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Assessment of Polycyclic Aromatic Hydrocarbons in Water and Sediments of Allor River in Ankpa Local Government of Kogi State, Nigeria

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Abstract: The distribution of the sixteen polycyclic aromatic hydrocarbons (PAHs) was studied in the upstream, mid-stream and lower stream of surface water and sediments of Allor River in Anpka Local Government Area of Kogi state. Liquid-liquid extraction was used for water samples, while PAHs in sediments were extracted using Liquid-Solid Extraction and finally analyzed by means of gas chromatography equipped with a flame ionization detection. Results showed that in water samples, the highest concentration was related to acenaphthene (3-ring PAH), whereas fluoranthene (4-ring PAH) was the most important pollutant in sediments. In both water and sediment samples, the highest and the lowest mean concentrations of PAHs were observed. Ratios of specific PAH compound including Phenantharene/Anthracene and Fluoranthene/Pyrene were calculated to evaluate the possible sources of PAHs contamination. These ratios reflect a pyrolytic origin of PAHs for sediments, as well as a pyrolytic or pyrogenic origin for water samples (with a dominant pyrolytic input) in the study area. This study underscores the importance of adhering to established guidelines for hazardous substances and implementing effective measures to protect both environmental and human health.

1. Introduction

Humanity has always recognised the profound importance of environmental well-being (Wang and Yang, 2016). River ecosystems, home to diverse microorganisms and larger organisms, face threats from pollution, as organic and inorganic pollutants enter through wastewater, industrial discharge, storm water, and air deposition (Abdel-Shafy and Mansour, 2018; Sabater and Elosegi, 2014; Lee *et al.*, 2020). Sediments act as reservoirs for pollutants, but their resuspension can release these toxins back into the water, potentially harming aquatic ecosystems (Lee *et al.*, 2013, 2020). The sediment's diverse contaminants are in a state of constant flux, continuously exchanging with the overlying water through processes of adsorption (attaching to the sediment) and emission (releasing into the water) (Zhu *et al.*, 2013; Hill *et al.*, 2013). When the physical and chemical properties of the water-sediment interface change through diffusion, desorption, disturbance, etc., pollutants may be re-released into the overlying water, and the sediments transform from being a “sink” to a “source” of contaminants. To mitigate the risks posed by polluted sediment's chemical and biological interactions with water, it's essential to gather data on sediment quality and ecological risk conditions (Wang *et al.*, 2020; Errich *et al.*, 2021; Armid *et al.*, 2014). As a result of low water solubility and high hydrophobicity, PAHs have a high affinity for the organic fraction of the sample and in water, which can be deposited as sediments (Zhao *et al.*, 2021).

Polycyclic aromatic hydrocarbons (PAHs) are chemical known for their hazardous nature and are classified as priority pollutants (USEPA, 2014). They are organic compounds consisting of one or multiple benzene/aromatic rings fused together (Marce and Borrull, 2000). They are omnipresent organic pollutants caused by humankind activities, PAHs are important in the environment because of their ability to cause cancer and gene mutation (Martinez *et al.*, 2004; Najurudeen *et al.*, 2023; Venkatraman *et al.*, 2024). PAHs have attracted more and more attention around the world (D'Agostino *et al.*, 2020, Sharifi *et al.*, 2022, Mihankhah *et al.*, 2020). PAHs enter aquatic environments through various pathways, including accidental oil spills, industrial and municipal discharges, urban runoff, and atmospheric deposition, among others.

PAHs are lipophilic compounds with very low water solubility and therefore, their concentration in water is very low (Nasr *et al.*, 2010; Qiu *et al.*, 2009). As a consequence of their hydrophobic nature, PAHs in aquatic environments rapidly tend to become associated the particulate matter ending up in sedimentation. Therefore, sediment represent the most significant reservoir of PAHs in the aquactic environment. For that reason, PAHs accumulation in coastal sediments is both due to human activities and natural emissions. Among anthropogenic factors, petrogenic and pyrolytic/pyrogenic sources are the most important. Whereas pyrolytic sources include combustion processes for example incomplete fossil fuel combustion and biomass that includes, forest fires and grass fires. The petrogenic input include the spill of petroleum and its products (Qiu *et al.*, 2009; Perra *et al.*, 2009; Cheruiyot *et al.*, 2015).

The PAH composition within the sediments reflects the source(s) from which the PAHs were derived (Simpson *et al.*, 1998; Yan *et al.*, 2009). Larger concentrations of lower molecular weight PAHs (e.g. acenaphthene and fluorene) most often occur in sample matrices contaminated with naturally occurring (petrogenic) PAHs. PAHs originating from combustion (pyrolytic) sources often contain elevated concentrations of higher molecular weight and higher membered-ring PAHs (e.g. phenanthrene, fluoranthene, and pyrene) and fewer low molecular weight PAHs (Helfrich and Armstrong 1986).

Recently, data on a given topic can be collected and analysed using database such Scopus, Web of Science, Publish or perish… Moreover, the VOS viewer tool is used to show the most published authors and their co-authors to form clusters called mapping (Pranckutė, 2021; Salim *et al.*, 2022; Nandiyanto *et al.*, 2024; Kachbou *et al.*, 2025). The analysis depicts the countries and the possible collaborations between laboratories and regions (Oyewola & Dada, (2022; Hammouti *et al.*, 2025). The authors and countries are presented by circles or nodes at different sizes and colors. The diameter of nodes indicates the number of articles. The lines linking of the nodes indicate the cooperation (Bai & Xin, (2025).

More than 101,500 articles were collected from Scopus using "Polycyclic aromatic hydrocarbons" from 1973 to present. **Figure 1** visualised the variation of the article with time and the increase during this decennium to observe the importance of these pollutants and their impact on the environment. Also, this exorbitant number in recent years is due to the demand for petroleum products, and the industrialization of many countries which do not respect standards and the environment (Ranjan *et al.*, 2017; Chen *et al.*, 2021; Montano *et al.*, 2025; Abdel-Shafy Hussein & Mansour Mona, 2016).

