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SPATIAL ASSESSMENT OF THE PETROLEUM BASED CONTAMINANTS IN FISH IN THE LOWER ORASHI AND SOMBRIERO RIVER SYSTEMS OF RIVERS STATE, NIGERIA

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Abstract

The study examined the spatial analysis of the level of physico-chemical properties of water quality in the Lower Orashi and Sombriero River Systems of Rivers State, Nigeria. The study area was divided into ten (10) grids and samples of fish were collected from each grid. The sampling sites are the Lower section of Orashi and Sombriero Rivers, specifically, from Mbiama water front to Hulk (Agada)/Degema which is in the transitional zone between the two River systems, and from there down through the Sombriero to the mouth of the Atlantic Ocean. Sampling was done in two seasons (dry and wet/rainy). The surface water samples were collected into sterilized well labeled bottles and taken to the laboratory to test parameters like physico-chemical, heavy metals, polycyclic aromatic hydrocarbons (PAHs), BTEX and polychlorinated biphenyls (PCBs) adopting standard laboratory methods such as the Standard Methods for Examination of Water and Wastewater (APHA) (2012). Descriptive statistics were used for the data analysis. Findings showed that the pollutant concentrations in the fish in the surface water are higher than the *USEPA/WHO, Canadian, Dutch and Consensus-based (CBSQGs) standards and FAO/JECFA permissible thresholds for fish quality. It is recommended among others that continuous monitoring of these two water systems has to be a routine activity; regular environmental enlightenment, conscientious sensitisation, advocacy and training of host and pipeline communities on the derivables of the new Petroleum Industry Act, and protection of hydrocarbon assets from theft and vandalism should be encouraged.*

Keywords: Assessment, Petroleum pollutants, Fish, Lower Orashi, Somberiro

Introduction

Polycyclic aromatic hydrocarbons are destructive to overall morphology and vital body parts of fish and mollusks/mussels (mono & bivalves) such as the gills, mantle and digestive diverticular. These are some of the major organs that absorb the toxins which impair fish metabolism, biochemistry and causes deaths (Ezekwe, Otiasah, Raimi&Asomeji, 2022). Aquatic mono/bivalves are sessile benthic filter feeders having low biodegradable enzymes; hence, bioaccumulate pollutants in greater quantity, and taken up along the food chain to man over time (Ezekwe, Otiasah, Raimi & Asomeji, 2022).

The situations make organisms to develop various adaptive resistance capabilities relative to the prevalent environmental stressor(s), thereby substantially losing their homogeneity in physical and biochemical compositions different from their primeval parent creatures due to bioaccumulation, biomagnification and bioamplification of various environmental toxins even at trace concentrations over time (Strong, Gargominy, Ponder, Winston & Bouchet, 2008). Odokuma & Okpokwasili (2004) found that these transformations render aquatic biota and other marine organisms unable to sustainably provide their regular ecosystem services of protein and food and climate change buffers, but, become deleterious to ecosystem and human health along the various trophic levels of the food chain to organisms when in contact, exposed or ingested. Sources of xenobiotics into the marine ecosystem are mostly geochemical inputs from background rock, anthropogenic (autochthonous & allochthonous) and atmospheric depositions. Of all the sources, the anthropogenic input always dwarfs others. Xenobiotics are classified into petrogenic, biogenic and pyrogenic groups (Anyakora, Coker and Arbabi, 2010; Ezekwe, Okone, Okechukwu, Nwodo & Ezra, 2012).

Sanchez-Marin, Bellas, Mubiana, Lorenzo, Blust and Beiras (2011) and Georgewill (2012) maintain that pollutants' stoichiometric concentrations in the marine or other environmental media and meteorological conditions that enable their lability alone does not give accurate account of their toxicological impact. It is rather the oxidation states in which they exist in the environmental media, dictated by their valence form that provides most reliable prediction of the bioavailability and toxicity to organisms and man. This position is also supported by Horsfall and Spiff (2013) and Narayanan (2007). Pollutants, once introduced into the marine ecosystem attach themselves to particulate matter in the surface, water column and sediments of rivers, from where they are taken-up by organisms and bioaccummlate along all trophic levels of the food web and finally ingested by man with negative health impacts including carcinogenic, mutagenic and genotoxic diseases (Georgewill, 2012; Ezekwe, Ezekwe & Endoro, 2013; Ezekwe & Utong, 2015). This is the genesis of the woes of mankind on earth (USEPA, 2000).

