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Assessment Of Polycyclic Aromatic Hydrocarbon Concentrations In Environmental And Biota Samples From Azuabie And Okujagu Creeks, Upper Bonny Estuary, Nigeria

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Abstract

Polycyclic aromatic hydrocarbons are persistent organic pollutants that are detrimental to the environment, wildlife and public health. In this research, the concentrations of PAH were evaluated in surface water, sediment and aquatic organisms from Azuabie and Okujagu Creeks of the Upper Bonny Estuary, Nigeria. Sample collection was done bimonthly from August 2023 to June 2024 from four locations, two from each of the Creeks. Both environmental and biota samples were collected using standard research techniques. Modified USEPA Method 522 was adopted for PAH analyses in the samples. The results obtained were analysed using appropriate statistical tools. PAH results in sediment samples ranged from 0.18±0.08 – 18.38±10.37ppm and 0.21±0.01 – 26.44±12.25ppm at Azuabie and Okujagu respectively. The higher values were recorded in August, 2023. There were no significant differences between location but there were differences by time. PAH results in surface water samples ranged from 0.16±0.00 – 23.81±18.05ppm and 0.16±0.00 – 26.44±12.25ppm at Azuabie and Okujagu respectively. There were no significant differences by location; August 2023 values were significantly higher than those recorded in other months. PAH values in oysters ranged from 0.11±0.007 – 6.34±0.49ppm and 0.17±0.007 – 5.06±0.69ppm at Azuabie and Okujagu respectively. There were no significant differences between location and time. PAH values in periwinkles ranged from 0.22±0.02 – 9.43±1.90ppm and 0.18±0.007 – 8.38±0.32ppm at Azuabie and Okujagu respectively. Study locations did not vary significantly but time did. The highest concentrations of the PAH constituents included those of Acenaphthene of 5.715ppm, Naphthalene 4.7ppm and Dibenz(a,h)anthracene of 3.985ppm in both surface water and sediment samples at Okujagu in August 2023. At Azuabie, Benzo[a]pyrene had a concentration of 6.595ppm while sediment had 4.12ppm for Dibenz(a,h)anthracene in August 2023. Biota samples had lower values. For instance, in August 2023, Fluorene had the highest value of 0.9ppm at Azuabie and 0.63ppm at Okujagu in oysters; in periwinkles, Fluorene recorded 1.01ppm at Okujagu, while Benzo[a]pyrene had 1.2ppm at Azuabie. Some of the PAH values obtained in the samples exceeded the USEPA and WHO permissible limits. Thus, urgent measures should be taken towards environmental restoration and food security. This research has revealed varying levels of PAH contamination of surface water, sediment and biota (periwinkles and oysters) samples from locations on the Azuabie and Okujagu Creeks, Upper Bonny Estuary, Nigeria. Preventive measures should therefore be taken to prevent continued pollution while aiding the recovery of both creeks. Measures should also be taken to ensure food safety among the population.

Keywords: PAH, marine pollution, environmental contamination, public health, food safety.

INTRODUCTION

Polycyclic aromatic hydrocarbons are persistent organic pollutants with several sources including electronic and other municipal solid wastes (Awino and Garland, 2025), crude oil and petroleum products (Itodo et al., 2019) and the incomplete combustion of organic substances (Zhang et al., 2022). Thus, artisanal refinery of crude oil, the combustion of old vehicle tires and combustion of municipal waste dumps are some of the common sources of PAHs in several parts of southern Nigeria (Ukpebor et al., 2023).

PAHs have been detected in the atmosphere, soil and aquatic environments, with soil having very great storage potentials. They have genotoxic, mutagenic and carcinogenic impacts on man and other living organisms (Cao et al., 2022; Szramowiat-Sala et al., 2025). Consumption of contaminated aquatic organisms such as crabs and fish are of public health consequences (Okolocha, 2018). Regular monitoring of the environment is hence required for early detection and control of PAH pollution.

In this research, the concentrations of PAHs in the surface water, sediment, periwinkle and oyster samples from Azuabie and Okujagu Creeks, Upper Bonny Estuary, Nigeria, were assessed.

MATERIALS AND METHODS

Study Area: Azuabie and Okujagu Creeks (latitude 7°3' N, longitude 4°48' E and latitude 7°1' 30" N and longitude 4°52" respectively; Figure 1) are tributaries of the Okpoka River that flows into the Upper Bonny Estuary. They are located along the Trans-Amadi Industrial Area of Port Harcourt, Nigeria. Both creeks are constantly impacted by anthropogenic activities due to the high population of riverine dwellers and industrial and other activities in the area including dumping of wastes, artisanal fishing (periwinkles, crabs and oysters etc.), dredging and motorized canoe transport (boating activities).