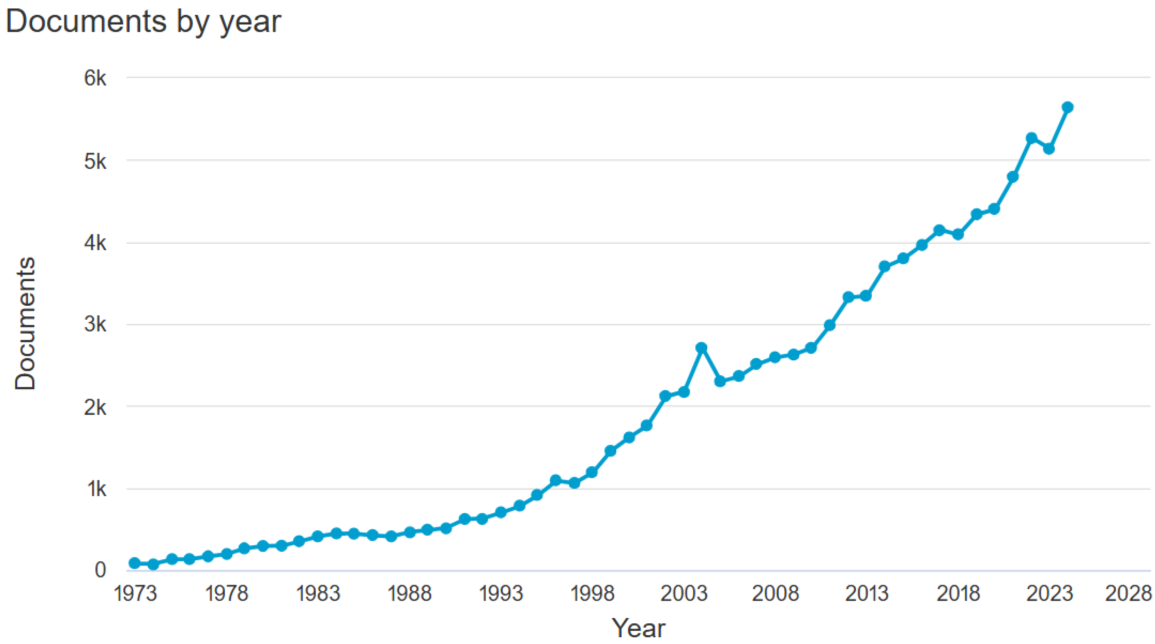

Figure 1: The high increase of articles from 1973 to 2024: "Polycyclic aromatic hydrocarbons"

When river was added to "Polycyclic aromatic hydrocarbons" as keyword, the number falls to 4427 articles were published by 16680 authors (**Figure 2**). The environmental science, earth and planet and agriculture are the high parts of this production (43.2%, 9% and 10%) near chemistry 11% (**Figure 3**). **Figure 4** indicates that over 96% of the production are articles and conference papers.

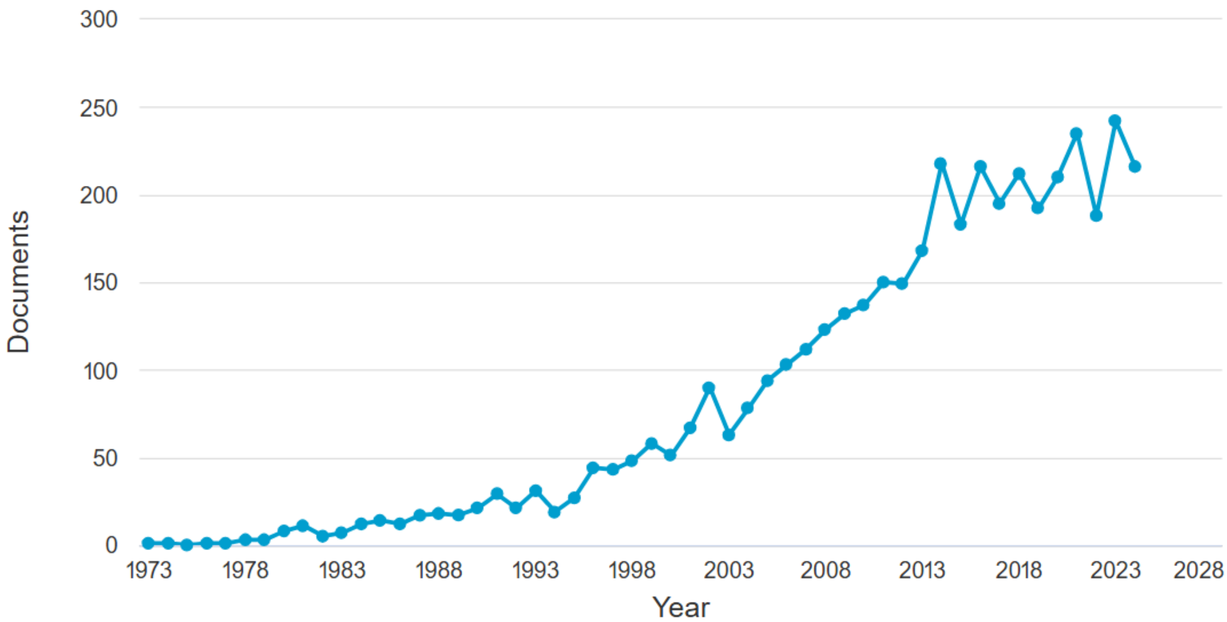

Figure 2: The evolution of articles from 1973 to 2024: "Polycyclic aromatic hydrocarbons+river"

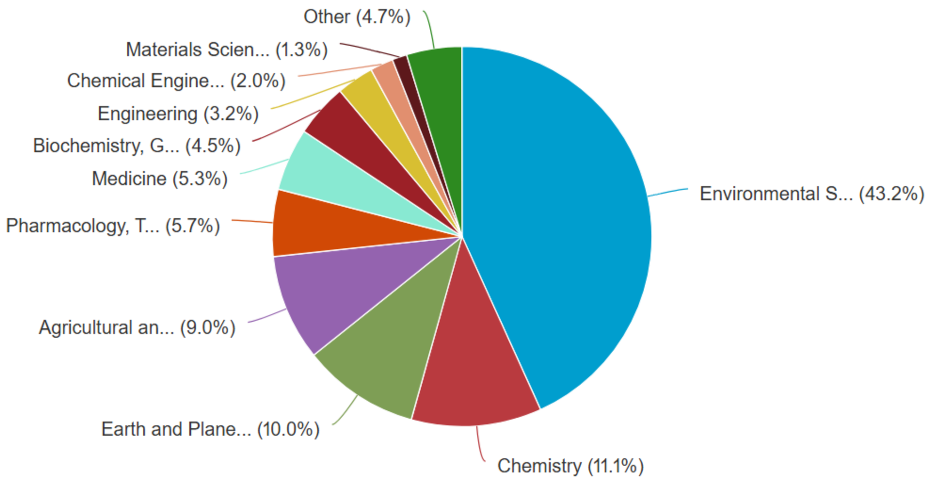

Figure 3: The percentage of articles: "Polycyclic aromatic hydrocarbons+river"

