Original Research Article

Risk Assessment of Heavy Metals and Hydrocarbon Contamination in selected Seafood from Coastal Regions of Southern Nigeria

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ABSTRACT

Aim: This study evaluated thehuman health risksassociated with consumption of selected seafood from coastal areas prone to crude oil pollutionin Southern Nigerian.

Study design: Four seafood samples - *Oreochromis niloticus*(Tilapia fish), *Macrobrachiumrosenbergii*(Prawn), *Crossostreagasar*(Oyster) and *Tympanotomusfuscatus*(Periwinkle) andwere tested for Polycyclic Aromatic Hydrocarbon (PAH) and Heavy Metal (HM) levels using USEPA standards. Health risk evaluation was performed using Estimated Daily Intake (EDI), Target Hazard Quotient (THQ) and Carcinogenic Risk (CR) assessment.

Place and Duration of Study: Department of Biochemistry, University of Port Harcourt, Nigeria between Juneand August 2024.

Methodology: Samples of Tilapia fish, Prawn, Oyster andPeriwinkle were collected from Bakana river, located within the crude oil-polluted coastal areas of the Niger Delta Region of Nigeria. Health risk assessments were conducted using indices such as Estimated Daily Intake (EDI), Target Hazard Quotient (THQ) and Carcinogenic Risk (CR) assessmentfor PAHs and HMs.

Results: Proximate analysis of the investigated seafood samples showed that Prawn hasthe highest crude protein(19.71%) and carbohydrate (8.38%) contents,when compared with other seafood in this study. The various seafood samples studied showed the presence of heavy metals namely Cr, Cd, Cu, Pb, Zn, Ni, althoughlevels recorded were below WHO permissible limits. PAH compounds (Naphthalene, Acenaphthylene, Acenaphthene, phenanthrene, Fluoranthene, Pyrene, Chrysene) in seafood samples showed significant ($p \leq 0.05$) presence.Values reported for Carcinogenic Risk (CR) assessment of heavy metals were significantly ($p \leq 0.05$)high for Cd, Pb, Cr and Ni in both adult and children populations.

Conclusion: This study revealed that heavy metal (Cd, Pb, Ni, Cr) levels in the seafood samples pose carcinogenic risk. Therefore, consumers of the studied seafood samples obtained from Bakana river may be exposed to the risk of consuming toxic environmental pollutants.

Keywords: Heavy metals, Polycyclic aromatic hydrocarbons, Seafood, Risk assessment

1. INTRODUCTION

Seafood has been a significant food source for humans, especially those in the coastal region, because of their flavor and nutritional value. Seafood describes various ocean creatures categorized into fish and shellfish (e.g. Oysters, squid, missile, lobster, prawns, crab and shrimp). The low calorific value and level of protein in seafood makes it a healthier alternative to red meats or poultry. Seafood is reported to be rich in calcium, iron, and vitamins A, E, C and D [1, 2]. Seafood consists of filter-feeding aquatic organisms, with high bioaccumulation rate for toxins in their tissues [3, 4]. They are vulnerable to ingesting chemical contaminants from sediment, water, micro- and macro-organisms [1]. These contaminants can further bioaccumulate in their tissues and subsequently be biomagnified in the food chain [5, 6].

Anthropogenic influences on aquatic habitats, especially arising from increased industrialization has heightened research on the safety of seafood. Anthropogenic sources include stubble burning and dispersion of contaminated sewage sludge on farmlands, exhausts from automobiles and oil pollution of surface waters [7 - 9]. Polycyclic aromatic hydrocarbons (PAHs) and heavy metals, among others have continued to pose environmental hazard [10]. Contamination of seafood by PAHs is as a result of deposition and transfer.PAHs are fat-soluble compoundsthat are carcinogenic, mutagenic, and capableof disrupting hormonal functions [11-13]. Sixteen PAHs compounds (Naphthalene, Benzo[*k*]fluoranthene, Acenaphthylene, Acenaphthene, Benzo[*a*]anthracene, Fluorene, Benzo[*b*]fluoranthene, Phenanthrene, Anthracene, Dibenz[*a*,*h*]anthracene Pyrene, Chrysene, Benzo[*a*]pyrene, Indeno[1,2,3-cd]pyrene, Fluoranthene, and Benzo[*g*,*h*,*i*]perylene) are considered by the U.S. Environmental Protection Agency (EPA)as priority pollutants as they are the most toxic, carcinogenic, and commonly found PAHs in the environment. These PAHs compounds are often used as markers for assessing PAH contamination and exposure. Meanwhile, Benzo(a)pyrene (BaP) a known carcinogen, is often used as a benchmark compound when evaluating the potential carcinogenicity of PAH mixtures [14].High exposure to some heavy metals have been reported to cause persistent brain damage, kidney failure cognitive decline, memory issues, mood swings, interference with enzyme activity leading to organ damage, neurological abnormalities and several other health issues [15 -17]. Akpabio et al. [18] also reported that excessive amounts of heavy metals in food have potentials to be fatal and cause serious health issues. Consuming seafood tainted with heavy metals has been linked to a number of diseases that are known to have negative health consequences on humans

