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Polycyclic aromatic hydrocarbon contamination in water, sediments and aquatic life of Nigerian inland and coastal waters

Onome Augustina Bubu-Davies *, Benjamin Bameyi Otene and Mpakaboari Vellington Cephas Ebini

Department of Fisheries and Aquatic Environment, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria.

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Abstract

Background and Objective: Polycyclic aromatic hydrocarbons (PAHs) are a group of different chemicals that are formed during incomplete combustions of organic substances but few to be mention such as cigarettes, coal etc. They are usually found as a mixture containing two or more compounds such as soot. The emissions of PAHs in Nigeria have contributed significantly to the environment and live of aquatic organisms. Thus, this paper reviewed the contamination of polycyclic aromatic hydrocarbon (PAHs) in the water, sediments and organisms in inland and coastal waters.

Methodology: Literatures of relevant and previous studies of polycyclic aromatic hydrocarbons in the water, sediment and organism within and outside Nigeria were reviewed.

Results: The contamination of polycyclic aromatic hydrocarbons (PAHs) was known to be carcinogenic, mutagenic, teratogenic and can cause adverse effect on human health, wildlife and aquatic lives with no report on mammals in the aquatic environments.

Conclusion and Recommendation: Polycyclic aromatic hydrocarbons (PAHs) reviewed displayed different effects caused in the lives of human and aquatic organism based on the concentration level. Their sources were more of anthropogenic than natural source with varied concentrations at various source points due to different activities in question. The positive impact of polycyclic aromatic hydrocarbon on fish and other aquatic organisms as a result of bioconcentration, biotransformation and biomagnification become a threat to humans that rely on eighty percent of aquatic resources. Therefore, conceived efforts should be made to reduce these effects, general public monitoring of polycyclic aromatic hydrocarbon on discharge sources in the biosphere.

Keywords: PAHs; Pollution; Aquatic organisms; Aquatic environments; Nigeria

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled meat (1). PAHs are a class of organic compounds consisting of two or more aromatic ring fused together. They are found everywhere and mostly hydrophobic in nature, capable of bio-accumulating in animal and human tissues (2). Polycyclic aromatic hydrocarbons (PAHs) are classified as persistent organic pollutants commonly occurring in the environment and are considered to be one of the most difficult organic contaminants to treat (3; 4;2).

*Corresponding author: O. A. Bubu-Davies
Department of Fisheries and Aquatic Environment, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria.

Polycyclic aromatic hydrocarbons (PAHs) are toxic and pose a significant environmental risk to public health (5) and emitted during forest fires, volcanic eruptions, fossil fuels and wood combustion, industrial processes and cooking (6). In the atmosphere, these compounds undergo photochemical and chemical oxidation reactions with nitrogen oxides (NOX), atmospheric oxygen (O_2), sulfur oxides (SOX) and hydroxyl radical (OH) producing more toxic compounds (7). PAHs are also manufactured for use as pesticide, pharmaceutical and dye making industries (8). The presence of PAHs in the environment has increased over the years, where its concentrations may have stabilized globally due to recent air and water quality regulations (9).

Contamination is the introduction of unwanted substances by man into the environment in a very low concentration which is not toxic to biotic organism but change the natural structure (10). PAHs are contaminants which occur in all parts of the environment; atmosphere, inland and sea waters, sediments, soils and vegetation (11). (12) reported that the contamination of Polycyclic Aromatic Hydrocarbons (PAHs) in the environment is a serious environmental issue. Thus, PAH bioaccumulates in the environment hence, coastal and marine sediments become the ultimate sinks for such compound (13).

Fishes and other aquatic organisms are liable to environmental contaminants, PAHs thus raising a public health concern as it serves as essential food for body growth to human. Consequently, PAHs have short residence time in the water column due to volatilization and oxidation, and can quickly be eliminated from the system (14). However, deposited PAHs in the sediments are remobilized into water column and become available to fish and other aquatic organisms (15). Thus, the liphophilic nature of PAHs makes it easier to penetrate biological membranes and accumulate in organisms (16).