The International Maritime Organization (IMO, 2000) observed that pollutions that destroy ecosystems are mainly anthropogenic. It is a consequence of man's attitudinal indifference and environmentally unfriendly behaviors. Pollution worsens the fate of oceans and rivers, giving them the unenviable status as "Global Commons". For this reason, Oceans and Rivers have become the highest sinks to xenobiotics and reservoir of all manner of man's recklessness, injustices and progressive abuses from industrialization, agriculture, urbanization and ancillary actions. The possibilistic tendencies of mankind are not abating. The need for efficient, consistent and concerted actions to salvage Mother-Earth sustainably for the sake of mankind is now. The curiosity behind the survival of aquatic lives in the fresh or marine water ecosystem is of vital importance to the sustainability of human kind in which many works have not properly addressed. Thus, the present study examined the spatial assessment of the petroleum based contaminants in fish in the lower Orashi and Sombriero River Systems of Rivers State, Nigeria.

Materials and Methods

The study area was the Lower Orashi and Sombriero River estuary covering territories of Ahoada West, Abua/Odual, Degema, Akuku-Toru and Asari-Toru Local Government Areas of Rivers State, Nigeria (Figure 1). The area is both freshwater and saline or brackish swamp wetland of tidal and semi tidal flat mud typical of the Niger Delta. The total flow pattern of the study area is influenced by the Orashi and Sombriero. The study area is bounded by Nembe Local Government Area of Bayelsa State on the west, the Atlantic Ocean on the southern of the Sombriero, Emohua Local Government area on the north and Bonny Local Government on the East, all of Rivers State. The transition zones are under the dual influence of the less saline (Oligohaline) Orashi freshwater River and polyhaline Sombriero River brackish waters.

The study area has the typical climate of the Niger Delta region previously described by Oyegun (1997). It is predominantly a humid tropical climate with long annual rainy season spanning March - October, a shorter dry season between November -February, and two characteristic air masses viz South-West Monsoon wind and North East trade wind. The monsoon is dominant during the rainy season while the trade wind dictates activities during the dry season characteristic of the rain forest zone. High annual rainfall up to 2500mm and a mean of 2800, an average temperature of $27^{o}C$ with seasonal variation of + or – $4^{o}C$ characterize the study area (Awosika, 1995; Oyegun, 1997). The geology of the study area is a low-lying plain of fresh unconsolidated fluvial sediments of Quaternary Age. Elevation is ≤ 7meters above mean sea level typical of the Niger Delta (Aweto, 2002). Four different vegetation zones characterized the Niger Delta area, viz: coastal inland zone, mangrove swamp zone, freshwater zone and low land rain forest zone (Abam and Okagbue, 1997). The study area is of freshwater and marine forest ecology with fresh and saline water on the Orashi and Sombriero respectively. The Orashi River, particularly from Mbiama to Hulk is fresh water while the Sombriero River from Degema where it beheads the Orashi River (Transition Zone) to Ebemaboko is saline water. The study area is mostly permanent intertidal and waterlogged mud flatlands with rich flora, fauna and complex strata of diverse trees. The ecosystem is highly diverse and support various terrestrial and aquatic fauna and flora, economic trees (predominant among which is P*entaclethra macrophylla, Chrysophyllum albidum and Irvingia gabonenesis*), herb plants, agricultural cultivation (fishery and crop), human livelihoods and enormous hydrocarbons (Ekundayo & Obuekwe, 2001; Nduka, et al., 2011). The economic activities included fishing, farming, crude oil and sand mining.

Research Design

This study adopted a mixed design consisting of the comparative, longitudinal, analytical and cross-sectional designs. A total of ten (10) sampling sites were used for this study whereby water samples were collected during the dry and wet/rainy seasons (Table 1). Dry season sampling was carried out on the 3rd of February, 2022 while wet/raining season sampling was done on 23rd June, 2022.