Pollution of the environment by crude oil spillage can be a source of PAH contamination mostly in fish, fishery products and seafood. In recent times, chemical contamination from oil spillage has shown to be a major source of pollution within the coastal areas of Nigeria's Niger Delta Region (NDR)[7, 19, 20]. The environment in the NDR has been seriously contaminated by oil production, according to numerous studies. Many illicit refineries and bunker operations exist in the region; these operations are not sufficiently regulated and thus, contaminants are released water bodies within the region. The aquatic system is most commonly contaminated component of the environment. This is due to the fact that pollutants in air, soil, or on land eventually find their way into the aquatic system due to a variety of factors, including local precipitation, water runoff, rock leaching, and solid waste. This poses a significant threat to marine ecosystems, with potentially devastating consequences for seafood safety. The bioaccumulation and toxic consequences associated with these marine creatures, as well as their subsequent transfer to people through the food chain, present considerable concerns due to their negative repercussions [21, 22]. Seafood Consumers are therefore gravely concerned about the health effects of consuming seafood from the Niger Delta Region.

This research examined the health risks of consuming seafood (Prawn, Oyster, Periwinkles and Tilapia fish) obtained from the study area. The study's objectives include; (i) to assess the concentrations of PAHs and heavy metals (HMs) in tissues of selected seafood obtained from Bakana River (ii) Determine the safety of the seafood samples under study for human consumption (iii) To evaluate the potential health hazards of consuming seafood from the study area.

2. MATERIAL AND METHODS

2.1 Study Location

The study area, shown in Fig. 1, is located within the pollution-prone mangrove swamp of Bakana River in Bakana Community in the coastal region of Southern Nigeria. Situated in the Degema Local Government Area of Rivers State, Bakana is home to the Kalabari ethnic Community. The Bakana River is situated within the Niger Delta basin. The basin spans 20,000 km^2 and includes all of the territories between latitudes 4^o 14'N and 5^o 35'N, and longitudes 5^o 26'E and 7^o 37'E.The location is characterized by silt and mud deposits, swampy areas, and mangrove plants. Bakana Community, as well as other coastal Communities within the Niger Delta region are known for fishing and serve as a source of seafood for marketers engaged in subsequent distribution.

Bakana River is constantly exposed to organic waste, litter, petroleum hydrocarbon pollutants, and toxic chemicals. The area lies in the Niger Delta wet equatorial climatic which experience extensive-rainy season from March to November, with mean annual rainfall range from 1500 mm around the northern fringe to 4500 mm around the coastal margin [23, 24].

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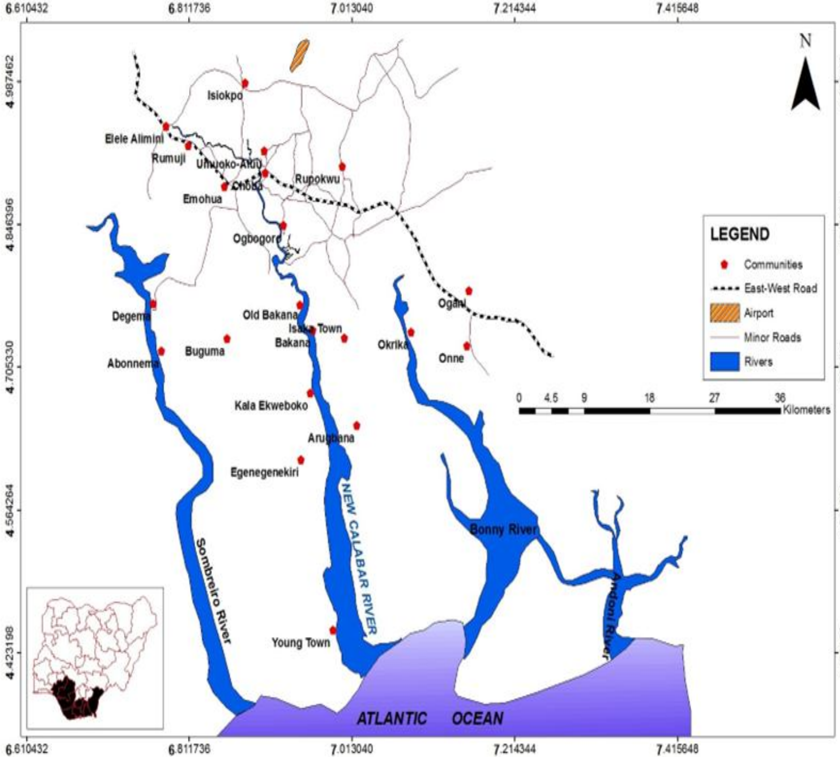

Fig. 1 Map of the study area

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2.2SeafoodSample Collection

Ten (10) samples each of Tilapia fish, Prawn, Oyster andPeriwinklewere collected between Juneand July 2024 in plastic containers from mangrove swamps along Bakana River.These species were selected considering their consumption rate and availability. Periwinkles and oysters were hand-picked at low tide from the mud in the creeks. Mangrove oysters were harvested from mangrove roots. Collected seafood samples were immediately transferred in sterile isothermal containerfor onward delivery to the laboratory for analysis. The samples were analyzed for proximate composition, mineral content, PAHs and heavy metals levels.