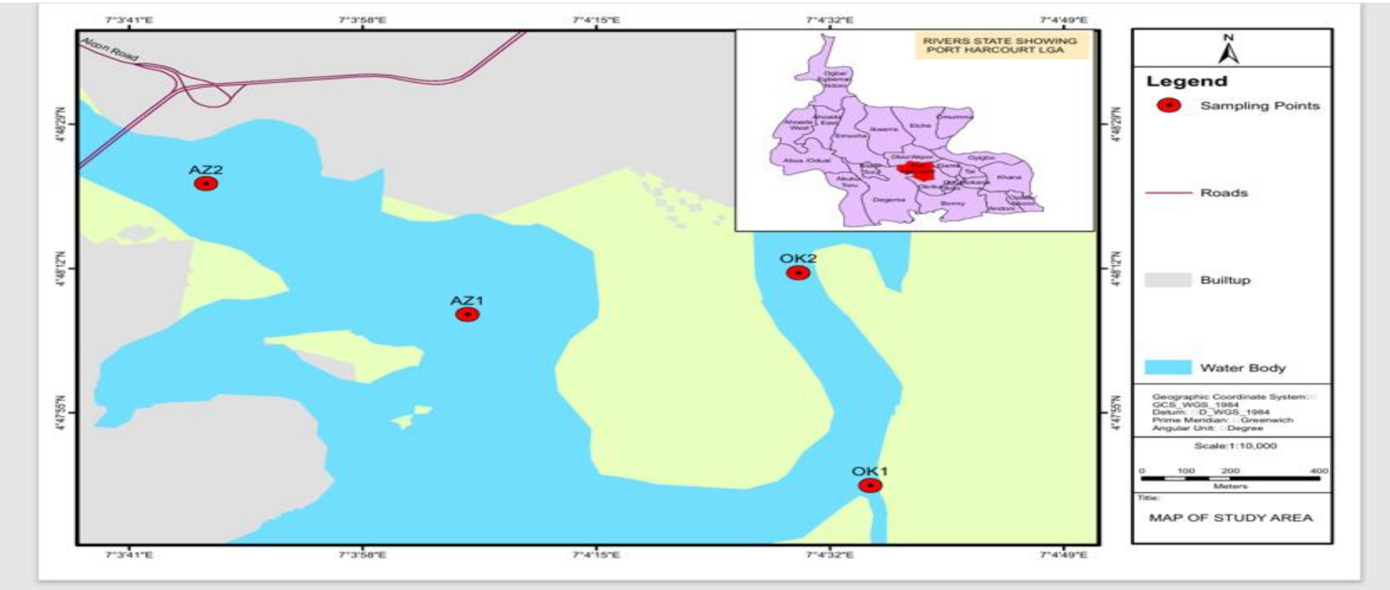

Fig. 1: Map showing Azuabie and Okujagu Creeks, Upper Bonny Estuary, Nigeria

Sample Collection: The surface water samples were collected using Winchester bottles from 15-25cm below the water surface from the sampling stations. They were immediately preserved in ice-packed coolers and transported to the laboratory for further analysis.

Sediment samples were collected using a graded shovel from the top 10 cm from the mid-tide level in two replicates at each sampling station during each sampling period. They were packed with aluminium foil into clean Ziploc bags and transported to Laboratory-EISL (Ebic integrated Services Ltd) where they were pooled to form composite samples for each study location.

Samples of periwinkles (*Tympanotonus fuscatus*) and oysters (*Crassostrea gigas*) were obtained with the help of fishers who harvested them from both creeks. The samples were thoroughly washed with sea water, placed in separate labeled aluminium foils and preserved in ice.

Laboratory Analysis: Sediments were air dried and ground to powder using a laboratory mortar and pestle, passed through a 2mm sieve and stored at -20^{o}C until analysed (Okunola *et al.*, 2012). The soft parts of the periwinkle and oyster were obtained by cracking the shells. The weight of the soft tissues of periwinkle and oyster were obtained by weighing with an electronic scale and then placed on a foil paper and oven dried at 80°C for 24 hours to obtain a dry tissue. The dried tissues were ground to powder form with ceramic mortar and pestle, sieved to obtain a uniform particle size using 2 mm mesh size and preserved in a well labeled plastic bottle indicating each month.

The United States Environmental Protection Agency (USEPA) method 522 was modified and used to analyze PAHs. About 50ml/20g of the sample (water, sediment or biota) were ground with 10g of anhydrous sodium sulfate into a dry homogenate which was then placed into extracting funnel. The biota samples were saponified with ethanolic solution of potassium hydroxide (Baumard *et al.,* 1998). To the mixture was added 10ul of the PAH internal standard and 50ml dichloromethane was added before subjecting to a 30 minutes ultrasonication. The extract was concentrated to 1 ml and cleaned in a silica gel column (4-mm i.d x 90mm). The column was eluted using dichloromethane (3.5 ml). All the elutes were concentrated under a gentle stream of liquid Nitrogen (N_2) to about 100Ul. The concentrations of a total of 16 congeners of the bio-accumulated United States Environmental Protection Agency (USEPA) PAHs were measured and obtained by GC-FID Agilent 7890 A USEPA method 522 GC/MS. The recovery rates were obtained for individual PAHs.

