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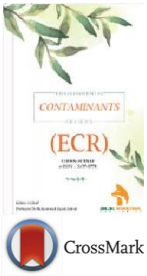

REVIEW ARTICLE

PROFILE COMPOSITION AND RISK EVALUATION OF PAHS IN BOREHOLE WATER FROM AMASSOMA, BAYELSA STATE, NIGERIA

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ABSTRACT

Water is an essential and indispensable natural resource. The most important to human endeavors, ecosystem and all living things. Thus, this study was carried out to determine the levels of concentration of sixteen (16) priority pollutants (PAHs) in borehole water from Amassoma, Bayelsa state. The PAH concentrations in the borehole water samples was performed using GC–MS method. The total PAHs concentration ranged from 0.003 – 0.364mg/l with a mean value of 0.132mg/l. Dibenzo(a,h)anthracene had the highest individual PAH concentration of 0.164mg/l. PAH accumulation in the environment and Toxic equivalency factor (TEF) used to estimate relative toxicity of a PAH compared to that of BaP, principal component analysis and pearson's correlation was employed. Pearson correlation matrice analysis reveals a positive correlation between the PAHs; this could indicate a common source for some of the PAHs, however, some were negatively correlated with each other. This behavior could indicate non-point source. Six principal component accounting for 88% of the entire variance were extracted. A comparative analysis of PAHs concentrations in the water samples with maximum allowable concentration (MAC) standards revealed that the results obtained in this study were within the permissible levels except for Ind(1,2,3-cd) P and DbahA, however, carcinogen PAHs present in the water of the Amassoma axis, Nun River may pose a threat to human health. PAH fingerprint ratios for determining both petrogenic and pyrogenic (pyrolytic) PAH accumulation such as (Ant/(Ant+Phe), BaA/(BaA+Chr), and ∑LMW/∑HMW) ratios was employed. The PAH diagnostic ratio indicates that within the Amassoma Town was of mixed ratios, petroleum (petrogenic) and combustion (pyrogenic) sources and grass/wood/straw combustion sources. This is a clarion call on policy makers and necessary regulatory authorities to step up.

KEYWORDS

Natural Resource, Dibenzo(A,H)Anthracene, Toxic Equivalency, Negatively

1. INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous and are part of several organic contaminants which might be chronic in the surroundings, have lengthy transport capability and may cause destructive environmental effects (Gao and Zhu, 2004; Layshock et al., 2010). A number of them are prone to dispersion on a international scale due to the fact, similarly to having environmental endurance, they may be "semi-risky", i.e. Environmental situations they flow between the ecosystem and the earth's floor in repeated, temperature-pushed cycles of deposition and volatilization (Farshid et al., 2011). PAHs are sincerely multimedia contaminants which occur in all elements of the environment: ecosystem, inland and sea waters, sediments, soils and flora (Sexton et al., 2011).

safe consuming water is one of the maximum vital primaries wishes of people universally. Many groups faucet into the closest water source in their location, whether it's far groundwater through a borehole or surface water consisting of a river (Oduko The protection of consuming water is consequently very critical and wishes to be well monitored. In most growing nations, surface and ground water are the primary assets of water for all fundamental desires. These water sources also are effortlessly prone to contamination by way of anthropogenic sources consisting of household waste (HHW), municipal waste dumps, agricultural runoff and commercial waste, among different pollution sources (Han et al., 2013). The degree of pollutants from any of these assets is depending on environmental management, waste management practices and environmental safety laws in every region. Of the couple of culprits of water pollutants, municipal dumpsites are one of the well-studied and documented resources. In developing nations, most municipal dumpsites (MD) are unplanned, open dumpsites (OD) with little to no engineering measures to shield the environment. Open dumpsites are the only and to start with the cheapest technique of waste disposal, and they are the number one manner of waste control in lots of developing countries (Taylor and Allen, 2006).

The price of remediating these websites can exceed the value of preserving an open dumpsite and the environmental harm can take decades to be ameliorated (Kurian, 2002). Additionally, the risks of open dumpsite move past the environmental effect and can result in poor fitness results which include most cancers (ATSDR, 2009). Sanitary landfills are an development to the OD waste control machine due to the fact they have an engineered, protective floors layer which could prevent the infection of groundwater. therefore, communities close to open dumpsites are at a excessive risk of getting infected water and sizable poor health results (Taylor and Allen, 2006). Common chemical pollution observed within the groundwater around open waste dumpsites are dependent on

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components of disposed waste, and the byproducts of the natural degradation of waste products. Waste with harmful byproduct includes paints, inks, plastics, electronics, pesticides, fuel, kerosene, and heating oil. Byproducts and pollution may inorganically metals, volatile natural compounds (VOCs), furans, dioxins, polycyclic aromatic hydrocarbons (PAHs), chlorinated solvents and greater humans can consequently be uncovered to those pollutants through dermal absorption, ingestion of infected water, inhalation of poisonous fumes and thru the meals chain (ATSDR, 2009; Iwegbue et al., 2010).