2.3Proximate Analysis

Proximate analysis was carried out according to the procedure of Association of Official Analytical Chemist (AOAC) [25] for moisture, ash, crude fibreand crude protein content. Carbohydrate component was calculated bythe Difference Method [25] by subtracting the sum (g/100g dry matter) of crude protein, crude fat, ash and fibre from 100g. The caloric value was determined based on the Atwater Factor [26].

2.4 PAHs and Heavy metal determination

Sixteen(16) priority PAHs listed by the USEPA and cited by the International Agency for Research on Cancer (IARC) were analyzed[27, 28].Sample analysis followed the method described by Odesa and Olannye [1]. The samples were homogenized and 25 ml of dichloromenthane was used for the extraction after it has been dehydrated with anhydrous sodium sulfate (Na_2SO_4**)**. The samples were further evaporated and a portion of the solution was examined using Gas Chromatography Flame Ionisation Detector (GC model: Agilent 6890N) and Atomic Absorption Spectrophotometry (AAS model: SP-AA4530). The congeners were detected via flame ionization detection. Heavy metal levels in seafood were determined using an atomic absorption spectrophotometer (ASTM-E594-96).

2.5Health Risk Assessment for PAHs and Heavy metals

Health risk evaluation was performed for children and adult population using Estimated Daily Intake(EDI), Target Hazard Quotient (THQ)and Carcinogenic Risk (CR)assessment.

2.5.1 Estimated Daily Intake (EDI)

Approximate daily consumption of theseafood was determined using the formula below, taking into account the levels of PAHs and heavy metals in the chosen sea food samples.

$$\text{EDI} = \frac{Cm\ x\ IR}{BWx10-3} \qquad (1)$$

Where BW is the average adult and child body weight who consume the seafood, IR is the ingestion rate of heavy metals and PAHs in kg/day, and Cm is the saturation of metals and PAHs in each chosen seafood in mg/kg.

2.5.2Target Hazard Quotient (THQ)

The Target Hazard Quotient (HQ), which is the ratio of the computed chronic intake (CDI) to the ingestion reference dose (RfD) of the chosen heavy metals, is typically used to highlight the degree of non-carcinogenic concerns [29]. USEPA [30] provides the formula, which is displayed in equation 2. If HQ > 1, it suggests that the exposed population is more likely to experience bad health impacts. Conversely, if HQ < 1 then there is no possibility of negative health effects with the ingestion reference dose for heavy metals to be that set by the WHO 2017, with PAHs having the ingested reference dose to be Acy 6.0×10^{-2}, Acp $6.0\text{-} \times 10^{-2}$, Flr 4.0×10^{-2}, Ant 3.0×10^{-1}, Phe3.0×10^{-2}, Flt 4.0×10^{-2} and Pyr 3.0×10^{-1} [30].

$$HQ = \frac{CDI}{RfD} \qquad (2)$$

The ratio of estimated daily intake (EDI) to RfD was used to compute the health risks associated with consuming seafood. Equation 4 was used to determine the EDI (Ding et al. 2012).

$$THQ = \frac{EDI\ X\ EF\ X\ ED}{AT\ X\ RFD} x10\text{-}3 \qquad (3)$$

$$RFD_{derm} = RFD_{oral}\ x\ ABSgi \qquad (4)$$

The ABSgi value is the gastrointestinal absorption factor. It has no unit of its own, Cr (0.25), Pb, (0.1), Cd (0.08), Cu (0.3) and Zinc (0.61) with Ni not assigned and is 0.89 for PAHs [31].

2.5.3Carcinogenic Risk Assessment

The malignant growth slant factor (SF) (USEPA 2000) was duplicated by the CDI or EDI to gauge the HQs for cancer-causing risk from ingestion/dermal openness to seafood, as indicated in equation 5. The Incremental Lifetime Cancer Risk (ILCR) is calculated using potential cancer risk when the ratios are larger than 1.

$$CR = EDI\ x\ CSFfor\ seafoodsample \qquad (5)$$

According to the toxicological assessments and risk system created by the USEPA, WHO, and International Agency for Research on Cancer (IARC), the following heavy metals have carcinogenic slopes coefficients of 0.38, 0.84, and 0.5 that indicate they are recognized human carcinogens: Cd, Ni, Cr, and Pb. and 8.5×10^{-3} (mg L-1 day-1)[29]while verified cancer slope factor for PAHs is 11.5 mg/kg/day [32].