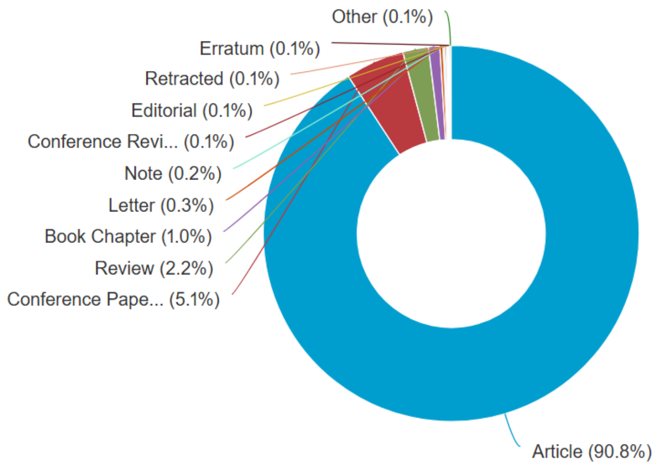

Figure 4: The percentage of documents on Scopus

Figure 5 shows the list of the ten most published authors on the contamination of Rivers by PAHs during the studied period. The Canadian Giesy J.P. is the most published author (34 papers), but, his profile on Scopus indicated more than 1260 articles attaining over 73,260 citations by 47,173 documents. Its H-index of 123 reflected the quality and quality of this prominent researcher receiving 9 awarded grants as show below.

The German Hollert H from Goethe-Universität Frankfurt occupied the second place with 31 articles. His Scopus profile provided all indicators as citations, paper's number, H-index etc… Hollert received 5 grants.

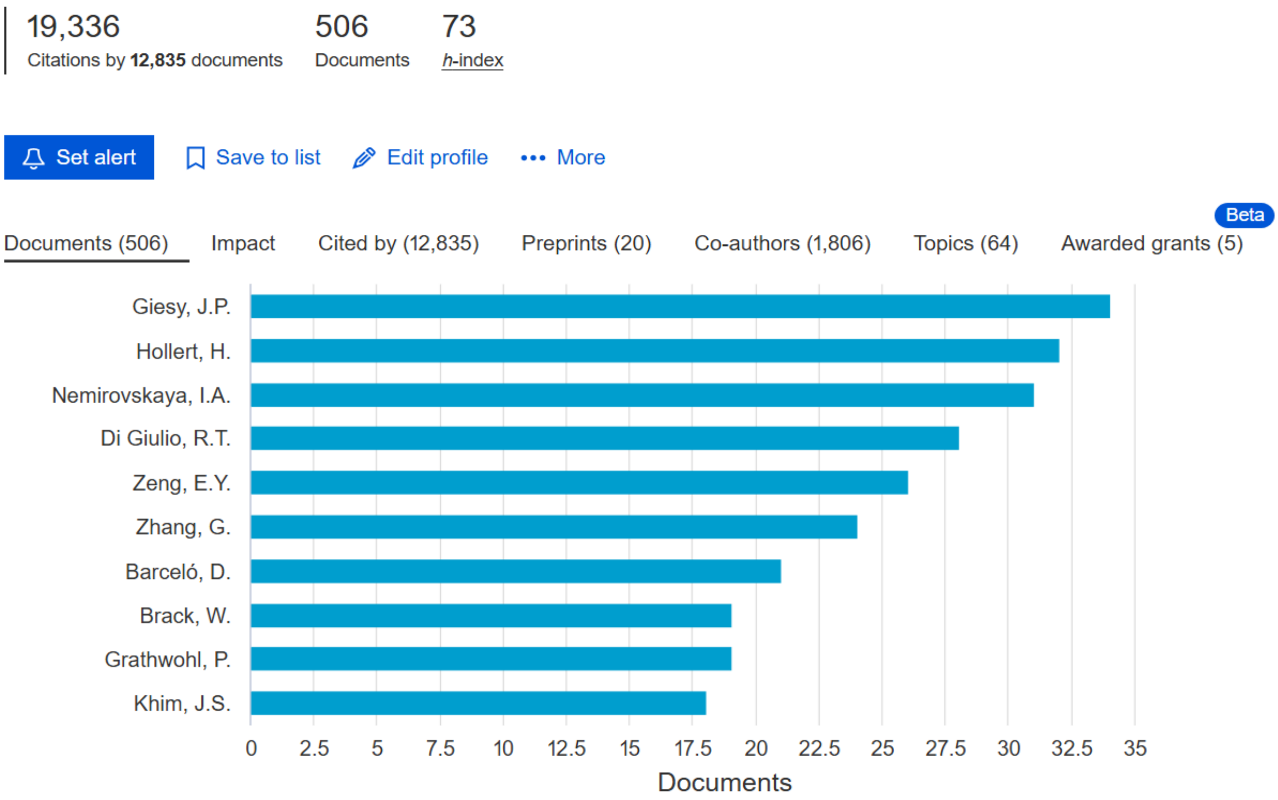

Figure 5: The ten most authors

Scopus analysis can be consolidated by VOS viewer which creates maps of co-authorship networks, highlighting collaborations between authors and visualizes co-occurrence networks for individual authors or groups. **Figure 6** identifies influential authors by node. Collaboration is shown on the maps co-authorship by linking the nodes of others partnerships.