Moreover, industrialization and the fast urbanization of towns in each developed and growing countries pose multiple problem for environmental safety. The unexpected, urbanized cities, the quantity of waste produced can exceed the capacity of a state or a country waste control machine, mainly out of control or inefficient waste management (Taylor and Allen, 2006). Although majority of the research on water contamination in growing countries has targeted on infection due to microorganism pollutants and inorganic contaminants, organic chemical contamination is unmistakably an essential issue that wishes more attention.

Monoaromatic hydrocarbons (MAH) and polycyclic aromatic hydrocarbons (PAHs) are acknowledged to be poisonous compounds, bronchopulmonary and cutaneous irritants, with risks of carcinogenicity and mutagenicity (Disdier et al., 1999). Cases of cutaneous, bronchopulmonary and vesical tumors have been related with aromatic hydrocarbons. The degree of risk depends on the compounds, benzo[a]pyrene is proven to be the maximumly poisonous The most poisonous hydrocarbons and pollutants tracers are pyrene, chrysene, benzanthracene, benzo[a]pyrene, fluoranthene, benzo[k]fluoranthene and indeno-1,2,3-pyrene (Disdier et al., 1999; IARC, 1983; INRS, 1992).

The toxic equivalency factor (TEF) is the carcinogenic efficiency of individual PAHs relative to benzo[a]pyrene (Bap). When a combination of chemical substances with the equal mechanism of action is encountered, the awareness of every chemical is measured and extended by means of its TEF value. The results are then added to offer the toxic equivalent quantity (TEQ) value of the mixture. Regulatory agencies in the united states of America, Europe, New Zealand and Canada have endorsed use of the TEQ approach (Orecchio and Papuzza, 2009; Carlon, 2007; Cavanagh, 2006; CCME, 2008).

2. Persistence of PAHs

PAHs include two or more fused benzene and/or pentacyclic rings in linear, angular or cluster arrangements. Relying on the number of rings, PAHs have been categorized into low molecular weight (LMW, containing 3 or fewer rings) and high molecular weight (HMW, containing four or more rings) PAHs. The high hydrophobicity and chemical stability of PAHs lead them to persist inside the surroundings. Their hydrophobicity generally will increase with increasing molecular mass, with aqueous solubility declining from the low mg/l variety for LMW PAHs to approximately 1µg/l for HMW PAHs (Kastner, 2000; Blumer, 1975; Wilson and Jones, 1993; Chauhan et al., 2008). The sixteen PAHs listed in US EPA priority pollution are shown in Figure 1.

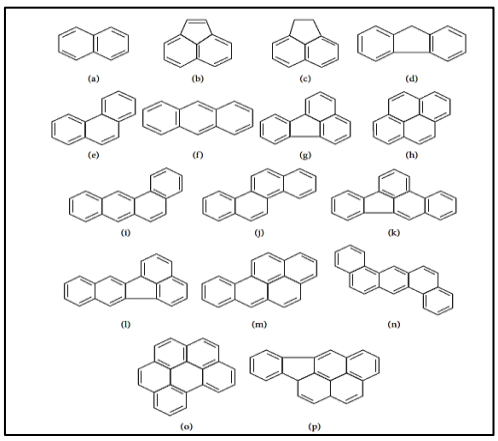

Figure 1: Chemical structure of the 16 PAHs listed in US EPA priority pollutants: (a) naphthalene; (b) acenaphthylene; (c) acenaphthene; (d) .uorene; (e) phenanthrene; (f) anthracene; (g) .uoranthene; (h) pyrene; (i) benzo(a)anthracene; (j) chrysene; (k) benzo(b).uoranthene; (l) benzo(k).uoranthene; (m) benzo(a)pyrene; (n) dibenzo(a,h)anthracene; (o) benzo(g,h,i)perylene; (p) indeno(1,2,3-cd)pyrene. SOURCE: Mahgoub, 2019

PAHs are present in environmental matrices in trace quantity and because of their lipophilic properties, they show excessive affinity for organic matter. The behaviour and toxicity of individual PAHs in the environment depend on their size, and the smallest ones (much less than three benzene rings) are extra soluble in water and might break down fast through dissolution, volatilisation, and microbial degradation which cause them to acutely toxic to fish and aquatic organisms (Greer et al., 2012). PAHs with three to five benzene rings are less water soluble and acquire in the tissues of aquatic organisms and stick with solid debris. Larger-length PAHs (greater than five benzene rings) do not break down quick and can persist for years specially in sediments (CCME, 2008). Some of these large compounds are acknowledged to cause cancer and affect DNA. More than one hundred PAHs have been characterized in nature, and sixteen of which have been classified as precedence pollutants because of their huge distribution and toxicity (Figure 2) (ATSDR, 2006). The U.S. Environmental Protection Agency (USEPA) has categorized PAHs into three groups primarily based on their carcinogenic tendencies (Figurer 2) Group B2 consist of substances that are probably human carcinogens, group C contains substances with possible carcinogenic effects in humans, and group D contains substances not classifiable as to human carcinogenicity. The aim of this study was to evaluate the content of PAHs in borehole water used within Amasoma, Niger Delta University and it's environ to estimate the contribution of these waters as source of PAHs exposure to humans.