2.6 Statistical analysis

Statistical analysis of data All values were expressed as mean ± SD and then subjected to analysis of variance (ANOVA) using the Statistical Package for Social Sciences (SPSS) version 17.0 (SPSS Inc., Chicago Illinois). Statistical significance was considered at P=0.05.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Seafood samples

Results forproximate analysis of Tilapia fish, Prawn, Oyster andPeriwinkleare presented in Figure 2. The results indicate that Prawn has the highest percentage of crude protein (19.71%) and carbohydrate (8.38%), when compared with other seafood in this study. Ash content was highest in Periwinkle, recording 6.00±0.78%.

3.2Mineral composition of the selected seafood

Analytical results for mineral composition of seafood samples in this study are shown in Figure 3. Prawn and Oystershowed the highest calcium contents, recording 72.14 mg/100g and 86.32 mg/100g respectively. Tilapia fish recorded the least calcium content (54.05 mg/100g). The highest potassium level is recorded in Periwinkle(33.60 mg/100g), followed by Prawn(27.61 mg/100g). The highest level of sodium is found in Oyster (18.2 mg/100g), closely followed by Periwinkle(16.70 mg/100g).

3.3 Heavy metal composition of seafood samples

Table 3 shows the results for heavy metal levels in the seafood samples under study.Seafood samples studied showed the presence of heavy metals namely Cr, Cd, Cu, Pb, Zn, Ni, but values were all below WHO permissible limits.Tilapia fishrecorded

0.009±0.001 mg/kg of chromium (Cr), while Prawnshowed 0.001±0.000 mg/kg, Oysterrecorded 0.001±0.000 mg/kg, and Periwinklehas 0.001±0.000 mg/kg.

3.4 PAH content inseafood samples

Table 4 shows the composition of PAHs in the selected seafood samples. Fluorene and anthracene was below the detectable limit for all the selected seafood samples whilephenanthrene was detected in all selected seafood samples and highest in Tilapia fish,recording 28.32±0.05 mg/kg. Benzo (a) pyrenewas below detectable limit in theinvestigatedseafood samples. Benzo (g,h, i) perylene was not detected (BDL) in all samples.