Data Analysis: The data were analyzed using descriptive analysis (means, range); graphs were plotted to aid data visualization. Pearson correlation coefficient was computed between PAH concentrations between pairs of samples. Two-way Analysis of variance (ANOVA) was used to test significant differences between stations and also between months. These were done using SPSS version 20.0 software.

RESULTS

The PAH constituents identified in the samples were Benzo[a]pyrene, Benzo[ghi]perylene, Indeno(1,2,3-cd) pyrene, Dibenz(a,h)anthracene, Benzo[k]fluoranthene, Benzo[b]fluoranthene, Chrysene, Benz[a]anthracene, Pyrene, Fluoranthene, Phenanthrene, Anthracene, Fluorene, Acenaphthene, Naphthalene and Acenaphthalene

Total PAH concentrations in the samples were plotted (Figures 2-5). Statistical analysis showed there were no significant differences in the concentrations of the PAHs between both locations ($p>0.05$). However, initial high values of total PAH were recorded at the onset of the research which differed significantly from the values obtained during the rest of the research duration.

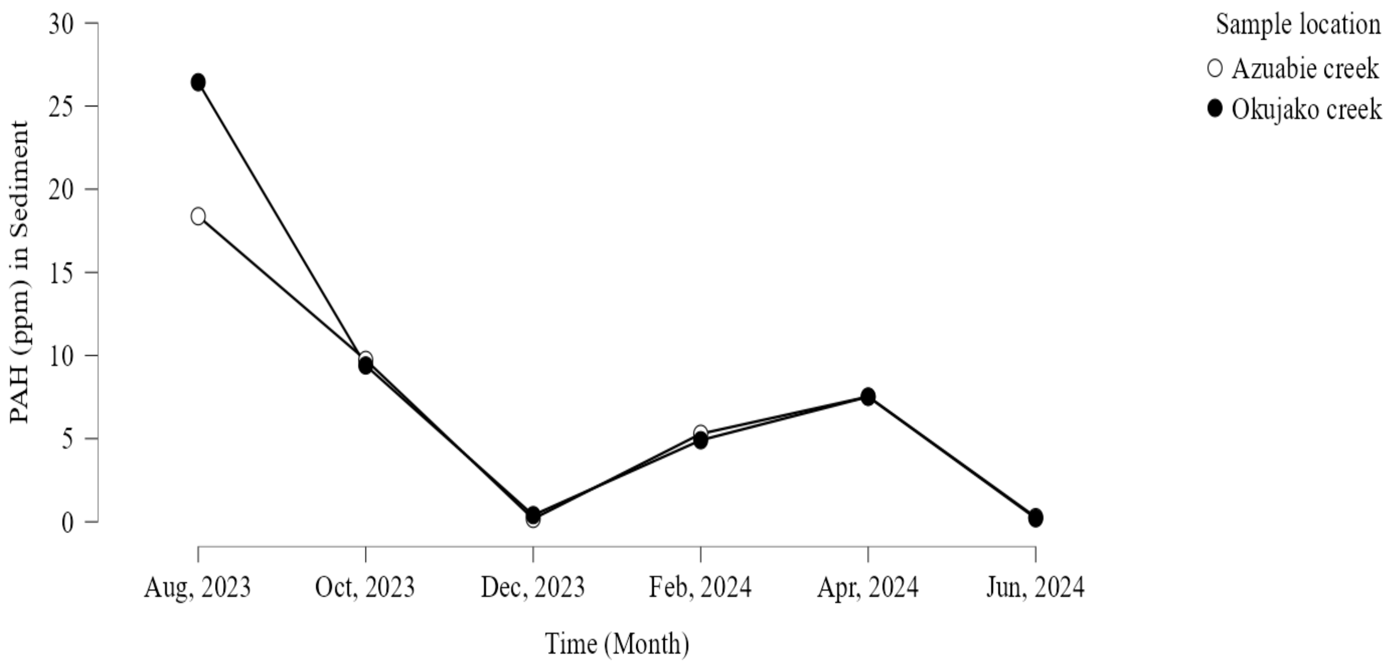

Fig. 2: Monthly variations in PAH values in sediment samples from Azuabie and Okujagu Creeks, Upper Bonny Estuary, Nigeria