3. Materials and Methods

3.1 Description of Study Area

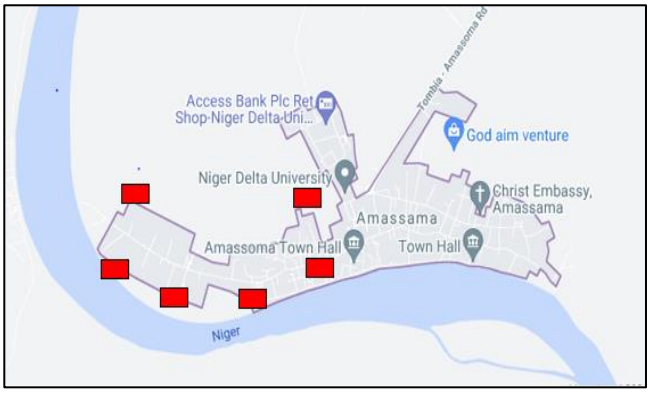

Figure 2: Study area showing sampling locations

The Amassoma lies between the coordinates of latitude 50 150N and longitude 60 05' E - 60 15'E. Amassoma is a big town in Southern Ijaw local government area of Bayelsa State, Nigeria. It is home to the Niger Delta university. The town is situated 30 km away from Yenagoa, Bayelsa State capital. The vegetation is freshwater swampy wooded area. Relative humidity is (83%) and the soil is freshwater alluvial type with a high ability for water retention. Farming and fishing are the two foremost occupations of the locals and the main food crops are plantain and cassava. Major sources of domestic water supply within the town and environ are personal owned boreholes.

3.2 Sample Collection

The water samples have been accumulated from six different boreholes located in Amassoma and its environs. The boreholes were carefully selected and are located at main Campus, New site, Ogobiri, End Pele, Tantua, and Town Hall. The water samples were collected with 500mL glass bottle fitted with aluminium foils to prevent contamination and appropriately. For each borehole, three water samples were collected. Water samples collected during the first five minutes of pumping was discarded. All water samples have been transported to the laboratory and kept at 4°C in sealed bins prior to PAHs analysis.

3.3 Extraction of PAHs in Water Samples

250mL of each water sample was transferred into a isolating funnel. The pH was adjusted to < pH 2. The solution was then extracted twice with 15ml methylene chloride. The extract become dried with 5g anhydrous sodium sulfate and concentrated to 1ml in rotary evaporator. 50mL of hexane became delivered and the pattern extracted again all the way down to 1mL. The concentrate was fractioned, first eluted with 10mL hexane, and accrued as aliphatic fraction, observed with the aid of elution with 15mL methylene chloride, and accumulated as aromatic fraction. each fraction concentrated to 1mL and stored capped in GC vials.

3.4 Gas Chromatography Analysis

Evaluation became accomplished with Perkin model 5890 gasoline chromatograph prepared with Ni sixty-three electron seize detector. Nitrogen was used as a carrier gas at a flow rate of 40ml/s. Information obtained had been processed using Hewlett Packard 3396 integrator. The operating parameters were as follows; injector temperature set at 250°C and three hundred°C for the detection, the oven temperature programmed at 150°C to begin with (5 min hold) and then increased to 300°C at 4°C/min to present the analysis a period of 34min. Water samples had been extracted in step with the installed fashionable procedures (Obiakor et al., 2014).

3.5 PAH Diagnostic Ratios for Source Apportionment

The following PAH diagnostic ratios (ΣLMW/ΣHMW, Ant/(Ant+Phe, Fla/(Fla+Pyr, BaA/(BaA+CHR) were applied on the data acquired from the GC/MS analysis (table 1). They allow to distinguish among PAH pollution originating from petrogenic (liquid fuels spills), pyrolytic (combustion of fuels) and burning biomass or coal resources (Tobiszewski, 2014).

Table 1: Characteristic diagnostic ratios values for particular pollution emission

Diagnostic Ratio	Pretrogenic	Fuel Combustion	Coal, Grass, Wood Burning
ANT/(ANT+PHE)	<0.1	>0.1	
FLA/(FLA+PYR)	<0.4	0.4-0.5	>0.5
BaA/(BaA+CHR)	<0.2	>0.35	0.2-0.35
IcdP/(IcdP+BghiP)	<0.2	0.2-0.5	>0.5

ANT – anthracene; BaA – benzo[a]anthracene; BghiP – benzo(ghi)pyrene; CHR – chrysene; FLA – fluoranthene; IcdP – indeno(cd)perylene; PHE – phenanthrene; PYR – pyrene.

The ratio of LMW PAHs/HMW PAHs < 1 indicates pyrogenic sources including incomplete combustion of fossil fuels or wood and that > 1 alerts petrogenic assets including spilled oil or petroleum products (Wang et al., 2017).