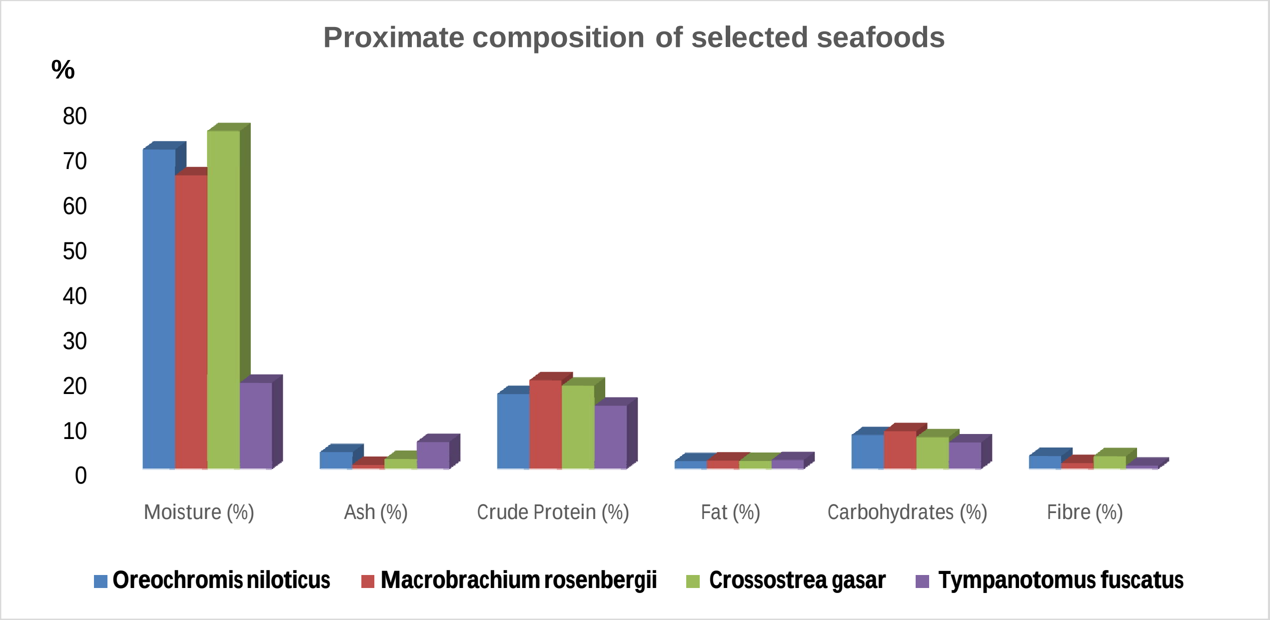

Figure 2.Proximate composition of selected seafood samples

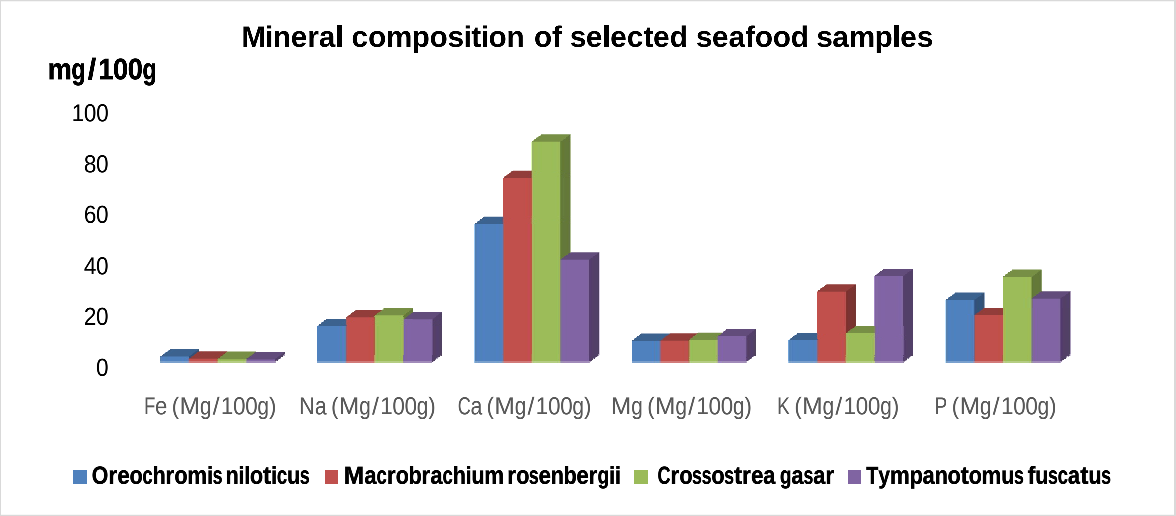

Figure3. Mineral composition of selected seafood samples

Table 1.Heavy metal content of selected seafood samples

SEAFOOD SAMPLE **PARAMETER**	**Tilapia fish**	**Prawn**	**Oyster**	**Periwinkle**	**Permissible Limits: FAO [26]; WHO [33]**
Cd (mg/kg)	0.001 ± 0.000^{ac}	0.003 ± 0.001^{b}	0.001 ± 0.00^{ac}	0.001 ± 0.00^{ac}	0.05
Pb (mg/kg)	0.008 ± 0.000^{abc}	0.008 ± 0.001^{abc}	0.008 ± 0.001^{abc}	0.075 ± 0.001^{c}	0.2
Cr (mg/kg)	0.009 ± 0.001^{a}	0.001 ± 0.000^{bcd}	0.001 ± 0.000^{bcd}	0.001 ± 0.000^{bcd}	0.6
Zn (mg/kg)	0.101 ± 0.000^{ab}	0.127 ± 0.001^{ab}	0.205 ± 0.01^{cd}	0.218 ± 0.002^{cd}	5.0
Ni (mg/kg)	0.163 ± 0.000^{a}	0.207 ± 0.001^{bc}	0.211 ± 0.01^{bc}	0.339 ± 0.002^{d}	NS
Cu (mg/kg)	0.003 ± 0.000^{a}	2.461 ± 0.003^{b}	0.296 ± 0.00^{c}	1.301 ± 0.001^{d}	3.0

Values are Mean ± Standard Deviation. Data with the same alphabets (a,b,c,d) as superscript shows non-significant differences ($p \geq 0.05$), while that with different alphabets as superscript shows significant differences ($p \leq 0.05$).

Table 2.PAH content of selected seafood samples

PAH Compound (mg/kg)	**Tilapia fish**	**Prawn**	**Oyster**	**Periwinkle**
Naphthalene	13.112 ± 0.1108^{a}	6.116 ± 0.141^{b}	BDL	4.116 ± 0.017^{c}
Acenaphthylene	5.404 ± 0.220^{a}	8.441 ± 0.081^{b}	11.411 ± 0.053^{c}	BDL
Acenaphthene	11.411 ± 0.012^{a}	2.153 ± 0.022^{b}	17.667 ± 0.032^{c}	BDL
Fluorene	BDL	BDL	BDL	BDL
Phenanthrene	28.323 ± 0.054^{a}	12.111 ± 0.004^{b}	20.183 ± 0.014^{c}	7.004 ± 0.013^{d}
Anthracene	BDL	BDL	BDL	BDL
Fluoranthene	BDL	15.550 ± 0.017^{a}	BDL	4.627 ± 0.028^{b}
Pyrene	BDL	BDL	BDL	8.111 ± 0.061
Benz (a) anthracene	7.008 ± 0.012^{a}	11.105 ± 0.021^{b}	BDL	BDL
Chrysene	BDL	BDL	BDL	3.077 ± 0.006^{a}
Benzo (b) fluoranthene	11.441 ± 0.016^{a}	8.408 ± 0.051^{b}	7.653 ± 0.017^{c}	BDL
Benzo (k) fluoranthene	BDL	BDL	BDL	BDL
Benzo (a) pyrene	BDL	BDL	BDL	BDL
Indeno (1,2,3-cd) pyrene	BDL	3.115 ± 0.042	BDL	BDL
Dibenz (a,h) anthracene	BDL	BDL	BDL	BDL
Benzo (g,h,i) perylene	BDL	BDL	BDL	BDL