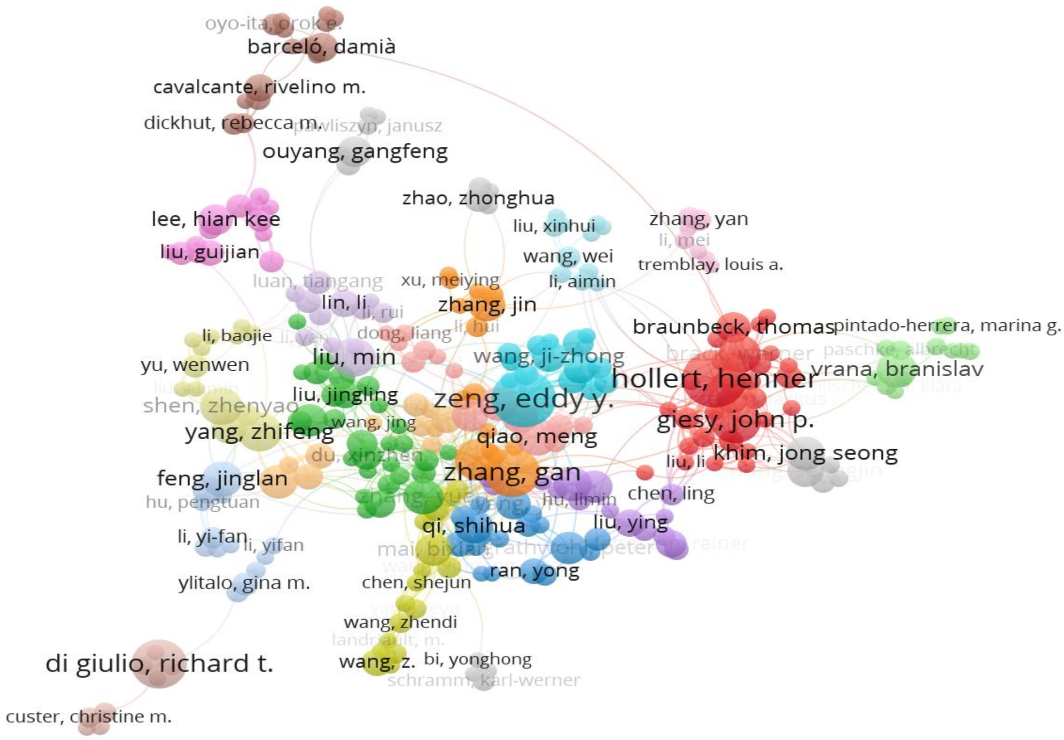

Figure 6: The network visualisation of 416 authors

Figure 7 depicts the overall visualization in relation with time. The mauve nodes indicates that the papers were published over 2010 and yellow ones around 2024. VOS viewer also provides the countries related to this topic: among a total of 135 countries, China is the distinguished with a light large node. The light green color shows the great concern last decades compared to the US, second place, mauve node as indicated in the time axis of **Figure 8**.