4. Results and Discussion

The presence of PAHs and their concentrations were decided in the water samples gathered from the numerous sampling locations of Amassoma town, Bayelsa State. Fourteen (14) out of the 16 PAHs recognized as priority pollutants had been detected. The full PAH concentration in every sampling vicinity was additionally determined. The results are presented in Table 2, while the distribution of individual PAHs, sum of PAHs in each site and compositional profile in the water samples are also graphically presented in Figure 3-4. The sum of PAHs ∑PAHs, the highest concentration was detected in new site, NDU followed by Main Campus, NDU in descending order: Ogobiri> Town Hall> Tantua> Ending Pele. The 2-3 rings PAHs, Nap, Acy, Ace were not detected in Main campus, NDU, similarly, Nap, Acy, Ace, and Flu were not detected at Ogobiri. PAHs were detected at all the sampling places and the total PAH concentrations on the numerous sampling sites ranged from 0.003mg/l to 0.346mg/L.

New web site had the highest concentration of PAHs (0.346mg/l), at the same time as Ending Pele had the lowest. Dibenzo (a, h) anthraces was the highest occurring individual PAH (0.164mg/L) at the same time fluorene was the lowest occurring individual PAH (0.0000215mg/L). Naphthalene concentrations ranged from 0.0000811 to 0.01008mg/L and was not detected at Main Campus and Ogobiri. Acenaphthylene and acenaphthene was not detected at the main campus and Ogobiri. Fluorene was not detected only in Ogobiri. The low molecular weight PAHs with 2 to 3 aromatic rings are mainly from petrogenic sources at the same time as the PAHs of high molecular weight, those with 4 to six aromatic rings, are mainly from pyrogenic assets (Cao et al., 2019). In this study, the high molecular weight PAHs (4 – 6 ring PAHs) were dominant over the low molecular weight PAHs (2 – 3 rings PAHs). This could indicate that the PAHs detected may be from pyrogenic sources.