Inland waters of Nigeria are marked with two major rivers called River Niger/Benue and Chad systems. PAHs contamination and pollution were due to urbanization, industrialization and trade growth. Hence, few hence inland waters across the Niger Delta and few others drain directly into the Atlantic Ocean while other flowing waters at long last empty into the Chad Basin or down the lower Niger and then to the sea.

1.1. Structure of PAHs

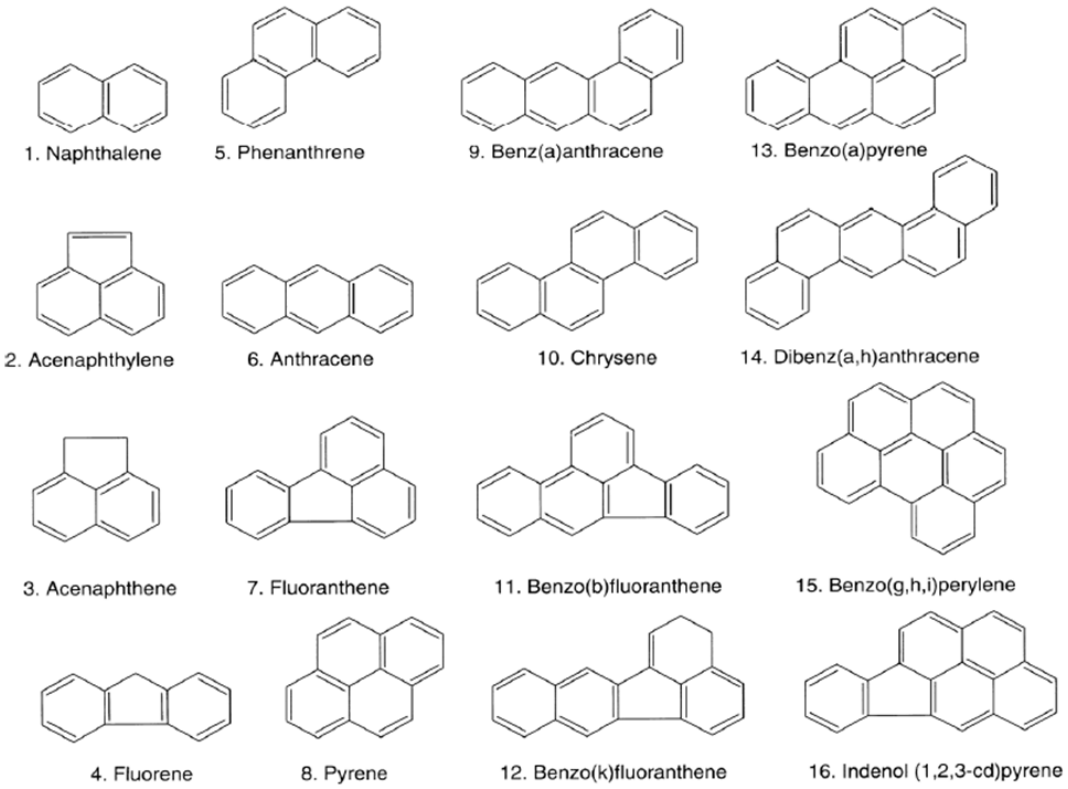

Figure 1 The structure of the sixteen (16) studied PAHs. Source: (17)

2. Sources of polycyclic aromatic hydrocarbon (PAHs)

There are two major sources of PAHs which include the natural sources and the anthropogenic sources.