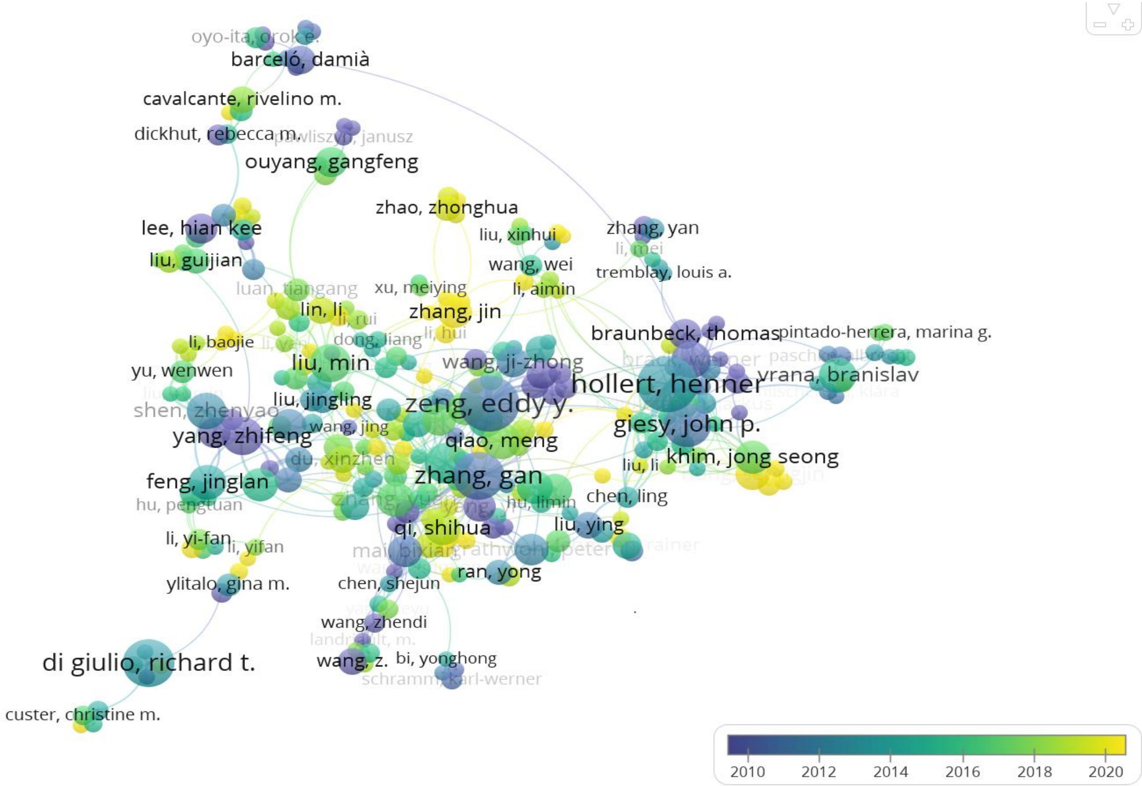

Figure 7: The Overall visualisation of 416 authors on VOS viewer

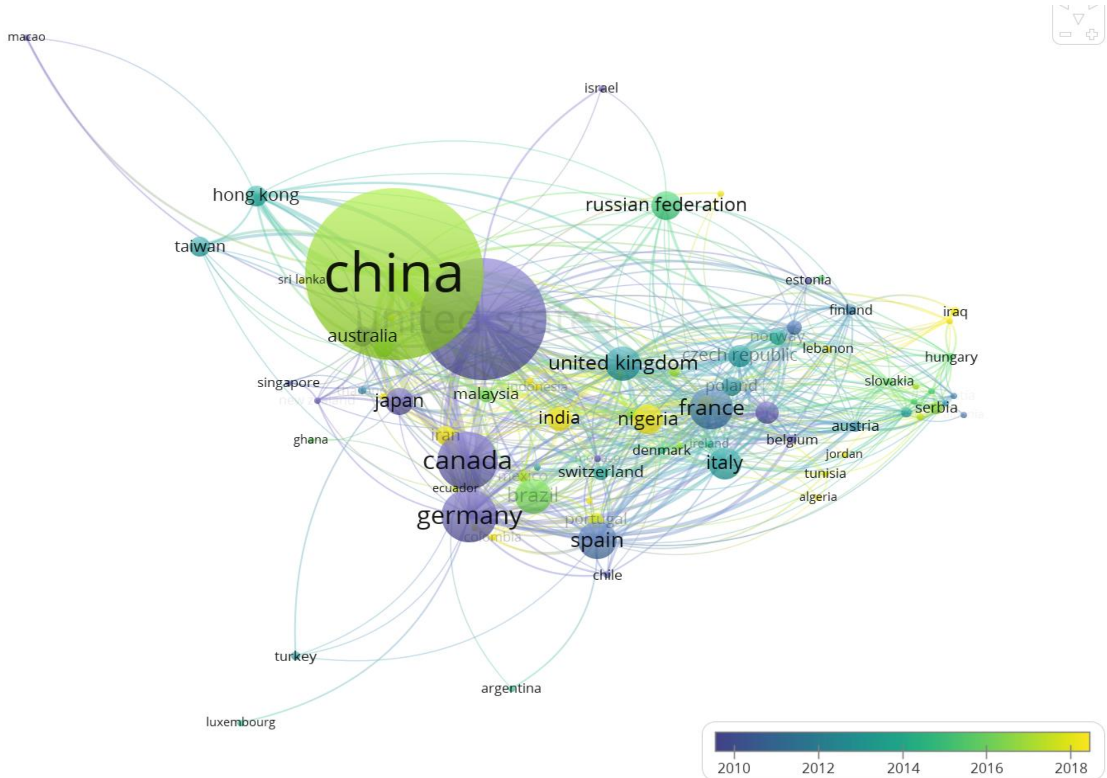

Figure 8: The overall visualisation of 135 countries

These hydrocarbons can become dangerous especially if they come into the alimentary chain, since some of the higher PAHs and their metabolites, can form DNA adducts which can induce mutations. Because of their carcinogenic and mutagenic properties, the USEPA classified 16 of them as priority pollutants. Some authors suggested that PAHs can be synthesized by unicellular algae, higher plants or bacteria but at the same time others concluded that organisms accumulate PAHs rather than synthesize those (Magi *et al.*, 2002).

Allor River is the most important river in Ankpa Local Government Area, Kogi State-Nigeria. It originates from a high land and flow down to form a tributary of the River Niger. Allor River provides water for domestic use (drinking, washing, cooking etc) for the residents of Ankpa town as well as neighboring villages. Farmers also depend on this river for their crops during the dry season. This ecosystem during the years, due to it closeness to the town and the richness of human activities (agricultural, urban activities and industrial) have accumulated sediment but high PAHs and organic matter levels. Therefore, the aim of this work is to study the distribution of the sixteen PAHs in the water and sediments of Allor River through three sampling points (upstream, mid-stream and downstream) and to determination of their source(s) on the basis of their concentrations.

The determination of PAH concentrations in water and sediments from the Allor River involves advanced analytical techniques such as gas chromatography-mass spectrometry equipped with flame ionization detector (GC-FID), which provides sensitive and accurate quantification of these compounds (Rezaei Kalantary *et al*., 2022). This study aims to assess the presence and distribution of PAHs in the Allor River water and sediments, identify potential sources of contamination, and evaluate the implications for environmental management. By doing so, it will contribute to a better understanding of the pollution status of the river and offer valuable insights for local authorities and policymakers to implement effective water quality monitoring and remediation programs (Zhu *et al*., 2022).

2. Materials and Methods

2.1 Study area description

The Allor River, located in Ankpa Local Government Area of Kogi State, Nigeria, serves as the primary study site for this research on poly aromatic hydrocarbons (PAHs) in water. The river traverses a diverse landscape that includes upstream, middle, and downstream sections, each of which may be influenced by varying environmental and anthropogenic factors. (GPS coordinates 7.40286 N, 7.63904 E). The river serves as natural resources for the population that leave along it pathway that depend on it for their daily livelihood (**Figure 9**).

2.2 Sample collection

Both water and sediment samples were collected during the wet season from the Allor River, Ankpa LGA of Kogi State, in three points, namely; upstream, midstream and lower stream. (Figure 9). For each sampling point—upstream, middle stream, and downstream sample were carried out in triplicates. 100 mL water sample was measured with a graduated cylinder and transferred into the 75 Cl container. To prevent microbial degradation of poly aromatic hydrocarbons (PAHs), nitric acid (HNO_3) was added to the samples immediately after collection. Also 50 g of sediment will be collected at the river bed at the depth of about 5 cm and put in the polyethylene bag. The samples were collected in the month of August.