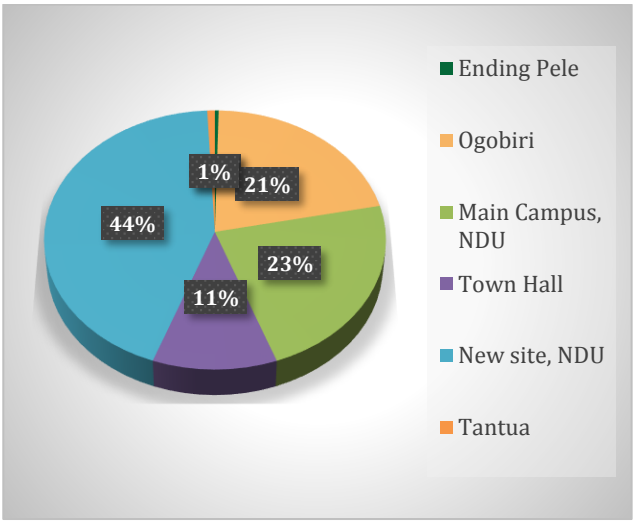

Figure 3: Distribution of total PAHs concentration insampling locations

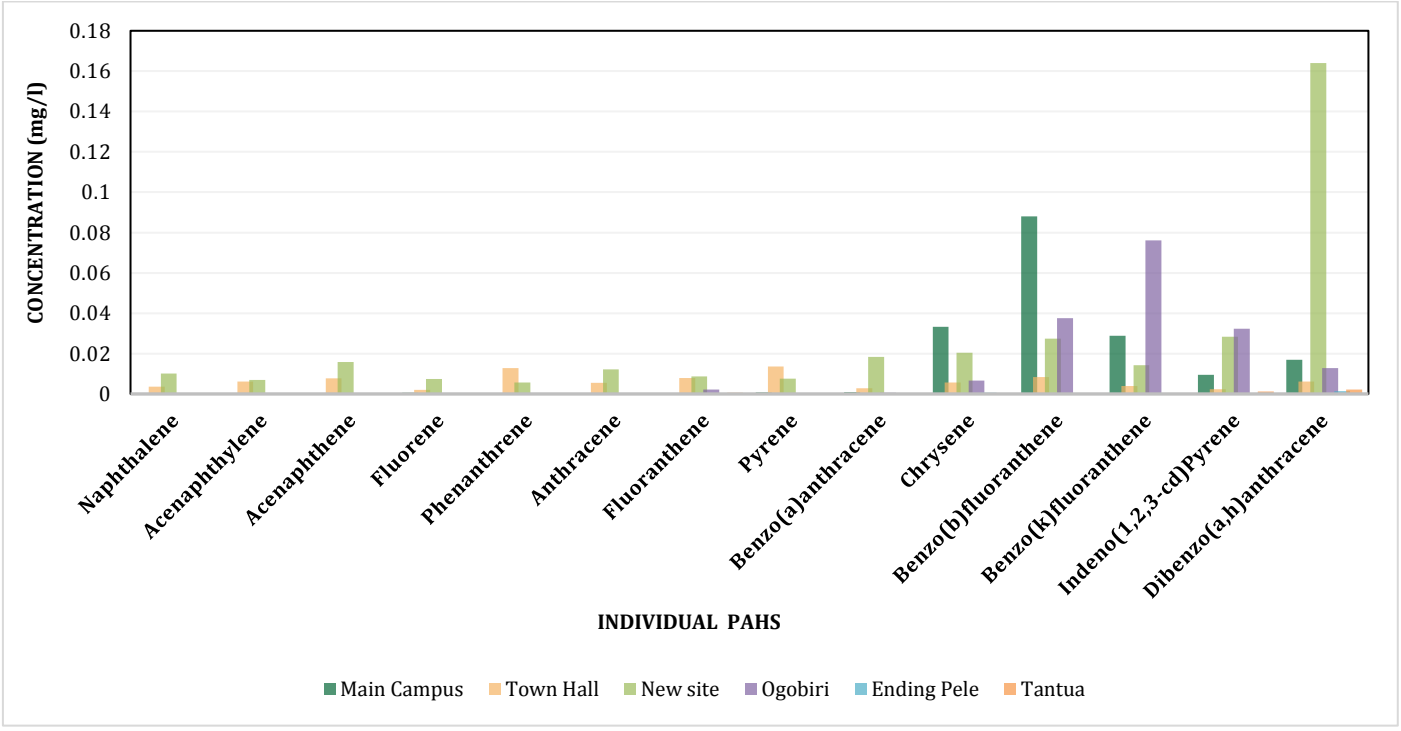

Figure 4: Distribution of Individual PAHs in water samples

Table 2: Distribution of individual PAHS in water samples

S/N	PAHs	No of Rings	Main Campus	Town Hall	New Site	Ogobiri	Ending Pele	Tantua
1	Nap	2	-	0.00367	0.01008	-	0.0000811	0.000395
2	Acy	3	-	0.00621	0.00690	-	0.000203	0.000139
3	Ace	3	-	0.00774	0.0158	-	0.0000357	0.0000360
4	Flu	3	0.000673	0.00198	0.00748	-	0.0000215	0.000199
5	Phe	3	0.000306	0.0128	0.00572	0.000160	0.0000627	0.000417
6	Ant	3	0.000356	0.005509	0.0122	0.000512	0.000127	0.000115
	TOTAL LPAHs		**0.001389**	**0.037909**	**0.05818**	**0.000672**	**0.0007245**	**0.00301**
7	Fla	4	0.000276	0.00789	0.00867	0.00216	0.000147	0.000630
8	Pyr	4	0.000727	0.0137	0.00758	0.000506	0.0000806	0.000243
9	BaA	4	0.000987	0.00283	0.0184	0.000589	0.0000499	0.0000853
10	CHy	4	0.0333	0.00565	0.0205	0.00664	0.000619	0.000134
11	BbF	5	0.0881	0.00846	0.0274	0.0376	0.000150	0.000360
12	BkF	5	0.0288	0.00394	0.0143	0.0761	0.0000804	0.0000466
13	DahiA	5	0.0170	0.00614	0.164	0.0128	0.00138	0.00216
14	In(1,2,3)P	6	0.00949	0.00229	0.0283	0.0324	0.000350	0.00129
	TOTAL HPAHs		**0.17868**	**0.0509**	**0.28915**	**0.168795**	**0.0028569**	**0.0040489**
	Sum of PAH ($\sum$***PAHs***)		**0.1800**	**0.08881**	**0.34733**	**0.16947**	**0.003388**	**0.00625**

The 16 PAHs had been divided consistent with the range of rings. those groups included two to three ring structures or light PAHs (Nap, Acy Ace, Fla, Phe, Ant, and Flu), 4 ring structures or medium PAHs (Pyr, BaA, Chr, BbF, and BkF) and 5 to six ring structures or heavy PAHs (BaP, DBA, InP, and BP). In this study, polycyclic aromatic hydrocarbons had been detected in all of the sampling sites of the town. According to the results, the low molecular weight (2-3 ring) or light polycyclic aromatic hydrocarbons (LPAHs) in water samples of Amassoma were lower than high molecular weight, 4-6 ring structures (HPAHs) . The sum of PAHs (∑PAHs) for LPAHs and HPAHs for the six sampling sites ranged from 0.001389-0.05818 mg/L and 0.002857-0.28915mg/L with mean values of 0.0169mg/L and 0.1157mg/L respectively.

This shows that water in Amassoma won't be too secure for human intake. Particularly the high values observed for HPAHs is worrisome and could be as result of anthropogenic activities, ranging from illegal refining of petroleum products and spillage in the area. The high levels of HPAHs throughout the sampling sites could even be due to the unregulated waste dumping by individuals and other sources. Polycyclic aromatic hydrocarbons of low molecular weight 2-3 ring structures are generally lost because of microbial degradation and volatilisation while large molecular weight compounds 4-5 ring structures wander off as a result of photo-oxidation and maybe attached to the underlying sediments (Mastran et al., 1994; Miller and Olejnik, 2001; Obiakor et al., 2014).

