Int. J. New. Chem., 2025, Vol. 12, Issue 4, pp. 567-580.

International Journal of New Chemistry

Published online 2024 in http://www.ijnc.ir/.

Open Access

Print ISSN: 2645-7236

Online ISSN: 2383-188x

Original Research Article

Spatial and Temporal Variations in The Concentrations Of Polycyclic Aromatic Hydrocarbon, In Ambient Air From Three Different Locations In River State, Nigeria.

Ekpo Ekokodu Rose [2], Erienu Obruche Kennedy [1*], Abiye Clement. Marcus [2]

[1*] Dept. of Chemistry, Delta State College of Education, Mosogar, Delta State.

[2] Dept. of Chemistry, Ignatus Ajuru University of Education, River State.

Received: 2024-10-19 ***Accepted: 2024-12-17*** ***Published: 2024-12-18***

ABSTRACT

This research study was conducted due to growing industrial activities and the associated consequences around the study areas to evaluate the temporal and spatial variations in the concentrations of polycyclic aromatic hydrocarbon (PAHs) content in ambient air from Eleme,Aluu and Ikoku in Rivers state, Nigeria. The duration of this study lasted from April, 2021 through January, 2022 which covered both dry and wet seasons. PAHs in ambient air were collected from these three different locations using air sampler (Mini volair sampler) and analysed in the laboratory using Gc-Ms. During the dry season, some of the PAHs were below detection limit, while some were detected. The mean concentrations of the PAHs detected range from 0.122 ± 0.065 to 0.600 ± 0.132 mg/kg,0.113 ± 0.037 to 0.407 ± 0.282 mg/kg and 0.360 ± 0.267 to 2.220 ± 2.183 mg/kg for Eleme,Ikoku and Aluu respectively. During the wet season, the mean concentrations of the PAHs detected range from 0.118 ± 0.081 to 0.737 ± 0.108 mg/kg and 0.398 ± 0.284 to 0.992 ±0.702 mg/kg for Eleme and Ikoku respectively. The mean concentrations of the polycyclic aromatic hydrocarbons reported are all above the WHO standard which is 0.0002 mg/kg. The results of this research are clear indication that the ambient air within the study areas is quite polluted

Keywords: PAHs, Eleme, Ikoku, Aluu, WHO, pollution, air

*Corresponding author email address: kenkennedy767@gmail.com

Introduction

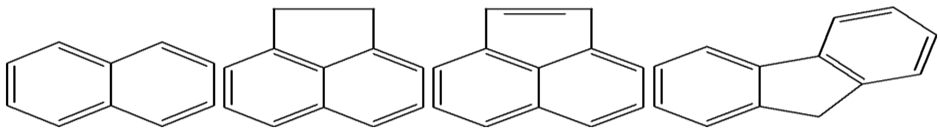
There is a family of organic molecules known as polycyclic aromatic hydrocarbons (PAHs) that do not include heteroatoms or carry substituents and consist of two or more fused aromatic rings [1]. One class of persistent organic contaminants is polycyclic aromatic hydrocarbons (PAHs). They are organic pollutants that are difficult to break down, have a long half-life in the environment, and may have negative consequences on the natural world [2]. PAHs are solids that range in color from colorless to yellow at room temperature. Water solubility tends to decrease with increasing molecular mass, however all members of this class have high melting and boiling temperatures and low vapour pressures. PAHs are very fat-loving [3-5]. There are hundreds of different compounds that make up polycyclic aromatic hydrocarbons, yet they all exist together in nature as mixes [6]. More than a hundred different compounds belong to the class of polycyclic aromatic hydrocarbons, which are made up of up to six benzene rings fused together in such a way that any two neighboring benzene rings share two carbon bonds. Incomplete combustion of organic resources like coal, fossil fuel, and wood, as well as from forest fires, volcanic activity, andpetroleum seeps, all contribute to the formation of polycyclic aromatic hydrocarbons, a class of environmental toxins [7]. PAHs may be broken down into three broad categories: biogenic (minimal), petrogenic, and pyrogenic. Identifying the origin of PAHs is complicated by the fact that they fall into three distinct categories. On the other hand, four of the top ten most dangerous compounds on the ATSDR Priority list from 2011 are polycyclic aromatic hydrocarbons [8-12]. Most PAHs in the atmosphere come from human-caused sources such volcanoes, forest fires, coal burning, and vehicle tailpipes [13-16]. In the atmosphere, polycyclic aromatic hydrocarbons may cling to dust particles. Evaporation from soil or water surfaces may quickly release certain PAHs into the atmosphere [17-19]. Over the course of many days to weeks, polycyclic aromatic hydrocarbons may be degraded by interacting with sunlight and other molecules in the air. The majority of PAHs have a low solubility in water [20-23]. They cling to the sediment at the bottom of rivers and lakes. PAHs in soil or water may be degraded by microorganisms over the course of many weeks to months. Soil is the environment in which PAHs are most likely to cling to tiny particles. Subterranean water supplies may be tainted by PAHs since they permeate the earth. It's possible that the levels of polycyclic aromatic hydrocarbons (PAHs) in the plants and animals that dwell in a certain area are much greater than the levels of PAHs in the soil and [24-28]. A class of chemicals known as polycyclic aromatic hydrocarbons (PAHs) may be produced from the combustion of certain substances. Forest fires and volcanic eruptions are two examples of natural activities that may produce and release them into the atmosphere [28-30]. Tobacco smoke, car exhaust, and other human activities account for the vast majority of PAHs in the air today. Coal tar, crude oil, roofing tar, and creosote (used for preserving wood and asphalt) are all good sources of PAHs, as are charbroiled or smoked meats [31-32]. Nigeria has been the site of petroleum exploration and extraction for many years, with sometimes disastrous effects on the country's landscape and population. Water, air, and soil pollution and contamination pose serious problems for the environment, and researchers, environmentalists, and scientists throughout the world are working to find answers. The widespread issue of pollution and contamination in the Niger Delta area, South-South, Nigeria, is a direct consequence of the disposal of hazardous waste chemicals and toxic elements into the land, water, sediments, and air [33].