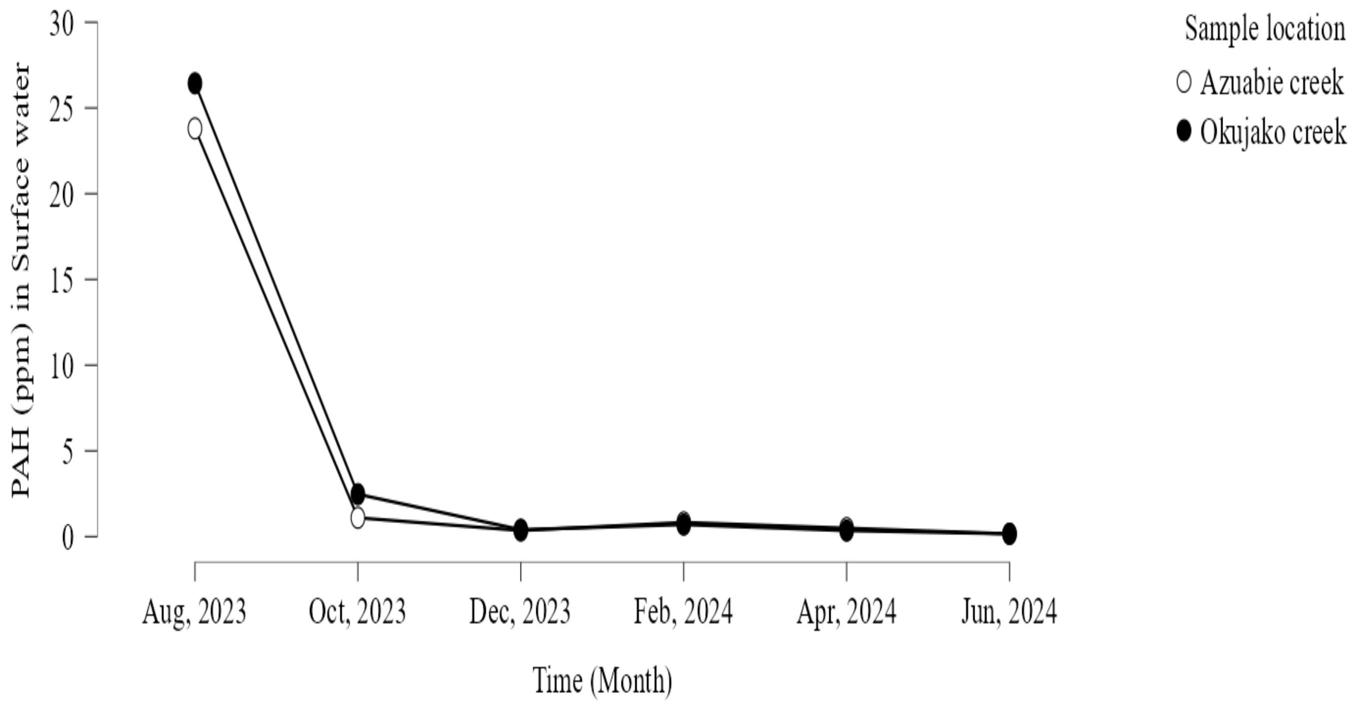

Fig. 3: Monthly variation of PAH in surface water samples from Azuabie and Okujagu Creeks, Upper Bonny Estuary, Nigeria