Amassoma is a non-industrialized place, apart from the slight industrial activities such as filling stations, schooling institutions among others, the presence of PAHs in appreciable concentrations could be hypothetically linked to atmospheric deposition considering the fact that Amassoma is surrounded by different industrialized cities like Warri and Port Harcourt. Weather variables and wind dispersion maybe good delivery source of the materials and come to be deposited at non-impact regions. Precipitation is a superb climatic pathway of PAH enter into the aquatic surroundings (Franz and Eisenreich, 1998; Obiakor et al., 2014). Comparison with previous studies, distribution of polycyclic aromatic hydrocarbons Woji Creek, in the Niger Delta [46], and polycyclic aromatic hydrocarbons in water samples from a Nigerian bitumen seepage: gasoline chromatography- mass spectrometry quantification, are similar environments, the concentration measured in this study were lower (Itodo et al., 2018).

4.1 Source of PAHs

The petroleum and combustion are the principal anthropogenic resources of PAHs within the Amassoma and its surroundings. Generally, low-molecular weight PAHs are more likely to come from petroleum, while the high molecular weight PAHs are much more likely to come from combustion. PAHs emitted from different sources showcase distinctive molecular compositions. There are numerous PAH source resolution methods proposed, however, the isomer ratio method is one of the most frequently or commonly used (Cao et al., 2019). The PAH diagnostic ratio proposed by and has been used by diverse people in their research suggest that a ratio of Flu/(Flu + Pyr) between 0.40–0.50 indicated that PAHs are specially derived from petroleum combustion, while less than 0.40 indicated an oil source, and greater than 0.50 indicated a coal and biomass combustion source (Yunker et al., 2002). An Ant/(Ant + Phe) ratio of less than 0.1 suggests that the supply is petroleum, and a ratio greater than 0.1 shows that the supply is combustion. The BaA / (BaA + Chr) ratio turned into between 0.2–0.35 for petroleum combustion sources, while less than 0.2 for petroleum sources, and greater than 0.35 for combustion sources. The InP/(Inp + BP) ratio became among 0.2–0.4 for petroleum combustion sources, less than 0.2 for petroleum sources, and higher than 0.4 for combustion sources (Table 4). According to this study, the PAH sources resolution methods, and the isomer ratio method indicates pyrogenic origins of the PAHs.

4.2 Correlation Between PAHs

Statistical multivariate methods were used to study the data by considering the objects and the determined parameters as variables, by constructing a Pearson's correlation matrix (PCM) and the facts offered in Table 3. The PCM analysis furnished a method of statistically ascertaining the affiliation/correlation of one parameter with another. PCM analysis well-known shows a high-quality correlation between the PAHs; this will imply a commonplace supply for a number of the PAHs, however, very few of the PAHs are negatively correlated with each other. This conduct could imply non-point source.

Table 3: Pearson correlation of PAHs in water from Amassoma

PAHs	FLA	PYR	BaA	CHY	BbF	BkF	DghiA	INP	TOTAL HPAH	Sum of PAHs
FLA	1									
PYR	1.00	1								
BaA	0.632	0.632	1							
CHY	0.221	0.221	0.349	1						
BbF	-0.188	-0.188	0.004	0.906	1					
BkF	-0.367	-0.367	-0.155	0.274	0.516	1				
DghiA	0.640	0.640	0.993	0.456	0.136	-0.101	1			
InP	0.175	0.175	0.610	0.446	0.403	0.687	0.645	1		
Total HPAH	0.364	0.364	0.732	0.782	0.630	0.438	0.798	0.876	1	
Sum of PAHs	-0.194	-0.194	-0.306	0.642	0.816	0.767	-0.200	0.374	0.412	1

4.3 Human Health Risk Estimations

Table 4: Maximum Allowable Concentrations (MACs) of PAHs in Water (ppm)

PAHs	TEFs	MAC
Nap	0.001	3.0
Acy	0.001	3.0
Ace	0.001	3.0
Flu	0.001	3.0
Phe	0.001	3.0
Ant	0.01	3.0
Fla	0.001	3.0
Pyr	0.001	3.0
BaA	0.1	0.005
Chy	0.01	-
BbF	0.1	0.005
BkF	0.1	-
BaP	1.0	0.005
InP	0.1	0.005
DibA	1.0	-
BghiP	0.01	3.0

(Sources: ATSDR, 2006; IARC, 2010; Mahgoub, 2019; Yang et al., 2014)

PAHs have unfavourable health consequences from brief- or long-term human exposure through breathing and/or skin touch in atmospheric environment (Kim et al., 2013)