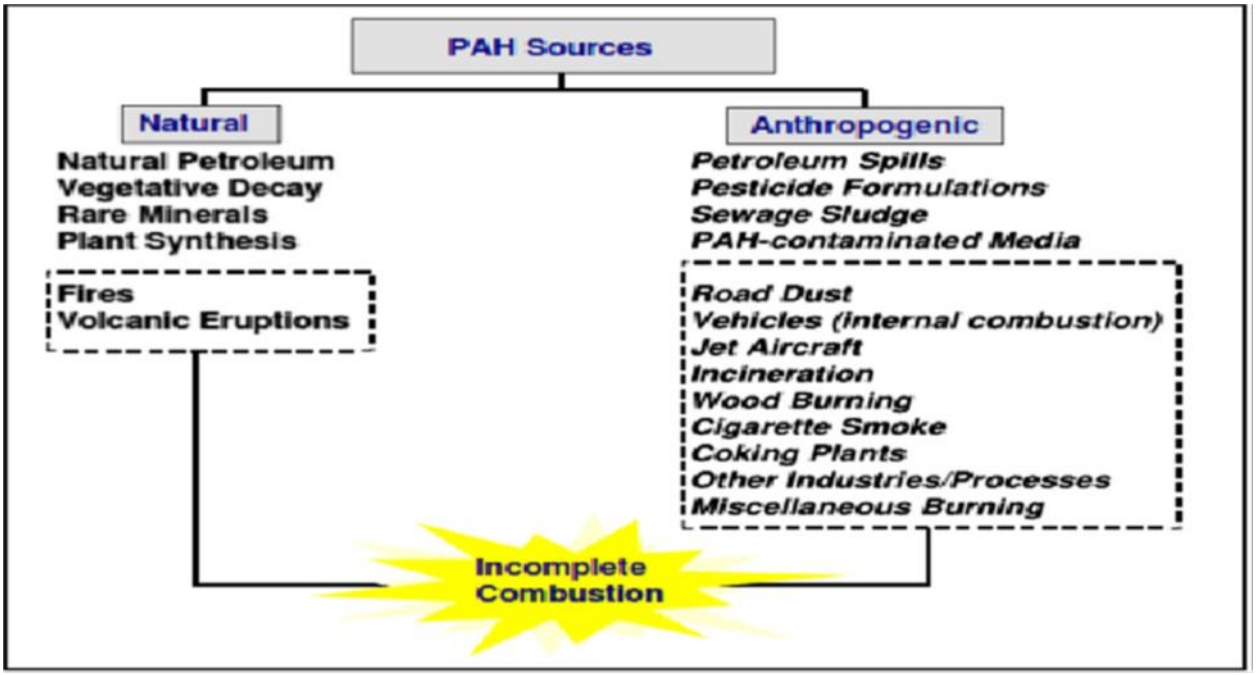

Figure 2 Natural and anthropogenic sources of PAHs

2.1. Natural sources

The natural sources are also known as pyrogenic; volcanoes and hydrothermal processes are natural emission sources of PAHs (18; 19; 20;21). PAH from forest fires and volcanic activities do not significantly contribute to the overall PAH emission (22; 23).

2.2. The anthropogenic sources of PAHs

There are techniques used to differentiate the different anthropogenic sources of PAHs (pyrogenic, petrogenic and pyrogenic) sources of PAHs, based on the amounts of relative molecular weight either high or low. According to (24) low molecular weight (LMW) PAHs compounds predominate in petrogenic sources while high molecular weight (HMW) compounds predominate in pyrogenic sources. These are subcategorised into;

2.2.1. Pyrolytic (pyrogenic)

PAHs are produced during incomplete combustion of fossil fuel, biomass burning, coal and organic matter (25). The formation of these compounds during gasification and combustion have been reported (26; 27).

2.2.2. Petrogenic

This is derived from slow maturation of organic matter under geothermal gradient conditions, petroleum spillage (28; 29; 30; 31).

2.2.3. Diagenetic

It is well known that PAHs are formed in large quantities as the result of secondary themochemical reactions at temperatures over 700^{o}C (32). Products derived from biogenic precursors (33; 24). Sources of environmental PAHs could be evaluated using ratio of different PAHs compounds (30).

3. PAHs Contamination

Contamination of PAHs in the world environments includes inland streams, rivers and marine environments has been reported by several authors (34; 35; 36; 37). PAHs are released into the environment in large quantities by various human activities and they may have additive or synergistic effects with other environmental contaminants (38). The deposition of contaminants led in the differences of PAHs distribution at different depth intervals (39).

3.1. PAHs in the Water

Aquatic ecosystems with high PAHs concentration might pose potential ecological risk, causing carcinogenic, mutagenic, and toxic effects on aquatic organisms (40). According to (41) body burden are present in high affinity for suspended particles in water and eventually go under the bottom sediments of rivers. The concentrations of different PAH fractions and the sum total of PAHs detected in different aquatic environment varies (42). PAHs decreases in water with increasing molecular weight with respect to its solubility (43, 44) resulting to its low concentration in water column (45). The hydrophobic nature of PAHs in surface water or groundwater indicates pollution (43).