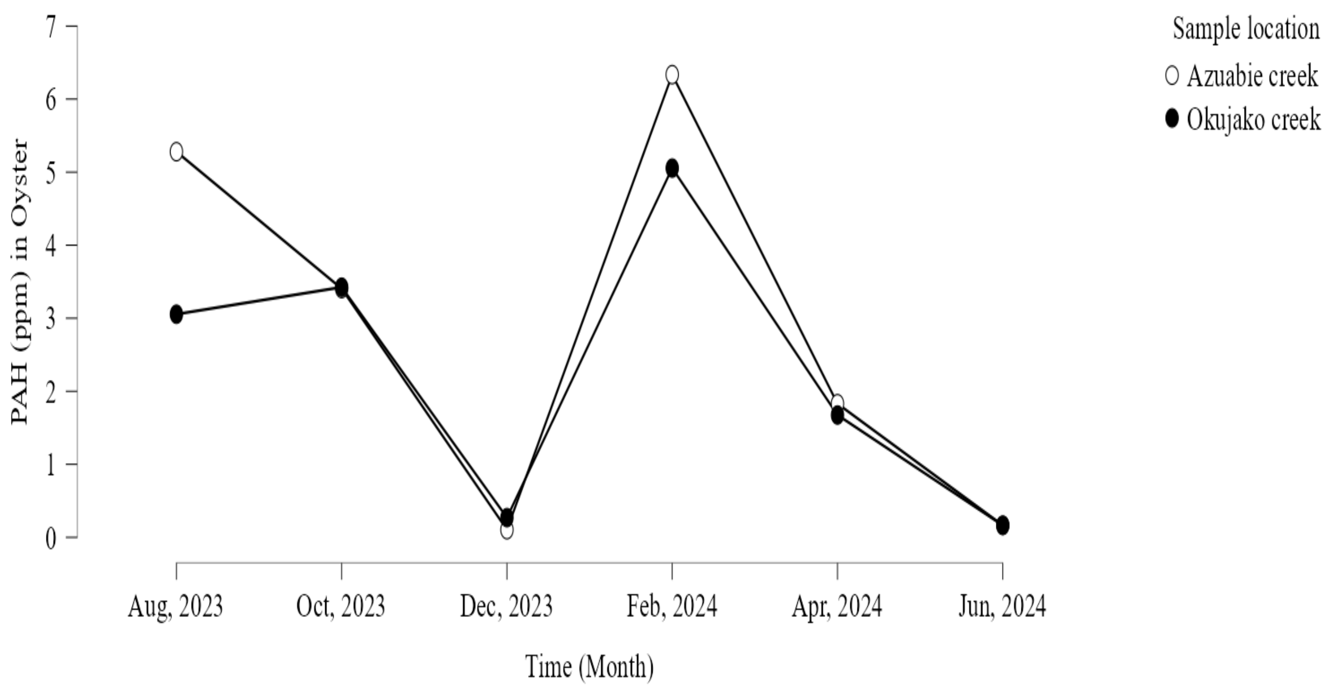

Fig. 4: Monthly variation of PAH in Oysters from Azuabie and Okujagu Creeks, Upper Bonny Estuary, Nigeria

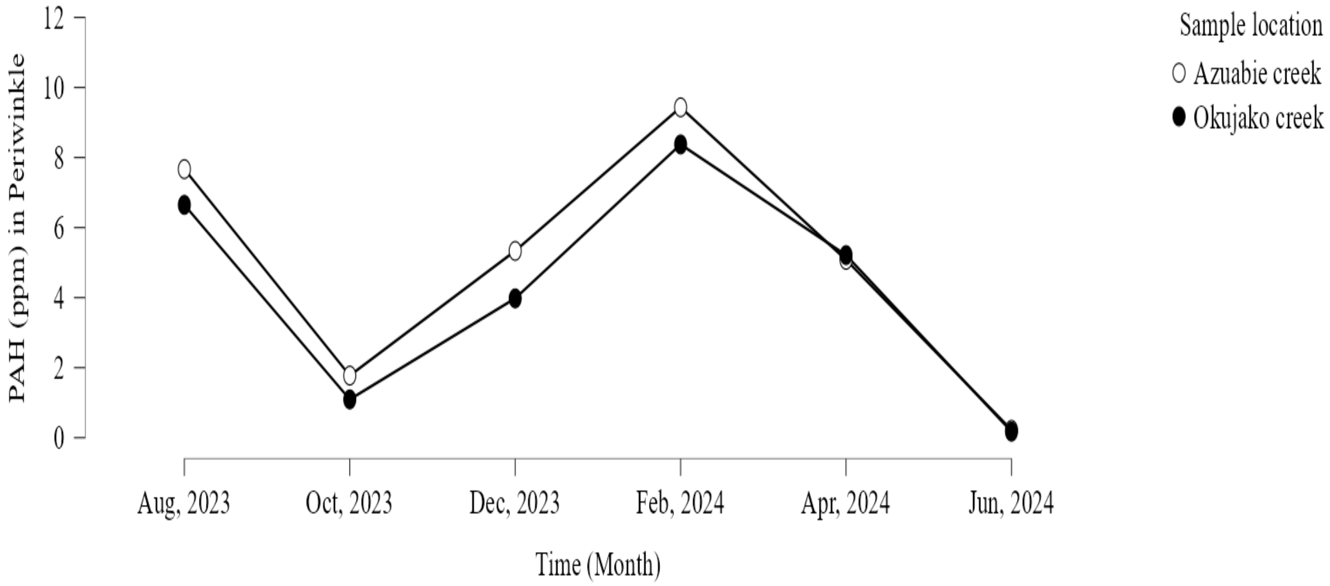

Fig. 5: Monthly variation of PAH in Periwinkles from Azuabie and Okujagu Creeks, Upper Bonny Estuary, Nigeria

The results of the Pearson correlation coefficient (Tables 1& 2) showed significant correlation between the total concentrations in sediment and surface water, oyster and surface water, oysters and sediment, and periwinkles and oysters at Azuabie. At Okujagu, the significant correlations were between PAH concentrations in sediment and surface water, oysters and sediment, and periwinkles and oysters (Table 2).

Table 1: Correlation Coefficient between pairs of PAH Concentrations from environmental and biota samples, Azuabie.

Parameters	SW PAH	SED PAH	OYS PAH
SED PAH	*0.842175881		
OYS PAH	*0.478531505	*0.667567457	
PER PAH	0.396845925	0.37107185	*0.7056425

Key: SW, Surface water; SED, sediment; OYS, Oysters; PER, periwinkles; PAH, polycyclic aromatic hydrocarbons.