Values are Mean ± Standard Deviation. Data with the same alphabets (a,b,c,d) as superscript shows non-significant differences (p≥0.05), while that with different alphabets as superscript shows significant differences (p≤0.05).

Table 3.Estimated Dietary Intake for Heavy Metals in selected seafood samples

	Tilapia fish		Prawn		Oyster		Periwinkle		USEPA [34]
	Adults	**Children**	**Adults**	**Children**	**Adults**	**Children**	**Adults**	**Children**	
Cd (mg/kg)	2.60E-10	3.13E-10	3.12E-03	3.75E-03	2.60E-10	3.13E-10	1.04E-03	1.25E-03	1
Pb (mg/kg)	1.66E-08	2.00E-08	1.04E-03	1.25E-03	1.66E-08	2.00E-08	9.75E-03	1.17E-02	1
Cr (mg/kg)	7.02E-06	8.44E-06	3.47E-07	4.17E-07	7.80E-07	9.38E-07	3.47E-07	4.17E-07	1
Zn (mg/kg)	1.58E-05	1.89E-05	2.20E-04	2.65E-04	3.20E-05	3.84E-05	3.78E-04	4.54E-04	1
Ni (mg/kg)	1.70E-06	2.04E-06	5.38E-03	6.47E-03	2.19E-06	2.64E-06	8.81E-03	1.06E-02	1
Cu (mg/kg)	6.24E-08	7.50E-08	3.20E-02	3.85E-02	6.16E-06	7.40E-06	1.69E-02	2.03E-02	1
THI	2.46E-05	2.95E-05	4.18E-02	5.02E-02	4.11E-05	4.94E-05	3.69E-02	4.43E-02	1

Table 4.Estimated Dietary Intake for PAHs in selected seafood samples

	Tilapia fish		Prawn		Oyster		Periwinkle	
	Adults	**Children**	**Adults**	**Children**	**Adults**	**Children**	**Adults**	**Children**
Naphthalene	6.82E-06	8.20E-05	3.18E-06	3.82E-05	0.00E+00	0.00E+00	2.14E-06	2.57E-05
Acenaphthylene	2.81E-06	3.38E-05	4.39E-06	5.28E-05	5.93E-06	7.13E-05	0.00E+00	0.00E+00
Acenaphthene	5.93E-06	7.13E-05	1.12E-06	1.35E-05	9.19E-06	1.10E-04	0.00E+00	0.00E+00
Fluorene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Phenanthrene	1.47E-05	1.77E-04	6.30E-06	7.57E-05	1.05E-05	1.26E-04	3.64E-06	4.38E-05
Anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fluoranthene	0.00E+00	0.00E+00	8.09E-06	9.72E-05	0.00E+00	0.00E+00	2.41E-06	2.89E-05
Pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.22E-06	5.07E-05
Benz (a) anthracene	3.64E-04	4.38E-03	5.77E-04	6.94E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.60E-05	1.92E-04
Benzo (b) fluoranthene	5.95E-04	7.15E-03	4.37E-04	5.26E-03	3.98E-04	4.78E-03	0.00E+00	0.00E+00
Benzo (k) fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo (a) pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno (1,2,3-cd) pyrene	0.00E+00	0.00E+00	1.62E-04	1.95E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenz (a,h) anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo (g,h,i) perylene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5.THQ for Heavy Metals in selected seafood samples

	Tilapia fish		Prawn		Oyster		Periwinkle		USEPA [34]
	Adults	Children	Adults	Children	Adults	Children	Adults	Children	
Cd (mg/kg)	2.60E-10	3.13E-10	3.12E-03	3.75E-03	2.60E-10	3.13E-10	1.04E-03	1.25E-03	1
Pb (mg/kg)	1.66E-08	2.00E-08	1.04E-03	1.25E-03	1.66E-08	2.00E-08	9.75E-03	1.17E-02	1
Cr (mg/kg)	7.02E-06	8.44E-06	3.47E-07	4.17E-07	7.80E-07	9.38E-07	3.47E-07	4.17E-07	1
Zn (mg/kg)	1.58E-05	1.89E-05	2.20E-04	2.65E-04	3.20E-05	3.84E-05	3.78E-04	4.54E-04	1
Ni (mg/kg)	1.70E-06	2.04E-06	5.38E-03	6.47E-03	2.19E-06	2.64E-06	8.81E-03	1.06E-02	1
Cu (mg/kg)	6.24E-08	7.50E-08	3.20E-02	3.85E-02	6.16E-06	7.40E-06	1.69E-02	2.03E-02	1
THI	2.46E-05	2.95E-05	4.18E-02	5.02E-02	4.11E-05	4.94E-05	3.69E-02	4.43E-02	1