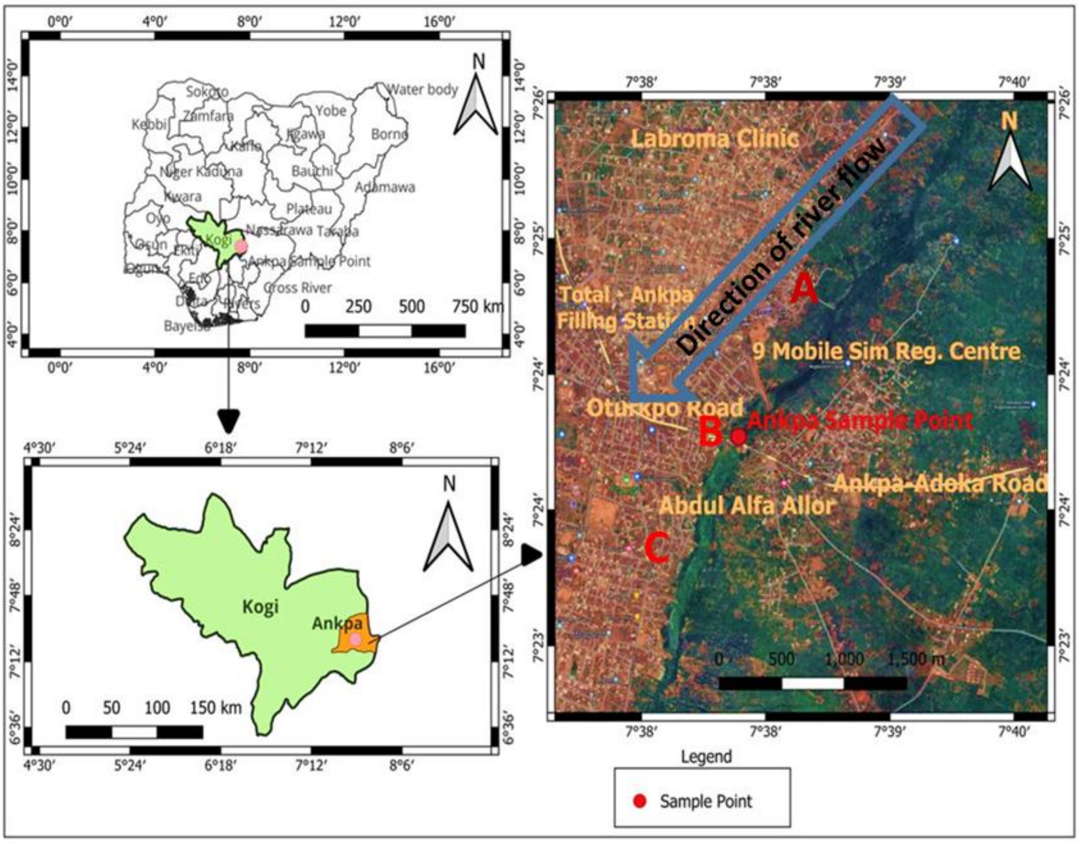

Figure 9. Map of the sampling areas.
KEY: A= upstream, B= mid-stream and C= lower stream

2.3 Sample preparation and extraction (water and sediments)

In the laboratory, a liquid-liquid extraction (LLE) method was employed as described by APHA (1998). 50 mL of each water sample was filtered to remove debris and suspended particle with Whitman filter paper (i.d 70 mm) poured into a separating funnel. This was then poured into a 2 liter separation funnel. To extract the organic compounds, 16 mL of n-hexane and 4 mL of dichloromethane was added. The mixture will be shaken vigorously for at least 3 times, with periodic venting to release pressure. The organic phase will be collected and passed through a column packed with glass wool and silica gel for purification. N-hexane will be used to elute the purified extract, which will then collected in sample valve (tube) for GC/MS equipped with flame ionization detector for analysis.

Air-dried sediments were sieved (mesh size 500 µm) and homogenized in mortar. PAHs in sediments were extracted using Liquid-Solid Extraction (USEPA, 1996). A 2.5 g sample of sediment will be placed into a centrifuge bottle, and 5 mL of acetone will be added. The mixture will be shaken, followed by the addition of 2 g of $MgSO_4$, and shaken again. Then, 0.25 g of sodium citrate tribasic and 0.5 g of sodium citrate dibasic will be added, and the mixture shaken for 5 minutes. This procedure will be repeated for the three samples. After shaking, the centrifuge will be plugged in, and operated for 5 minutes. Subsequently, the extract will be transferred into a burette with n-hexane for purification. The filtrate was then collected into a sample bottle for analysis using GC/MS equipped with flame ionization detector.

Clean up and separation of water and sediments was achieved through chromatography with a silica/alumina column. Saturated aliphatic hydrocarbons were eluted with 20 ml of n-hexane and then aromatic hydrocarbons were eluted with 30 ml of a mixture of hexane and dichloromethane (90:10) (v/v). The volume of the eluted fraction was reduced to 1 ml and then the aromatic hydrocarbon fraction was injected into a gas liquid chromatography equipped with a flam ionization detector (GC/FID) (Nasr *et al.*, 2010). GC analysis was conducted on a fused silica capillary column of 60 m length, 0.25 mm id and 0.5 μm film thicknesses to detect 16 PAH components. The following PAHs were used for quantitation: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene, benzo [a] anthracene, benzo [b] fluoranthene, benzo [k] fluoranthene, benzo [a] pyrene, dibenzo [a,h] anthracene, benzo [g,h,i] perylene, Indeno [1,2,3-cd] pyrene.

Recoveries were carried out by the addition of PAHs standards mixture at the three levels of 1, 5 and 10 μg. The overall mean of recovery percentages were found to be 96.80% and 91.26% for water and sediment samples, respectively. All data were corrected according to the recovery percentage values. Statistical analyses were carried out by analysis of variance (ANOVA) using SPSS 15 software. Mean values were analyzed by the Duncan's test.

3. Results and Discussion

The concentrations of the 16 detected polycyclic aromatic hydrocarbons (PAHs) in surface water and sediment of Allor River are shown on Tables 1 and Table 2. In terms of individual PAH composition in water most compounds analyzed were detected at all location site. As can be seen in water samples, the highest concentration was related to acenaphthene (3-ring PAH), which the mean value (ng/ L) in three sites was 7.55, 10.20 and 22.14, respectively. ANOVA and Duncan tests showed a significant difference between mean concentration of acenaphthene and other detected PAHs ($P \leq 0.01$). At the same time, the lowest concentration of PAH components in water samples of Allor River was related to Indeno [1, 2, 3-cd] pyrene. The associated mean values (ng/L) were 0.15, 0.26 and 0.4.

Table 1: Concentrations of PAHs (ng L^{-1}) in surface water of the Allor River

	Upstream		Midstream		Lower stream	
	………....		…………....		…………….....	
Components	Mean	Range	Mean	Range	Mean	Range
Naphthalene	3.57	2.6-5.1	5.59	3.1-7.1	5.08	3.3-7.3
Acenaphthylene	3.01	2.4-4.7	4.91	3.6-7.1	9.21	7.4-13.9
Acenaphthene	7.55	8.2-11.2	10.20	8.2-13.2	22.14	18.4-29.2
Fluorene	1.58	1.5-2.1	2.60	1.5-3.1	4.91	3.6-6.7
Phenanthrene	3.06	2.6-4.2	4.60	3.1-6.1	7.33	5.3-8.6
Anthracene	2.48	2.0-3.3	3.80	2.6-4.5	15.71	13.4-21.6
Total LPAH	21.24	19.3-30.6	31.70	22.1-39.1	64.39	51.4-87.3
Fluoranthene	0.46	0.4-0.7	0.71	0.6-1.1	1.60	1.4-2.7
Pyrene	0.39	0.4-0.6	0.83	0.6-1.5	1.79	1.4-2.4
Chrysene	0.38	0.4-0.6	1.20	2.0-1.8	2.60	1.7-3.4
Benzo[a]anthracene	0.67	0.3-0.6	1.21	1.1-1.7	1.67	1.4-2.8
Benzo[b]fluoranthene	0.49	0.4-0.7	0.75	0.6-1.3	1.98	1.6-2.6
Benzo[k]fluoranthene	0.64	0.5-0.9	0.63	0.6-1.8	0.96	0.7-1.8
Benzo[a]pyrene	0.75	0.6-1.0	0.61	0.4-1.3	2.07	1.6-2.6
Dibenzo[a,h]anthracene	0.30	0.2-0.6	0.55	0.4-2.0	0.76	0.6-1.9
Benzo[g,h,I]perylene	0.26	0.2-0.4	1.08	0.8-1.6	1.29	0.8-3.0
Indeno[1,2,3-cd]pyrene	0.15	0.1-0.3	0.26	0.2-0.4	0.40	0.2-0.7
Total HPAH	4.49	3.5-6.4	7.83	7.3-14.5	15.12	11.4-23.9
Total	25.73	22.8-37.0	39.53	29.4-53.6	79.51	62.8-111.2

