239.
43. Shovon MNH, Majumdar BC, Rahman Z. Heavy metals (Lead, Cadmium and Nickel) concentration in different organs of three commonly consumed fishes in bangladesh. Fisheries and Aquaculture Journal. 2017; 8:3.
DOI: 10.4172/2150-3508.1000207
44. Mgbemena NM, Illecchukwu I, Ubadi JO, Ndukwe GI. Status of heavy metal pollution in the sediments of the new Calabar River in Rivers State, Nigeria. Journal of Chemical Society of Nigeria. 2017;42(2): 84-87.



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