Table 6.THQ for PAHs in selected seafood samples

	Tilapia fish		Prawn		Oyster		Periwinkle		USEPA [34]
	Adults	Children	Adults	Children	Adults	Children	Adults	Children	
Naphthalene	3.41E-04	4.10E-03	1.59E-04	1.91E-03	0.00E+00	0.00E+00	1.07E-04	1.29E-03	1
Acenaphthylene	-	-	-	-	-	-	-	-	1
Acenaphthene	9.89E-05	1.19E-03	1.87E-05	2.24E-04	1.53E-04	1.84E-03	0.00E+00	0.00E+00	1
Fluorene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1
phenanthrene	-	-	-	-	-	-	-	-	1
Anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	1
Fluoranthene	0.00E+00	0.00E+00	2.02E-04	2.43E-03	0.00E+00	0.00E+00	6.02E-05	7.23E-04	1
Pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E-04	1.69E-03	1
Benz (a) anthracene	-	-	-	-	-	-	-	-	1
Chrysene	-	-	-	-	-	-	-	-	1
Benzo (b) fluoranthene	-	-	-	-	-	-	-	-	1
Benzo (k) fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1
Benzo (a) pyrene	-	-	-	-	-	-	-	-	1
Indeno (1,2,3-cd) pyr	-	-	-	-	-	-	-	-	1
Dibenz (a,h) anthr	-	-	-	-	-	-	-	-	1
Benzo (g,h,i) perylene	-	-	-	-	-	-	-	-	1
THI	4.40E-04	5.29E-03	3.80E-04	4.56E-03	1.53E-04	1.84E-03	3.08E-04	3.70E-03	1

Table 7.LifetimeCarcinogenic risk assessment of heavy metals in selected seafood

	Tilapia fish		Prawn		Oyster		Periwinkle	
	Adults	Children	Adults	Children	Adults	Children	Adults	Children
Cd (mg/kg)	1.01X10-5	2.53X10-5	3.04X10-5	7.6X10-5	1.01X10-5	2.5X10-5	1.015X10-5	2.5X10-5
Pb (mg/kg)	1.81X10-6	4.7X10-6	1.81X10-6	4.5X10-6	1.81X10-6	4.53X10-6	1.71X10-5	4.25X10-5
Cr (mg/kg)	1.2X10-4	3X10-4	1.33X10-5	5.58X10-6	1.33X10-3	3.33X10-5	1.33X10-5	3.35X10-5
Zn (mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA
Ni (mg/kg)	3.65X10-3	9.23X10-3	4.6X10-3	0.011	4.72X10-3	0.012	7.5X10-3	0.018
Cu (mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA

Table 8.LifetimeCarcinogenic risk assessment of PAHs in selected seafood

	Tilapia fish		**Prawn**		**Oyster**		**Periwinkle**		**USEPA [34]**
	Adults	**Children**	**Adults**	**Children**	**Adults**	**Children**	**Adults**	**Children**	
Naphthalene	4.98E-05	8.55E-05	2.32E-05	3.99E-05	0.00E+00	0.00E+00	1.56E-05	2.68E-05	10E-6 – 10E-4
Acenaphthylene	2.05E-05	3.52E-05	3.20E-05	5.50E-05	4.33E-05	7.44E-05	0.00E+00	0.00E+00	10E-6 – 10E-4
Acenaphthene	4.33E-05	7.44E-05	8.17E-06	1.40E-05	6.71E-05	1.15E-04	0.00E+00	0.00E+00	10E-6 – 10E-4
Fluorene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10E-6 – 10E-4
phenanthrene	1.08E-04	1.85E-04	4.60E-05	7.89E-05	7.66E-05	1.32E-04	2.66E-05	4.57E-05	10E-6 – 10E-4
Anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	10E-6 – 10E-4
Fluoranthene	0.00E+00	0.00E+00	5.90E-05	1.01E-04	0.00E+00	0.00E+00	1.76E-05	3.02E-05	10E-6 – 10E-4
Pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.08E-05	5.29E-05	10E-6 – 10E-4
Benz (a) anthr	2.66E-03	4.57E-03	4.22E-03	7.24E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10E-6 – 10E-4
Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E-04	2.01E-04	10E-6 – 10E-4
Benzo (b) fluor	4.34E-03	7.46E-03	3.19E-03	5.48E-03	2.91E-03	4.99E-03	0.00E+00	0.00E+00	10E-6 – 10E-4
Benzo (k) fluor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10E-6 – 10E-4
Benzo (a) pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10E-6 – 10E-4
Indeno (1,2,3-cd) p	0.00E+00	0.00E+00	1.18E-03	2.03E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10E-6 – 10E-4
Dibenz (a,h) anthr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10E-6 – 10E-4
Benzo (g,h,i) per	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10E-6 – 10E-4