Table 2: Correlation Coefficient between pairs of PAH Concentrations from environmental and biota samples, Okujagu

Parameters	SW PAH	SED PAH	OYS PAH
SED PAH	*0.943233372		
OYS PAH	0.238775406	*0.42209379	
PER PAH	0.348991857	0.39226138	*0.5989317

NOTE: * shows parameters with significant values because its Values $\geq$ 0.40

Key: SW, Surface water; SED, sediment; OYS, Oysters; PER, periwinkles; PAH, polycyclic aromatic hydrocarbons.

DISCUSSION

Concentration of PAH in Surface Water, sediment and Biota (Oysters & Periwinkle) from Azuabie and Okujagu Creeks

PAH values in surface water, sediment, oysters and periwinkles at Azuabie ranged from 0.16 to 23.81ppm, 0.18 to 18.38ppm, 0.11 to 6.34ppm, and 0.22 to 9.43ppm respectively. At Okujagu, the values were as follows: 0.16 to 26.44ppm, 0.21 to 26.44ppm, 0.17 to 5.06ppm and 0.18 to 8.38ppm in surface water, sediment, oysters and periwinkles, respectively. Thus, higher values were recorded in the surface water.

Moslen and Aigberua (2018) reported mean PAH values which ranged from 0.001 ± 0.0003 – 0.384 ± 0.104 mg/l in their study on the hydrocarbon contamination of surface water at Azuabie Creek using Okujagu Creek as the control. These authors noted that the PAH values were significantly higher at Azuabie, and explained that it was due to oil bunkering and other anthropogenic activities in the study area. In the current research, however, PAH levels did not differ significantly between both locations, except for those in periwinkles which were significantly higher in samples from Azuabie. This means that over the years, anthropogenic activities have impacted much on the Okujagu Creek making it comparable to Azuabie Creek in pollution levels.

In their research on pollution of surface water, Iyama et al. (2020) recorded PAH values of 0.24±0.021 - 0.30±0.021 mg/L with a mean value of 0.27± 0.03 mg/L at Rumuwoji/Elelenwo River, 0.22±0.00 - 0.23±0.008 mg/L and a mean value of 0.22± 0.006 mg/L at Woji Creek and 0.18±0.007 - 0.20±0.007 mg/L, with a mean value of 0.19±0.01 mg/L at Akpajo River all in Rivers State. They noted that though PAH levels in water systems may be below WHO (2006) standards, they still constitute health threats to both aquatic organisms and man.

The PAH constituents identified in both environmental samples (surface water and sediment) and biota (oysters and periwinkles) included Benzo[a]pyrene, Benzo[ghi]perylene, Indeno(1,2,3-cd) pyrene, Dibenz(a,h)anthracene, Benzo[k]fluoranthene, Benzo[b]fluoranthene, Chrysene, Benz[a]anthracene, Pyrene, Fluoranthene, Phenanthrene, Anthracene, Fluorene, Acenaphthene, Naphthalene and Acenaphthalene. The highest concentrations were recorded in August 2023 and this was significantly higher than the lower values recorded during the rest of the sampling period. Their concentrations ranged from 0.01ppm to over 6.0ppm. The highest concentrations recorded were those of Naphthalene (4.7ppm) and Acenaphthalene (5.715ppm) in both surface water and sediment in August 2023 at Okujagu. Benzo[a]pyrene reached a concentration of 0.73ppm in both surface water and sediment at Okujagu (August 2023) and 0.135ppm in oysters and 0.21ppm in periwinkles at Okujagu (August 2023). In the same month at Azuabie, periwinkle recorded Benzo[a]pyrene concentration of 0.13ppm in oysters and 1.2ppm in periwinkles, and the highest value of 6.595ppm in surface water and 1.165ppm in sediment.

Benzo[a]pyrene is a known indicator of the presence of carcinogenic PAHs (Ekere et al., 2019). Human activities contribute enormously to the increased quantity of PAHs in the ecosystem (Venkatraman et al., 2024). In their own research, Ekere et al. (2019) reported the following PAH in surface water, catfish and tilapia from Rivers Niger and Benue confluence, Nigeria: naphthalene, phenanthrene, anthracene, benzo [b] fluoranthene, benzo [k] fluoranthene and benzo [a] pyrene. In surface water, they recorded naphthalene 0.420 to 0.543µg/L, phenanthrene and anthracene 0.083µg/L, Benzo[b]fluoranthene and benzo[k] fluoranthene 0.08 – 0.093 µg/L, and Benzo[a]pyrene 0.083 to 0.113 µg/L. In fish, their results were as follows: naphthalene 2.383 mg/kg and 1.947 mg/kg Tilapia; phenanthrene and anthracene had similar values of 0. 050 and 0.057 µg/kg in catfish and tilapia, respectively; Benzo[b] fluoranthene, Benzo[k]fluoranthene and Benzo[a]pyrene were not detected in Tilapia but ranged from 0.043–0.05 µg/kg in catfish. These authors argued that the feeding habits of fish contributed to the type and level of PAHs they accumulate, stating that high molecular weight PAHs are more absorbed by surface water feeders than by those that live on sediments which characteristically hold more low weight PAHs. They cited Berto et al. (2009) stating that "during PAHs transport, high molecular weight PAHs could be degraded to lower ones and are buried in the sediments".