Table 1. Sampling Sites and their GPS Positions

S/No	Sampling Sites	Designation	GPS
1	Ozuochi	OR1	E006^{o} 32 02.0” N04^{o}57 45.5”
2	Emesu	OR2	E006^{o} 34 29.9”N04^{o}53 03.1”
3	Ogbema Corridor	OR3	E006^{o} 36 07.0” N04^{o}48 44.3”
4	Ogonokom	OR4	E006^{o} 45 06.0” N04^{o} 45.33.0”
5	Hulk-Transition Zone	TZ1	E006^{o} 45 31.4” N04^{o}45 46.7”
6	Atala-Degema Waterfront	TZ2	E006^{o} 45 51.4” N04^{o}45 40.4”
7	Opulogoloboko	SR1	E006^{o} 45 34.1” N04^{o}44 08.3”
8	Idama Flow Station	SR2	E006^{o} 46 34.7” N04^{o}44 38 3”
9	Minjidukiri	SR3	E006^{o} 46 52.5” N04^{o}40 36.9”
10	Ebemaboko	SR4	E006^{o} 48 08.0” N04^{o}38 38.7”

Sample and Sampling Techniques

The study area was divided into ten (10) grids and samples from each of water, sediment and fish was collected from each grid. The sampling sites are the Lower section of Orashi and Sombriero Rivers, specifically, from Mbiama water front to Hulk (Agada)/Degema which is in the transitional zone between the two River systems, and from there down through the Sombriero to the mouth of the Atlantic Ocean. Sampling was done in two seasons (dry and wet/rainy). The fish samples were collected and taken to the laboratory to test parameters like physico-chemical, heavy metals, polycyclic aromatic hydrocarbons (PAHs), BTEX and polychlorinated biphenyls (PCBs) adopting standard laboratory methods such as the Standard Methods for Examination of Water and Wastewater (APHA) (2012). Descriptive statistics were used for the data analysis. Descriptive statistics were used for the data analysis.

Results and Discussions

Table 2 present results of fish quality for the dry and wet/rainy seasons from sections of the Orashi and Sombriero Rivers of the study area. The analysis showed that seasonal concentrations of PAHs in the fish tissue ranged from 0.002 ±0.007mg/L to 0.001±0.024mg/L. Sampling locations OR2 /TZ1 with 0.002±0.001mg/L recorded the minimum observed concentrations of PAHs in the biota for the dry season, while locations TZ1/OR2 with 0.007±0.024mg/L recorded the maximum concentration of PAHs. The seasonal mean concentration of PAHs in the study is 0.004±0.010mg/L. The result reveals that PAHs was more concentrated in the fish tissues in the dry season than the wet season. This could be a result of dilution effect by rain water on the available PAHs in the River column during the wet/rainy season.

PAHs concentration differs significantly from the three stations for both seasons. However, PAHs concentration was more in the body tissue of the African traditional periwinkle (*Tympanotonus fuscatus)* than in the body tissue of the fish in the dry season, whereas the fish tissue bioaccummulated more than the African periwinkle during the wet season. This is probably due to the high bioaccumulation characteristics for ecotoxins by the native periwinkle. The African periwinkle is a sessile filter feeding aquaticmonovalve mollusks that bioaccumulates ecotoxins in their shells, skin, breathing gills and other subcutaneous body parts by diffusion. The ingestion or oral intake of water and sediments of these sentinels could be another factor (Nusseyet et al., 2000; Oguzie et al., 2003; Ezekwe et al., 2022)compared to the labile fish. This is a notable factor that makes shellfish/mollusks better environmental biomarkers or sentinels over labile fishes. On the contrary, the labile fish may have taken in more fresh suspended terrestrial pollutants watched down by urban runoff during the raining season. The wet season pollutants are yet to be settled down or sedimented, hence abundant in the water column for take-in as against sedimented ones available for the bottom feeding African periwinkle.