Results for proximate analysis of the seafood samples showed that prawn has the highest percentage of crude protein (19.71%) and carbohydrate (8.38%) when compared with other seafood samples in this study. This confirms that prawn is a good source of dietary protein.Since prawn has high carbohydrates content, its consumption could provide the body with fuel and energy that is required for daily activities and exercise [35]. Offor *et al*. [36]noted that adequate carbohydrate is also required for optimum function of the brain, heart, nervous, digestive and immune system while carbohydrate deficiency causes depletion of body tissue.

Results for mineral composition revealed that prawn and oyster had the next highest calcium contents, recording 72.14 mg/100g and 86.32 mg/100g respectively. The least calcium-containing seafood in this study is Tilapia fish which recorded 54.05 mg/100g. The highest potassium level was found in periwinkle(33.60 mg/100g), followed by prawn (27.61 mg/100g). Calcium deficiency can lead to osteoporosis in which the bone deteriorates and there is an increased risk of fractures. If there is more phosphorus than calcium in the diet, the body will start to take calcium from its own reserves (the bones) to compensate. Over a long or short period of time, this may affect the bones in a negative way. It is therefore necessary that a good source of calcium is used to complement diets [37].

The levels of six (6) heavy metals (Zn, Cu, Ni, Pb, Cr and Cd) were investigated in the selected seafood samples. Results showed that heavy metal content of the selected seafood samples were all below permissible limitsas as set by the Food and Agriculture Organization (FAO)[26] and World Health Organisation (WHO)[33].Results from previous similar studies indicated a low to moderate level of heavy metals in seafood collected from the Niger Delta Region. Also, few studies from this region reported very high levels of some heavy metals in seafood collected from sites that have been severely impacted by decades of crude oil pollution and had suffered from various environmental impacts [38], [39], [40], [41]. Similarly, Ezemonye et al. [42] reported that hazardous levels of Pb, Ni and Co were detected by in seafood sampled from the Benin River in Southern Nigeria.

Sixteen (16) PAH compounds recognized PAHs by USEPA [43] (acenaphthene, acenaphthylene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, pyrene, benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, chrysene, dibenz[*a,h*]anthracene, and indeno[1,2,3-*cd*]pyrene) were investigated in the seafood samples under study. GCMS analysis detected nine (9)out of the sixteen (16) PAH compounds. Fluorene, Anthracene, Benzo (k) fluoranthene, Benzo (a) pyrene, Dibenz (a,h) anthracene and Benzo (g,h,i) perylenewerenot detected in any of the seafood samples. Established guidelines suggest the use benzo[a]pyrene as a marker for occurrence of carcinogenic PAHs in food [44]. The below-detectable levels of benzo(a)pyrene as observed in tilapa fish, prawn, oyster and periwinkles is at variance with the report by Odesa and Olannye [1], and Tongo et al. [45], who both assessed the concentrations of polycyclic aromatic hydrocarbons (PAHs) in various types of seafood sourced from crude oil-contaminated coastal regions of Southern Nigeria. BothAuthors in separate submissions notedthat high levels of benzo(a)pyrene were detected in periwinkles and crabs.

The results of LifetimeCarcinogenic risk assessment for Heavy metals and the PAHs in children and adults are presented in Tables 7 & 8. No traces of the potential carcinogenic PAHs were recorded for Fluorene, Anthracene, Benzo (k) fluoranthene, Benzo (a) pyrene, Dibenz (a,h) anthracene and Benzo (g,h,i) perylene in both adult and children. The LifetimeCarcinogenic risk assessment of other PAH compounds in the selected seafood samples were estimated and observed to show mean values within the regulatory threshold of 10E-6 – 10E-4. However, values reported for Carcinogenic Risk (CR) assessment of heavy metals were significantly ($p \leq 0.05$) high for Cd, Pb, Cr and Ni in both adult and children populations. It follows that the riskof intake ofcarcinogenic heavy metals is high for consumers of the investigatedseafood obtained from Bakana River.

4. CONCLUSION

The results of this study clearly demonstrate that there are significant impact of human activities that could lead to serious contamination of seafood in the study area, and the resultant risks to human health. The study has revealed that the presence of PAHs and heavy metals, in this coastal environment in the Niger Delta Region of Nigeria, as reported in other studies, can contaminate the food chain, and endanger both human and aquatic life within the study area. Therefore, consumers of the studied seafood samples may be exposed to the risk of consuming carcinogenic environmental pollutants.

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