The World Health Organization (2003) maximum permissible limits for PAH are as follows: 0.2 µg/L (equivalent to 0.2/1000ppm = 0.0002ppm) for total PAHs in drinking water while that of benzo(a) pyrene is 0.1 µg/L (= 0.0001ppm); 10 mg/l (equivalent to 10ppm) in natural waters, and 0.001 µg/g (= 0.001ppm) in fish and shell fish respectively. The European Commission, 2015, however set a recommended limit of PAHs value of 12 µg/kg (equivalent to, 12 / 1000ppm = 0.012ppm) in fish. Whereas most of the PAH values recorded in surface water and sediments were below the maximum permissible limit of 10ppm, the values in biota all exceeded the maximum permissible limit of 0.001ppm and 0.012ppm set by WHO (2003) and European Commission (2015), respectively.

Pollutants get absorbed by periwinkles and oysters directly from the water body through their food, gills and body surface (Onwumere and Oladimeji, 1990). They are stored in organs with high lipid content and eventually bioaccumulate through the food chain.

Correlation Analysis of PAHs in test organisms and environmental samples

The results of the Pearson correlation analysis showed that at Azuabie, total PAH concentrations in surface water were significantly positively correlated with the concentrations in the sediment and oysters; the concentration in the sediment was significantly positively correlated with that in the oysters; and the concentrations in oysters were significantly correlated with those in periwinkles. At Okujagu, the only significant correlations were between surface water and sediment, sediment and oysters, and oysters and periwinkles.

Depending on the environmental characteristics and sources of the pollutant, other authors report either significant positive or negative correlation coefficients between samples (Cui et al., 2016; Umudi et al., 2025).

However, strong positive correlation between PAH concentrations from different samples from the same location point to the fact that the pollution in the samples was from a similar source (Ekere et al., 2019; Umudi et al., 2025). The results obtained from this research hence indicate a similar source of PAHs from the environment which is related to run-off from municipal waste dumps characterized by frequent incomplete combustion (to reduce waste load), combustion of old vehicle tires and other anthropogenic activities.

RECOMMENDATIONS

Regulatory mechanisms should be put in place to adequately handle municipal solid waste. Frequent monitoring of aquatic ecosystems for the detection of persistent organic pollutants is important. Also, the research by Ayedun et al. (2024) showed that plant products such as Moringa seed and garlic extracts were effective in cleaning out polycyclic aromatic hydrocarbons from water samples; this can be adopted by locals for the purification of drinking water.

CONCLUSION

This research has shown that sediment and surface water samples as well as periwinkles and oysters obtained from Azuabie and Okujagu Creeks are polluted with varying levels of PAH. All the concentrations recorded in biota exceeded the regulatory limits accounting for urgent action to safe guard public health.

REFERENCES

Awino, F.B. & Garland, G. (2025). Occurrence of emerging and persistent organic pollutants in dumpsite environments: A review. Environmental Challenges, 18: 101094. https://doi.org/10.16/j.envc.2025.101094.

Ayedun, H., Jaiyeola, O.O., Onigbinde, S.O., Folarin, O.M. & Oyedeji, A.O. (2024). Polycyclic aromatic hydrocarbons (PAHs) in crude oil-contaminated water and soil and their removal using locally available plant materials. *Water Practice and Technology*, 19(10): 3956-3971.

Baumard, P., Budzinski, H. & Garriques, P. (1998) Polycyclic Aromatic Hydrocarbons in Sediment and Mussels of the Western Mediterranean Sea. *Environmental Toxicology and Chemistry*, 17, 765-776.

Berto, D, Cacciatore F, Ausili A, Sunseri G, Luca G, Bellucci LG, Frignani M, Albertazzi S, Giani M. (2009). Polycyclic aromatic Hydrocarbons (PAHs) from diffuse sources in coastal sediments of a not industrialised Mediterranean Island. *Water, Air and Soil Pollution, 2*00, 199–209.

Cao, W., Yuan, J., Geng, S., Zou, J., Dou, J., & Fan, F. (2022). Oxygenated and nitrated polycyclic aromatic hydrocarbons: sources, quantification, incidence, toxicity, and fate in soil—a review study. *Processes*, *11*(1), 52. https://doi.org/10.3390/pr11010052.