PAHs in the aquatic biota is above the WHO/FAO permissible threshold exposure level of 0.002mg/L or $10^{-3} – 10^{-8}$ (JEFCA, 2005; EFSA, 2008) in all sampling stations. EFSA (2008) advised that no level of exposure to carcinogens is entirely safe for the marine ecosystems and public health. It is therefore safe to conclude that fish and other aquatic organisms from the River waters and sediment of the Lower Orashi and Sombriero Rivers of the study area are polluted by polycyclic aromatic hydrocarbons. The result is therefore indicative that consumption of fish and aquatic organisms from the study environment pose ecological and human health risks for the riparian populations along the Lower Orashi and Sombriero River systems axis. Therefore, the riparian populations in the study area are at risk of suffering cancer and related ailments from dietary consumption of fish and other aquatic organisms; and fishery products from these locations. Bamidele, Isaac, Benson and Joseph (2020) documented higher concentrations of PAHs in a toxicity study in Heterotis niloticus (Actinopterygii) from Epe Lagoon, Lagos, Nigeria. Also, Isibor et al. (2021) investigated petrogenic PAHs and BTEX in Malapterurus electricus of Lekki Lagoon, Lagos, Nigeria and observed trace bioaccumulation of PAHs. This study therefore agrees with (Bamidele et al., 2020; Isibor et al., 2021) to the effect that River waters of the Niger Delta are polluted by ecotoxin, particularly polynucleated hydrocarbons arising from unremediated crude oil spills. Furthermore, Ezekwe et al. (2022) undertook a study of levels of hydrocarbon-based pollutants in drinking water sources and shellfish in the Soku oil and gas fields of South-South Nigeria. The study implicated heavy metals (H/Ms) and polycyclic aromatic hydrocarbons elevation as causative factors posing likely adverse human health risks to the riparian populations from ingestion of the polluted water and sheffish. This study therefore in concordance with Ezekwe, et al. (2022) to the effect that the marine ecosystem and aquatic organisms, particularly fish and the traditional African periwinkle (*Phenacogrammus and Tympanotonus fuscatus*) in the Niger Delta are polluted by polycyclic aromatic hydrocarbons (PAHs) and other ecotoxins. The seasonal concentrations of BTEX in the biota maintained a uniform value of 0.001mg/L in the three stations with a mean of 0.001mg/L during the dry season. The wet season concentration also had uniform value of <0.001mg/L in all stations with a mean of 0.001mg/L. Both individual and mean values, the BTEX concentrations are below the WHO/FAO permissible threshold exposure levels of B= 0.005mg/L, T= 1mg/L, E= 0.7mg/L, and $X_{[1-4]}$ =10mg/L respectively for both seasons (JEFCA, 2005; EFSA, 2008; Fengsheng & Sukai, 2010; IARC, 2010). It is therefore safe to conclude that population exposed to ingestion of fish and aquatic organisms from these stations of the study are not likely to be predisposed to any ecological and human health risks of BTEX exposure, however, constant monitoring is advised. Furthermore, the heavy metals involving Cd, Cr, Pb, Cu, Zinc, Fe, and K are also analysed and the results showed that the Cadmium ranged from 0.75±1.96mg/L to 0.63±2.28mg/L. In both seasons, location OR2 and TZ1 have the minimum and maximum observed Cadium concentrations of 0.75±0.63mg/L and 1.96±2.28mg/L. Mean Cadmium concentrations is 1.39±1.34mg/L.

Chromium had a seasonal concentration ranging from 1.10±3.78mg/L to <0.001±3.32mg/L. The seasonal means were 2.59±1.42mg/L. The least concentrations of 1.10±<0.001mg/L were observed at OR2 in both seasons, while the highest concentrations of 3.78±3.32mg/L were observed at TZ1/TZ2 respectively. Lead concentrations in the biota ranged from 3.52±3.80mg/L to 14.96±17.93mg/L. Minimum and maximum observed concentrations were recorded at locations OR2 and TZ1 respectively. The seasonal mean Lead concentration was 6.87±12.56mg/L. Copper concentrations ranged from 1.30±23.80mg/L to <0.001±100.66mg/L. The lowest copper abundance of 1.30±<0.001mg/L was observed at OR2, whereas the highest concentrations of 23.80±100.66mg/L were recorded at TZ1 in both seasons. Mean copper concentrations are 11.49±51.13mg/L. Zinc concentrations in the fish of the three stations ranged from 27.23±37.92mg/L to 12.78±18.13mg/L. OR2 at 27.23±12.78mg/L was the least while 37.92±18.13mg/L at sampling locations TZ2 and TZ1 had the observed maximum. The seasonal mean concentration of Zinc in the biota of the study is 33.13±15.40mg/L. Iron concentrations in biota of the study ranged from 31.39±430.60mg/L to 76.14±894.81mg/L. Minimum and maximum concentrations were observed at OR2 and TZ1/TZ2 respectively. The seasonal means of Iron is 244.24±597.30mg/L.