According to our results, the concentration of low molecular weight (2-3 ring) polycyclic aromatic hydrocarbons (LPAHs) in water samples of Allor River is higher than high molecular weight (4-6 ring) PAHs (HPAHs). (Fig. 10A). The mean values of total concentration (mg/L) of LPAHs and HPAHs in three sampling sites were 39.11 and 9.15 respectively, which are significantly different (P≤ 0.01). Our findings did not accord with the report of (Grmasha *et al.*, 2023) on PAHs in surface water of Euphrate River system, they concluded that 5-6 rings were the dominant pollutant in water.

As far as the sediments sample are concerned, fluoranthene (4-ring PAH) was the most important pollutant with mean concentrations (ng g^{-1}) of 13.17, in the uper stream, 25.56, in the midstream and 33.29 in th lower stream respectively. The difference between fluoranthene and other PAHs concentration was highly significant (P≤ 0.01). Meanwhile, in terms of the lowest concentration, fluorene (3-ring PAH) ranked the first position, followed by phenanthrene (3-ring PAH). The respective Figures (ng g^{-1}) in three sampling points (upper stream, midstream and lower stream) are 2.76, 3.21, 3.72 for fluorene and 2.91, 3.14, 3.90 for phenanthrene. Contrary to observed compositions of PAHs in surface water, HPAHs are more dominant in the sediments of Allor River rather than LPAHs (Fig. 10B). The mean total concentration values (ng g^{-1}) were 115.43 for the former and 25.30 for the later which are significantly different (p≤0.01). According to (Nasr *et al*. 2010), (Mohammed *et al*. 2009) and (Koh *et al*. 2004), the composition pattern of PAH in sediments is mostly dominated by four-ring PAHs, while water samples are dominated by three-ring PAHs.

Table 2: Concentrations of PAHs (ng g^{-1}) in surface sediment of Allor River

	Upstream ………....		Midstream ………….		Lower stream …………..	
Components	Mean	Range	Mean	Range	Mean	Range
Naphthalene	5.44	4.2-7.3	5.75	3.6-8.3	6.26	4.6-8.9
Acenaphthylene	3.79	2.9-6.1	3.71	3.1-6.3	5.25	4.3-7.5
Acenaphthene	3.89	3.1-5.6	4.81	3.6-6.1	4.62	3.8-7.2
Fluorene	2.76	2.4-3.5	3.21	2.5-4.2	3.72	3.2-4.6
Phenanthrene	2.91	2.1-4.3	3.14	2.6-4.2	3.09	2.7-4.8
Anthracene	4.18	3.4-5.2	3.95	3.3-5.6	4.06	3.1-6.4
Total LPAH	22.97	18.1-32	24.57	18.7-34.7	28.35	21.7-39.4
Fluoranthene	13.17	8.3-20.3	25.56	19.8-39.6	33.29	24.9-45.2
Pyrene	11.69	7.6-16.3	12.12	9.0-19.2	13.44	9.8-21.2
Chrysene	10.26	7.2-15.8	12.13	8.6-19.5	10.56	7.8-19.7
Benzo[a]anthracene	12.11	9.6-17.6	18.09	15.0-18.5	17.92	13.6-19.3
Benzo[b]fluoranthene	7.61	5.8-10.8	9.13	6.7-12.9	9.83	7.4-14.2
Benzo[k]fluoranthene	4.76	3.7-7.5	4.20	2.9-6.1	8.80	6.3-12.1
Benzo[a]pyrene	7.52	5.3-12.1	8.76	6.3-13.2	9.74	7.7-14.1
Dibenzo[a,h]anthracene	11.07	7.6-16.6	12.98	10.2-17.9	13.99	10.2-18.1
Benzo[g,h,I]perylene	12.89	9.9-15.6	12.75	9.8-16.5	14.48	10.1-18.1
Indeno[1,2,3-cd]pyrene	2.15	1.1-3.9	2.67	1.9-4.4	2.61	1.4-4.3
Total HPAH	93.23	66.1-136.5	118.39	90.2-167.8	134.66	99.2-160.1
Total	116.20	84.2-168.5	142.96	108.9-202.5	163.01	120.9-199.5

The difference in contaminant abundance by different PAH may be attributed to molecular weight and bacterial degradation. A wide array of microorganisms including fungi, algae and bacteria are known to degrade PAHs. However, bacteria play by far the most important role in complete mineralization. Lower molecular weight PAHs such as naphthalene and phenanthrene are degraded rapidly in sediments, but higher molecular weight PAHs such as pyrene, fluoranthene, benzo[a]anthracene and benzo[a]pyrene are more recalcitrant (Obayori, Salam, 2010). Those PAHs that can survive the down column transport will reach the sediment bed, such PAHs are quite likely to be of a relatively high molecular weight with high ring numbers and hence more resistant to degradation processes. The degree of sorption in aquatic systems of hydrophobic PAHs contaminants is often related to a compounds octanol/water partition coefficient (Kow) too (Djomo, Garrigues and Narbonne, 1996).