Table 1 PAHs in some Nigeria inland waters

S/no.	Location	Level of PAHs	References
1.	Oburun Lake Bayelsa	Low	(1)
2.	Makurdi River	High	(46)
3.	Makurdi River	PAHs below maximum conc.	(46)
4.	Num River, Bayelsa State	Average	(47)
5.	Ekpan River, Delta State	Low	(48)
6.	Benue River	Low	(49)
7.	Warri River at Ubeji, Delta State	Low	(50)
8.	Lagos lagoon	High	(51)

3.2. PAHs in Aquatic Live

Aquatic lives such as fishes are extensively used for environmental monitoring as good indicators of water pollution (52,53). The concentration of PAHs in the aquatic environments appear to show seasonal variation on aquatic organisms which may be influenced by number of factors (54).

Some aquatic organisms precisely fish, can be exposed to PAHs depending on its formation and the ability to metabolize body burden in water and sediments. Thus, fish appears to be the most important source of animal protein, and provides over sixty percent of animal protein intake (55). (56) reported that pelagic fishes are susceptible to very low concentration of PAHs as compared to demersal fishes. Thus, PAHs accumulate in certain tissues with the highest proportions found in the liver of vertebrates or the hepato-pancreas of invertebrates (57). Lipid-rich tissues preferentially accumulate PAHs because of their strong hydrophobic nature (58). Food consumption has been identified as an important pathway of human exposure to many contaminants including PAHs (59).

Table 2 Contamination of PAHs is some fishes in Nigeria

S/No.	Location	Species	Level of PAHs	References
1.	Akure	*Clarias gariepinus*	High	(60)
2.	"	Croaker (*Pseudotolithus senegalensis*)	High	(60); (8)
3.	"	Mackerel	High	(60); (8)
4.	"	Jackfish	High	(60)
5.	Mushin, Lagos	O*. niloticus*	High	(8)
6.	"	Herring	Average	(8)
7.	"	Horse mackerel	Average	(8)
8.	"	Blue whitting	Average	(8)
9.	Bodo and Kaa rivers, Rivers State	Catfish *Chrysichthys nigrodigitatus*	High	(61)
10.	Qua Iboe River	Atlantic croacker (*Micropogonias undulatus*)	High	(62)
11.	"	Tilapia (*Oreochromis niloticus*)	High	(62)
12.	"	Yellow tail (*Seriolala landi*)	High	(62)
13.	Warri River at Ubeji, Delta State	*Tilapia zillii*, *Oreochromis niloticus* and *Hemiochromis fasciatus*	Low	(50)

Table 3 Aquatic life criteria for PAHs (µg/L)

PAH	Freshwater (chronic)	Freshwater (phototoxic)
Naphthalene	1.00	NR
Acenaphthene	6.00	NR
Fluorene	12.00	NR
Phenanthrene	3.00	NR
Anthracene	4.00	0.10
Pyrene	NR	0.02
Fluoranthene	4.00	0.20
Benz[a]pyrene	0.01	NR

Source: (63)

3.3. PAHs in the Sediment

PAHs in sediment have been studied extensively around the world and many of them show temporal trends corresponding to the vertical distributions in sediment (64-66). Polycyclic aromatic hydrocarbons (PAHs) are found in all compartments of the environment and tend to adsorb to aquatic sediments (67-68). Polycyclic aromatic hydrocarbons (PAHs) tend to be attracted to stable particles in the water which settles in the sediment and thereafter,

remobilized into water column and become available to fish and other aquatic organisms(15). The bottom sediments is the habitat of many aquatic organisms and are known as potential reservoir of petroleum hydrocarbons in marine environments, posing risk of bioaccumulation (69; 70). Fluoranthene is one of the high molecular weight PAHs that resist biodegradation and tend to accumulate in sediment (71).

However, some fish species can be exposed to PAHs present in the sediments and the PAH level of concentration trust greatly on the ability of the aquatic organisms to metabolize them (72).