The TEFs, first introduced for figuring out the carcinogenic potencies of individual PAHs BaP_{teq} with the aid of multiplying the PAH concentration within the pattern by the individual toxicity equivalency (TEF) and has been used by numerous people in their research (Nisbet and LaGoy, 1992; Karyab et al., 2013; Leizou and Muhammad, 2019; Tongo et al., 2017). The TEF is an estimate of the relative toxicity of individual PAH fractions compared to benzo(a)pyrene. Toxic equivalency elements had been implemented as a beneficial tool for the regulation of compounds with a common mechanism of actions (e.g PAHs). The results revealed that the mean PAHs concentration as BaP equivalent was in the range of $7.10E^{-5}$ – 0.09241mg/L in the water samples. The potential health threat assessment of PAHs may be evaluated primarily based on the toxic equivalency factors (BaPeq) (Li et al., 2016). Comparison of this study with most allowable concentrations (Table 4) of PAHs (MAC) in water(ppm) proposed by ATSDR, 2006 and IARC, 2010 it was revealed that the concentrations of this study were lower.

Table 5: Inhalation Unit Risk (IUR) Formula and Physicochemical Properties of the Studied PAHs Adopted from (Byambaa et al., 2019)

PAH Species	Abbreviation	Chemical Formula	mw, g/mol	RINGS	MW, GROUP	IμR $(\mu gm^{-3})^{-1}$
Naphthalene	Nap	$C_{10}H_8$	128.2	2	LMW	3.4×10^{-5}
Acenaphthene	Ace	$C_{12}H_{10}$	154.2	3	LMW	1.1×10^{-6}
Fluorene	Flu	$C_{13}H_{10}$	166.2	3	LMW	1.1×10^{-6}
Phenanthrene	Phe	$C_{14}H_{10}$	178.2	3	LMW	1.1×10^{-6}
Antracene	Ant	$C_{14}H_{10}$	178.2	3	LMW	1.1×10^{-5}
Fluoranthene	Fla	$C_{16}H_{10}$	202.3	4	MMW	1.1×10^{-6}
Pyrene	Pyr	$C_{16}H_{10}$	203.3	4	MMW	1.1×10^{-6}
Benz(a) anthracene	BaA	$C_{18}H_{12}$	228.3	4	MMW	1.4×10^{-4}
Chrysene	Chr	$C_{18}H_{12}$	228.3	4	HMW	1.1×10^{-5}
Benzo(b) fluoranthene	BbF	$C_{20}H_{12}$	252.3	5	HMW	1.1×10^{-4}
Benzo(k) fluoranthene	BkF	$C_{20}H_{12}$	252.3	5	HMW	1.1×10^{-4}
Ben(a) pyrene	BapP	$C_{20}H_{12}$	252.3	5	HMW	1.1×10^{-3}
Dibenzo(a, h) anthracene	DbA	$C_{22}H_{14}$	278.4	5	HMW	1.1×10^{-3}
Benzo(ghi) perylene	Bpe	$C_{22}H_{12}$	276.3	6	HMW	1.1×10^{-5}
Indeno(1, 2, 3-cd) pyrene	Inp	$C_{22}H_{12}$	276.3	6	HMW	1.1×10^{-4}

Table 6: Carcinogenic classifications of selected PAHs in airborne materials (PAHs data from (Hossain and Hossain, 2019)

ORDER	AGENCY	PAH COMPOUNDS	CARCINOGENIC CLASSIFICATION	REFERENCES
1	Agency for Toxic Substances and Disease Registry (ATSDR)	Benzo[a]anthrancene	Known animal carcinogens	ATSDR, 1995
		Benzo[b]fluoranthene		
		Benzo[a]pyrene		
		Dibenzo[a,h]anthrancene		
		Indeno[1, 2, 3-cd]pyrene		
		Benzo[a] anthrancene	Probably carcinogenic to humans	
		Benzo[a]pyrene		
2	International Agency for Research on Cancer (IARC)	Benzo[a]fluoranthene	Probably carcinogenic to humans	IARC, 2010
		Benzo[k]fluoranthene and		
		Indeno[1, 2, 3-cd]pyrene		
		Chrysene		
3	US Environmental Protection Agency (USEPA)	Benzo[a]anthracene	Probably carcinogenic to humans	USEPA, 2008
		Benzo[a]pyrene		
		Benzo[b]fluoranthene		
		Benzo[k]fluoranthene		
		Chrysene		
		Indeno[1, 2, 3-cd]pyrene		

But atmospheric PAHs are partitioned among particulate matter and fuel segment (Table 5-6), they may be commonly related basically with particulate number. Moreover, particulate PAHs are taken into consideration to be huge dangerous substances to human health through inhaling due to their extended residence time within the natural environment. Especially, BaP has been identified as being tremendously carcinogenic to human beings through uptake of PAHs (e.g. BaP) (Fang et al., 2004; Huang et al., 2006). PAHs are extremely carcinogenic to human exposures than individual PAHs. The probable human carcinogen PAHs includes BaA, BaP, Bflas, Chry, and InP (USEPA, 2008). The increasing molecular weight with increasing carcinogenicity of the heavier PAHs. Also reported that the first chemical regarded or observed so far as carcinogen is BaP. The partial combustion of coal makes a big contribution to the gross PAHs emission to the atmosphere worldwide (Ravindra et al., 2008). For that reason, anticipated that about 430 kg BaP has been generated from timber burning in Sweden at some stage in 1994, although gasoline and diesel automobiles combinedly make contributions an awful lot low BaP (~320 kg) (Bostrom et al., 2002). Additionally, cited that biomass burning appears to contribute 17 to 45% of PAHs load of first-class particles in residential regions of suburban Tokyo (Kumata et al., 2006; Hosaain and Hossain, 2019).