Similarly, the metallic ion are also analysed and the findings are also presented in Table 2. Potassium concentration in the biota body ranged from 634.88±6,121.1mg/L to 440.97±470.53mg/L. Seasonal Potassium concentration was highest at OR2 and TZ2 with values of 6,121.1±470.53mg/L while the lowest of 634.88±440.97mg/L were observed at TZ2/TZ1. The mean seasonal Potassium concentration is of 2,550.83±453.28mg/L. Finally, Sodium concentration in the biota of the study ranged from 1,149.8±1,897.1mg/L to 733.75±1935.3mg/L. The least seasonal Sodium concentration of 1,149.8±733.75mg/L was observed at TZ2 and OR2 while the highest concentration of 1,897.1±1935.3mg/L was observed at OR2and TZ1. The seasonal mean Sodium concentration was 1,504.73±1229.81mg/L. From the above, the study reveals that biota from the different sections of the Lower Orashi and Sombriero Rivers system of the study have trace and macro levels of xenobiotics in them that portend cancer, bronchial and other human cardiovascular, neurological and organ related illnesses ingested by predisposed populations. Again, there is the more likelihood of cancer, failure of targeted organs and neurological related ailments in the biota consumed from all three stations of the study due to the higher concentration of PAHs and BTEX against the backdrop of the cancer dose levels of PAHs/BTEX which is between 10^{-3} – $10^{-8}$and B= 0.005mg/L, T= 1mg/L, E= 0.7mg/L, and $X_{[1-4]}$ =10mg/L respectively (JEFCA, 2005; EFSA, 2008; Fengsheng & Sukai, 2010; IARC, 2010). According to Clase, Carrero, Ellison, Grams, Hemmelgarn and Jardine (2019), elevated potassium uptake from fish causes dyskalemia with kidney failure and complications in humans. David, Bradley, Benjamin and Brians (2015) and Ilhan and Grizzle (2001), observed that salinity and water hardness causes flavobacteria columnare pathogens in channel benthics. Abbas and Rex (2021) found high levels of Sodium to affect fish osmoregulation, and causes disjointed fish growth with likelihood of adverse health implications on its consuming populations. Other impacts of elevated heavy metals and sodium concentrations include changes in bowel habits (diarrhoea) and cholera (Sengupta, 2013). In a study of Omics of the marine Medaka (*Oryziasmelastigma*) and its relevance to marine environmental research, Kim (2016) found different rates of taunted development in fish species, whereas, Ilhan and Grizzle (2019) reported different sex-based reactions by fish to salinity environment. Ansai, Mochida, Fujimoto, Mokodongan, Sumarto, Masengi, Hadiaty, Nagano, Toyoda, Naruse, Yamahira, and Kitano (2021) reported fitness effect of fishes in a study of Genome editing for sexual dichromatism in Sulawasian fishes. Since heavy metal, sodium, potassium, PAHs and BTEX abundance are above the WHO/FAO standards for marine biota, it implies the fish and African perwinkle are unfit for consumption and may cause Laxative effects arising from the elevated intake of magnesium in stenohalines, except for euryhalines and osmoconformer species (Sengupta, 2013; Rodriguez, et al. 2021; Takvam, et al., 2021). Consumption of fish by populations from these sources predisposes populations to acute effects of high blood pressure (hyperkalaemia) and accidental mortalities from overdoses of sodium chloride (WHO, 2015; Enrique et al., 2021; Jury, et al., 2021). It could also give rise to chest congestions, nausea, vomiting, diarrhoea, breath shortness, heart failure, haemolytic anaemia and Addison disease for excess potassium intake (WHO, 2007; Kurhaluk & Halyna, 2021; Wang, et al., 2021). All xenobiotics (PAHs, Cd, Cr, Pb, Cu, Zinc, Fe, K and Na) of the study except BTEX were above the WHO tolerable value levels for ecological and human health toxicity. This study is therefore in tandem with the findings of Mathew et al. (2011) where heavy metal toxicity was found to adversely affect development of rare minnows, reduced growth and development of mangrove and other aquatic lives. The study is also in tandem with Ansai, et al (2021) that documented effect of metal elevation on fishes to suffer fitness issues in a study of Genome editing for sexual dichromatism in Sulawasian fishes. Excessive heavy metals, PAHs and BTEX is causative of cancer, organ damage, autoimmunity, rheumatoid arthritis, diseases of the kidney, circulatory organs; cause cardiovascular diseases, nervous systems and death in extreme cases (Galan, Arnaud, Czernichow, Delabroise, Preziosi, Bertrais, Franchisseur, Maurel, Favier and Hercberg, 2002; Ezekwe, Otiasah, Raimi and Asomeji, 2022) to the effect that heavy metals and other environmental stressors pollutes the marine ecosystem of the Niger Delta, Nigeria. It also agrees with the findings of these reports that these environmental contaminants pose likely ecological and human health risks to populations of the Niger Delta.