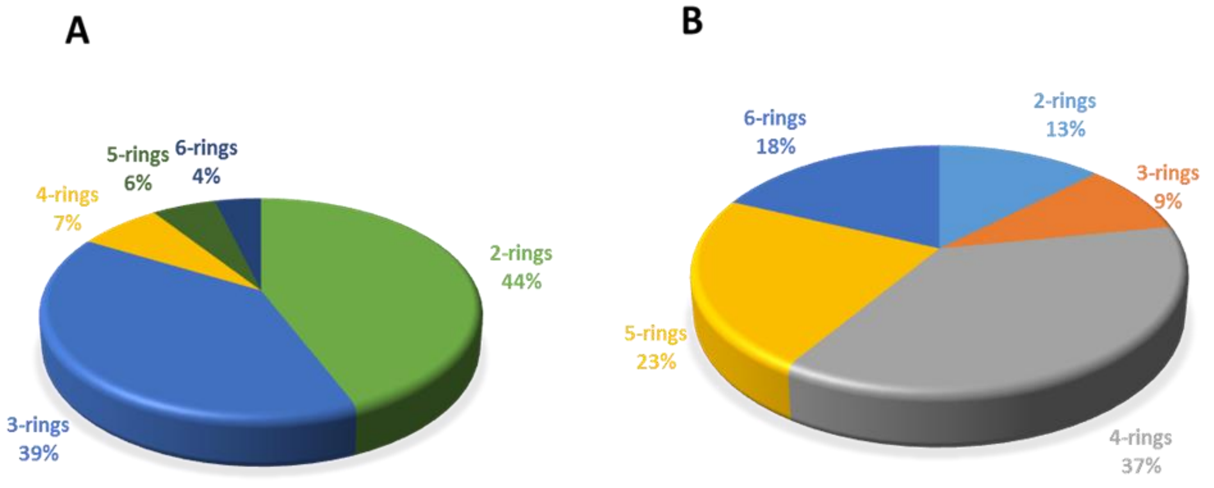

Figure 10: The percentage of mean concentration of 2-rings, 3-rings, 4-rings, 5-rings and 6-rings PAHs in water (A) and sediment (B) samples of Allor River water samples

Therefore, the solubility of polycyclic aromatic hydrocarbons decreases as the Kow and molecular weight increase. As a consequence, the heavier molecular weight compounds with higher Kow favour association with inorganic and organic suspended particles and will settle in sediments. The present results referred to significant differences in the concentrations of PAHs in water and sediment samples among seasons ($P<0.01$) during the study. These results collaborate the study of PAHs distribution in water and sediments as reported by (Kafilzadeh, Shiva and Malekpour 2011).

Anthropogenic PAHs stem mainly from combustion of fossil fuels and spillage of petroleum. The sources of PAHs, whether from fuel combustion (pyrolytic) or from crude oil (petrogenic) contamination, may be identified by ratios of individual PAH compounds based on peculiarities in PAH composition and distribution pattern as a function of the emission source. Ratios of phenanthrene to anthracene (Ph/An) and fluoranthene to pyrene (Fl/Py) have been widely used to distinguish petrogenic and pyrogenic (pyrolytic) sources of PAHs (Magi *et al.*, 2002), (Chen *et al.*, 2006) and (Yunker *et al.*, 2002).

PAHs of petrogenic origin are generally characterized by Ph/An values >10, whereas combustion processes often result in low Ph/An ratios (<10). For the Fl/Py ratios, values greater than 1 have been used to indicate pyrolytic origins and values less than 1 are attributed to petrogenic source (Qiu *et al.*, 2009). In the present study, Ph/An ratios for water samples were 1.23, 1.21 and 0.47 for the upstream, midstream and lower stream in the sampling points respectively. The accompanied values for Fl/Py ratio figures were 1.17 for the upstream, 0.86 for the mid strean and 0.89 for the lower stream. In term of sediment samples, Ph/An ratios in three sample points were 0.69 for the upstream, 0.79 for the mid-stream and 0.76 for the lower stream respectively. While the respective figures for Fl/Py ratios were 1.12, 2.11 and 2.48 for the three sample points. The contrary results indicated by the Ph/An and Fl/Py ratio suggest that PAHs in Allor River may originate from both of pyrolytic and petrogenic sources. As can be seen, PAHs have pyrolytic sources in sediment samples of all the tree sampl points of the upper, middle and the lower streams.

The PAHs in water samples of upstream originate from pyrolytic sources while the midstream and lower stream originate from both pyrolytic and petrogenic sources (pyrolytic sources are more dominant). This was consistent with the results of the Langat River, Peninsular Malaysia (Riyahi Bakhtiari *et al.,* 2009). In another similar study, (Duke, 2008) reported that composition of PAHs in surface water was found to be largely different from that of the sediment of Ekpan Creek of the Warri River. While the origin of PAHs in the surface water was determined to be petrogenic because phenanthrene, anthracene, fluranthene, pyrene, chrysene and Banzo[a]anthracene were not detected, that of the sediment were from pyrogenic sources. The results obtained in this study generally agree with their findings. However, Pyrogenic PAHs are combustion by-products that are mostly produced into the atmosphere by the combustion of fossil fuels (coal, petroleum, and wood) and biomass (forest, grassland, or agricultural) (Lima *et al.,* 2005).

Conclusion

The assessment of polycyclic aromatic hydrocarbons (PAHs) in the Allor River has revealed the present of contamination in the water body and sediments. Results obtained from the present study provided useful information in order to evaluate PAHs contamination in water and sediments of Allor River. In the water sample from the upstream, mid-stream and downstream, lower rings compounds (2-3 rings) were the most important pollutants. They were found in concentration several times higher than 4-6 rings (HPAHs). According to the ratios of Flouranthene/Pyrene and Phenanthrene/ Anthracene, the PAHs in all sediment samples originate from pyrolytic sources, while in water samples have different origins including pyrolytic and petrogenic sources. These findings underscore the severe pollution of the Allor River, suggesting a major impact on water quality and an increased risk to human health from potential exposure to these carcinogenic compounds associated with polycyclic aromatic hydrocarbons.

The results indicate that the river's contamination levels are reasonable enough to warrant immediate action to address the pollution sources and protect public health. The discrepancy between detected PAH levels and WHO guidelines illustrates a critical need for effective water management and pollution control measures. The presence of multiple PAHs, in all sample points (up stream, mid-stream and lower stream) emphasizes that PAHs contamination is a widespread issue affecting different sections of the river. Consequently, the data points to an urgent requirement for comprehensive preventive strategies and enhanced monitoring to ensure water safety and environmental protection.

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