Table 4 Contamination of PAHs in the sediments of Nigeria waters

S/no.	PAHs	Location	Level of PAHs	References
1.	All PAHs	Ethiope River Delta State	Low	(73)
2.	Naphthalene, (Acy), (Ace), etc	Warri River at Ubeji, Delta State	High	(50)
3.	Anthracene, Fluoranthene, [2H12] and [2H10]	Sediments from Imo River	High near the fish settlement (study area)	(74)
4.	PAHs	Makurdi River	High	(75)
5.	Acenaphthene, fluoranthene, 2-Methylnaphthalene and naphthalene	Benue River	Low	(49)

4. Uses of PAHs

The major emission of PAHs is the incomplete combustion of organic matter which includes coal, oil and wood etc. They are mostly used as intermediaries in pharmaceutical, agricultural product, photographic products, thermosetting plastic, lubricating materials, and other chemical industries (76). Some uses of PAHs are presented in Table 5.

Table 5 Summary of some PAHs and their uses

S/No.	PAHs	Uses
1.	Acenaphthene	Manufacturing of dyes, plastic, diluents, pharmaceutical and Pesticides, processing of certain foods, pigments and diluents For wood preservatives.
2.	Anthracene	It is used in the manufacture of some dyes and the wood preservative creosote.
3.	Chrysene	Manufacture of dyes, pharmaceuticals and agrochemicals, it is also use as a fumigant in households, soil museum etc
4.	Fluorene	To repel moths/ insects attacks
5.	Naphthalene	Manufacture of pesticides and resins
6.	Phenanthrene Pyrene	Manufacture of pigments

Source (76)

5. Effects of PAHs

There has been alarming awareness on the concern of PAHs to human health, even at minute concentration. They tend to increase over time because they are known to be carcinogenic, mutagenic, teratogenic and can cause adverse effect on human health, wildlife and aquatic lives as in Table 6. Aquatic organism bio-accumulate PAHs because they have membranes that are easily penetrated by PAHs due to their lipophilicity. Hence, dietary intake of PAHs via fish and water is a public health concern (77). Adverse effects of PAHs were also observed in human and aquatic organisms which include growth reduction (78), endocrine alteration (79), malformations of embryo and larvae (80-81) and DNA damage (82).

Table 6 Effects of PAHs on health

S/No.	PAHs	Effects	References
1.	Anthrancene	Toxic, skin sensitizer, eye irritation, nausea, vomiting, diarrhea and confusion.	(83)
2.	Acenaphthylene Benzo (a) anthrance Benzo(a)fluoranthene	Toxic, eye irritation. Toxic, carcinogenic, heart malformations, childhood asthma, skin irritations.	(76) and (84)
3.	Pyrene	Toxic	(69)
4.	Benzo(a)pyrene	Toxic, eye irritation	(69), (84)
5.	Benzo(j)fluoranthene Benzo(b)fluoranthene Napththalene	Toxic, carcinogenic, tumors of the gastrointestinal tract and lungs	(76), (84) and (69)
6.	Dibenz(a,h)anthracene	Toxic, tumors of the breast, lungs, toxic, carcinogenic, skin irritants, breakdown of red blood cells, heart malformations, childhood asthma, eye irritation, nausea, vomiting, diarrhea and confusion.	(69)

6. Conclusion

This article reveals that anthropogenic sources of polycyclic aromatic hydrocarbons (PAHs) release greater volume than natural sources of PAHs. Automobile, industries, vehicles, cooking (electric appliances and gas burning) and cigarettes emissions are the major sources of PAHs. PAHs can be transported long distances in the atmosphere and removed from it through precipitation and dry deposition and final end point of PAHs is transported into surface waters by volatilization and erosion of PAHs bonded particulate materials in biosphere.

6.1. Recommendations

- Nigeria government should set up a regulatory standard that are relevant to PAHs exposures in the environments.
- Government should establish ambient water quality criteria to protect aquatic live and human health from the effects of PAH exposure.
- Filtration of industrial emissions should be taken into account.
- Treatment of industrial effluents must be carried out strictly, particularly Nigeria and other developing countries.
- Rural and urban enlightenment programme on the awareness of PAHs toxicity in aquatic organism, human health and the environments is of importance.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be declared.

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