4.4 Principal Component Analysis

The vital idea of principal component analysis (PCA) is to lessen the dimensionality of a statistics set inclusive of a large number of interrelated variables, at the same time as keeping as a good deal as feasible of the variation present in the data set. That is done by means of remodeling to a brand new set of variables, the PRINCIPAL components (PC), which are uncorrelated, and which can be ordered in order that the primary few keep most of the variation found in all the unique variables (Mishra et al., 2017). Principal component analysis (PCA) turned into evaluate the contribution of different PAH sources, and the effects are provided in Table 7, which shows the variable loadings, describing the main contamination patterns and their defined variance. Six principal component accounting for 88% of the entire variance were extracted via PCA. The first element (PC1) changed into predominately loaded with BbF, BkF and DahiA. The second component (PC2) contributed 9% to the total variance and became weighted with Chyr, BbF, BkF and Ind, this issue have been diagnosed as regular tracers of combustion source (Biache et al., 2014).

Table 7: Principal component analysis

	PC 1	PC 2	PC 3	PC 4	PC 5	PC6
1	-0.045871	-0.0032794	-7.1467E-06	-0.0026726	0.00011548	-2.3062E-05
2	-0.048074	-0.0013748	0.00023855	0.00015088	-0.000215	0.00012989
3	-0.040998	-0.0069435	0.00020142	0.00076354	-0.00050739	-0.0001060
4	-0.047767	-0.0012337	0.00037132	-0.0041496	3.4168E-05	-4.617E-05
5	-0.048082	-0.00057457	0.00084479	0.0067841	-0.000242	-3.9362E-05
6	-0.043653	-0.0041663	-3.2549E-05	-0.0010952	-0.00027119	1.6002E-05
7	-0.045479	-0.0011992	-0.0010459	0.00169	0.00017121	2.7075E-05
8	-0.046205	-0.0013279	0.00091794	0.0074532	-0.00047618	-2.9411E-05
9	-0.038802	-0.0075412	3.64E-05	-0.0044244	-0.00024735	-9.979E-05
10	-0.019609	0.012583	0.017919	-0.0043948	-4.5308E-05	0.00039619
11	0.024041	0.055947	0.033021	-0.0061078	0.00039746	-0.0002088
12	0.0026228	0.051686	-0.035579	-0.0033266	-9.2941E-05	-3.0663E-05
13	0.087145	-0.082424	-0.00011534	-0.016741	0.00011625	-6.0406E-05
14	-0.013871	0.0083876	-0.017443	-0.0058028	0.00093098	6.2336E-05

The PC 3 contributed 2% to the whole variance and was weighted with Acy, Ace, Flu, Phe Chyr and BbF reflective of PAHs derived from combustion. The fourth component (PC4) was dominated by Acy, Ace, Phe, Fla and Pyr. The fifth component (PC5) was weighted by Nap, Flu, Fla, BbF, DahiA and Ind, has been diagnosed as a hallmark of diesel combustion, even as it has been mentioned that Ant and Phe were related to coal combustion (Li and Kamens, 1993; Motelay-Massei et al., 2007; Yunker et al., 2002; Masclet et al., 1967). The six component (PC6) was weighted with Acy, Ant, Flu, and Ind. It's been reported that Flua and Ant had been related to combustion-generated PAHs (Yunker et al., 2002; Liu et al., 2009; Masclet et al., 1967; Biache et al., 2014). Loadings of Acy and Nap have been related to vaporization or spill of petroleum-related products and spill of petroleum-associated (Liu et al., 2009).

5. Conclusion

The results from this research confirmed the presence of PAHs in Amassoma town drinking water. Fourteen out of the 16 PAHs recognized as priority pollution had been detected. Total PAHs concentration had been low. The total PAHs concentration ranged from 0.003 – 0.364mg/l with a mean value of 0.132mg/l. Source identification was performed by using principal component and diagnostic ratios. Six principal component accounting for 88% of the entire variance were extracted. PCA. Ant/(Ant + Phe), BaA/(BaA + Chr) and ΣLMW/ΣHMW diagnostic ratios implemented for sources apportionment asserted the PAHs to be often of pyrogenic origins. Although the results obtained from this study showed very low concentrations of PAHs in Amassoma drinking water, PAH concentrations in the community should be constantly monitored to reduce ecological risk, human exposure, and PAHs in the aquatic environment.

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