Cui, S., Fu, Q., Li, T., Ma, W., Liu, D., & Wang, M. (2016). Sediment-Water Exchange, Spatial Variations, and Ecological Risk Assessment of Polycyclic AromaticHydrocarbons (PAHs) in the Songhua River, China. *Water*, 8(334), 1-13. doi:10.3390/w8080334.

Ekere, N.R., Yakubu, N.M., Oparanozie, T., & Ihedioha, J.N. (2019). Levels and risk assessment of polycyclic aromatic hydrocarbons in water and fish of Rivers Niger and Benue confluence Lokoja, Nigeria. Journal of Environmental Health Science and Engineering, 17(1):383-392. doi: 10.1007/s40201-019-00356-z.

European Commission.(2015). EC regulation 2015/1933 amending EC regulation 1881/2006 regarding maximum levels of PAHs in foodstuffs, Torino Italy.

Itodo, A.U., Akeju, T.T. and Itodo, H.U. (2019). Polycyclic aromatic hydrocarbons (PAHs) in crude oil contaminated water from Ese-Odo offshore, Nigeria. *Annals of Ecology and Environmental Science*, 3: 12-19.

Iyama, W.A., Edori, O.S. & Nwagbara, V.U. (2020). Assessment of the Pollution Load of the Woji Creek Water Body, Port Harcourt, Rivers State, South-South, Nigeria. International Journal of Advanced Research in Chemical Science, 7(1), 1-8 DOI: http://dx.doi.org/10.20431/2349-0403.0701001.

Moslen, M., & Aigberua, A. (2018). Heavy Metals and Hydrocarbon Contamination of Surface water in Azuabie Creek within Bonny Estuary, Nigeria. *Journal of Applied Science and Environmental Management*, 22(7), 1083-1088.

Okolocha, C.M. (2018). Evaluation of persistent organic pollutants in sediment and biota obtained from Azuabie and Okujagu Creeks in the Upper Bonny Estuary, Nigeria. An MSc dissertation submitted to Rivers State University, Port Harcourt. 132pp.

Okunola, A.A., Adekunle, A., Xijun, K., Bin, L., Yuling, Z. & Xia, H. (2012). Comparative evaluation of environmental contamination by electronic wastes in Nigeria and China. *Science of Total Environment*, 423, 62-72.

Onwumere, B.G. & Oladimeji, A.A. (1990). Accumulation of metals and histopathology in *Oreochromis niloticus* exposed to treated NNPC Kaduna (Nigeria) petroleum refinery effluent. *Ecotoxicology and Environmental Safety*, 19(2), 123-134. https://doi.org/10.1016/0147-6513(90)90061-9.

Szramowiat-Sala, K., Marczak-Grzesik, M., Karczewski, M., Kistler, M., Giebl, A. K., & Styszko, K. (2025). Chemical investigation of polycyclic aromatic hydrocarbon sources in an urban area with complex air quality challenges. *Scientific Reports*, *15*(1), 6987. https://doi.org/10.1038/s41598-025-91018-8.

Ukpebor, J.E., Omoruyi, C.I., Omonmhenle, S.I., Imhontu, M., Oghoje, S.U., Isara, A.R. & Ukpebor, E.E. (2023). Concentrations of PAHs from urban and rural areas in southern Nigeria using polyurethane foams (PUF) passive samplers: health impact and cancer risk assessment. *Scientific African*, 22: e01976.

Umudi, E. Q., Obruche E. K., Sani M. I., Onwugbuta G. C., Aghemwenhio I.S.,Ikechukwu S. C., Clark P. D., Essiet A.G., Eresanya O.I., Ibe M.C. & Hashimu. A. (2025). Evaluation of Polycyclic Aromatic Hydrocarbons (PAHs) Contents of Fishes, Waters and Sediments of River Niger: Human Health Risk Assessment. *Journal of Basic and Applied Science Research*, 3(5), 187-199. https://dx.doi.org/10.4314/jobasr.v3i5.20.

Venkatraman, G., Giribabu, N., Mohan, P.S., Muttiah, B., Govindarajan, V.K., Alagiri, M., Rahman, P.S.A., & Karsani, S.A. (2024). Environmental impact and human health effects of polycyclic aromatic hydrocarbons and remedial strategies: A detailed review. *Chemosphere*, 351, 141227, https://doi.org/10.1016/j.chemosphere.2024.141227.

World Health Organization (2006). Protecting groundwater for health: managing the quality of drinking-water sources. Geneva: World Health Organization.

World Health Organization. (2003). Polynuclear aromatic hydrocarbons in drinking-water. Background document for development of WHO guidelines for drinking-water quality. Geneva: World Health Organization.

Zhang, H., Zhang, X., Wang, Y., Bai, P., Hayakawa, K., Zhang, L. & Tang, N. (2022). Characteristics and influencing factors of polycyclic aromatic hydrocarbons emitted from open burning and stove burning biomass: a brief review. *International Journal of Environmental Research and Public Health*, 19(7): 3944.