Table 2. Results and Comparison of Heavy Metals, Sodium, BTEX and Polycyclic Aromatic Hydrocarbons (PAHs) Concentrations in Aquatic Biota of the Study and FAO/WHO Standards for Food

Aquatic Biota – Fish & Periwinkle (*Phenacogrammus and Tympanotonus Fuscatus*) Samples										
	Dry Season					**Wet/Rainy Season**				
No	**Parameters**	**OR2**	**TZ1**	**TZ2**	**Mean 1**	**OR2**	**TZ1**	**TZ2**	**Mean 2**	**WHO/FAO for Food (mg/L)**
1	PAHs (mg/L)	0.002	0.007	0.004	0.004	0.024	0.001	0.006	0.010	<0.002mg/L
2	BTEX	0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	**0.001**	B= 0.005mg/L, T= 1mg/L, E=0.7mg/L, & $X_{[1-4]}$ =10mg/L resp**.**
3	Cadmium, Cd, (mg/L)	0.75	1.96	1.46	1.39	0.63	2.28	1.12	1.343	<0.005 & 28/20
4	Chromium, Cr, (mg/L)	1.10	3.78	2.88	2.59	<0.001	0.93	3.32	1.417	<0.05&16/10
5	Lead, Pb, (mg/L)	3.52	14.96	2.12	6.87	3.80	17.93	15.96	12.563	<0.01
6	Copper, Cu, (mg/L)	1.30	23.80	9.38	11.49	<0.001	100.66	52.73	51.130	0.05
7	Zinc, Zn (mg/L)	27.23	34.25	37.92	33.13	12.78	18.13	15.29	15.400	<1.0
8	Iron, Fe (mg/L)	31.39	430.60	270.73	244.24	76.14	820.95	894.81	597.3	0.05
9	Sodium, Na (mg/L)	1,897.1	1,467.3	1,149.8	1,504.73	733.75	1935.34	1020.4	1229.813	200
10	Potassium, K (mg/L)	6,121.1	896.43	634.88	2,550.83	448.35	440.95	470.53	453.277	0.01

Conclusions and Recommendations

The study concluded that it is safe to infer that the aquatic biota (fish and African periwinkle – Phenacogrammus and Tympanotonus Fuscatus) in the lower Orashi and Sombriero River systems were polluted with petroleum-based pollutants (PAHs, heavy metals, PCBs) when compared with the USEPA/WHO, Canadian, Dutch and Consensus-based (CBSQGs) standards for sediment quality and FAO/JECFA permissible thresholds for fish quality. Therefore, it is therefore recommended among others that continuous monitoring of these two water systems has to be a routine activity; regular environmental enlightenment, conscientious sensitisation, advocacy and training of host and pipeline communities on the derivables of the new Petroleum Industry Act, and protection of hydrocarbon assets from theft and vandalism should be encouraged. Hence, the host communities should be empowered with contracts of the non-technical services. The Hydrocarbon Pollution Remediation and Restoration Project (HYPREP) in Ogoni should be upgraded and expanded in scope to cover the entire Niger Delta by appropriate parliamentary action and strengthened into a commission with full powers, adequate and regular funding. There is need for compulsory environmental psychology to be incorporated in our Primary through Tertiary institutions curriculums so as to complement growing knowledge in environmental science and management.

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