This study was aimed at evaluating the spatial and temporal variations in the concentrations of PAHs in ambient air of Eleme, Aluu and Ikoku in Rivers State, Nigeria. Table 1 and figures 1 show several common types of polycyclic aromatic hydrocarbons together with their corresponding molecular weights.

Table 1. molecular weight and molecular formula of some PAHs

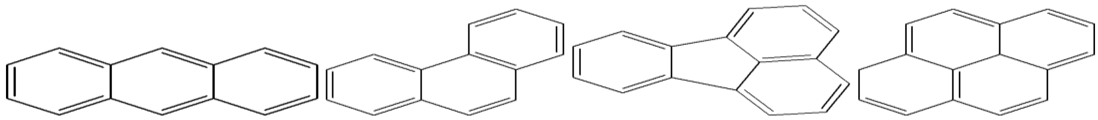
S/N	PAHs	molecular weight	molecular formular
1	Naphthalene	128	$C_{10}H_8$
2	Acenaphthylene	152	$C_{12}H_8$
3	Acenaphthene	154.21	$C_{12}H_{10}$
4	Fluorene	166.2	$C_{13}H_{10}$
5	Phenanthrene	178.2	$C_{14}H_{10}$
6	Anthracene	78.2	$C_{14}H_{10}$
7	Fluoranthene	202.26	$C_{16}H_{10}$
8	Pyrene	202.3	$C_{16}H_{10}$
9	Chrysene	228.3	$C_{18}H_{12}$
10	Benzo(b)fluoranthenecs	252.3	$C_{20}H_{12}$

(Obruche *et al, 2022*)



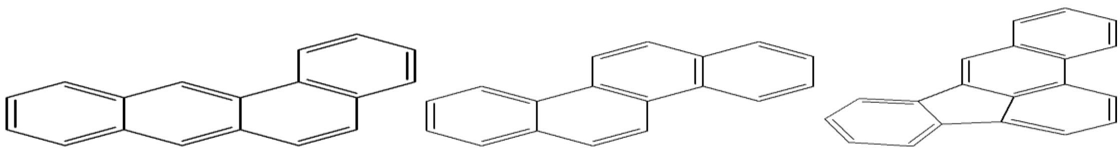
A B C D

Figure 1. Naphthalene (A) (M_w = 128), acenaphthene (B) (M_w= 152), acenaphthylene (C) (M_w = 153) andFluorine (D) (M_w = 166)



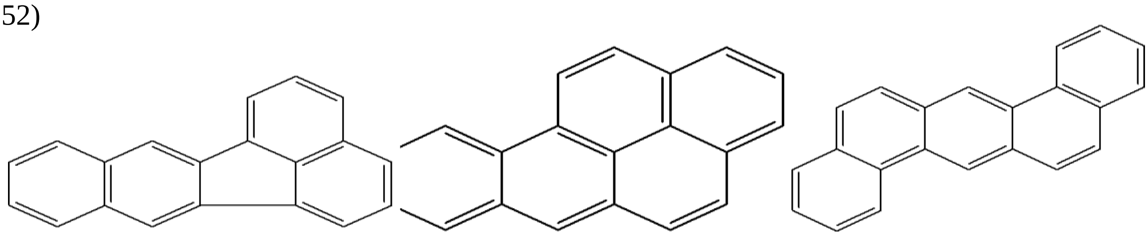
A B C D

Figure 2. Anthracene (A) (M_w = 178), phenanthrene (B) (M_w = 178), Floranthene (C) (M_w = 202) pyrene (D) (M_w = 202)



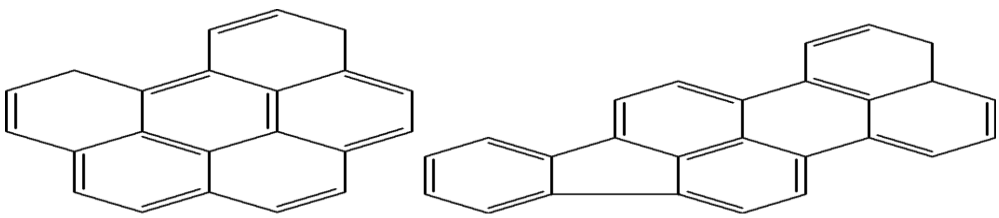
A B C

Figure 3. benzo[a]anthracene (A) (M_w = 228),Chrysene (B) (M_w = 228),benzo[*b*]fluoranthene (C) (M_w = 252)



A B C

Figure 4. benzo[*k*]fluoranthene (A) (M_w = 252), Benzo[*a*]pyrene (B) (M_w = 252) dibenzo[*a*,*h*]anthracene (C) (M_w = 278)



A B

Figure 5. benzo[*g*,*h*,*i*]peryrelene (A) (M_w 2= 76), Indeno[1,2,3-*c*,*d*]pyrene (B) (M_w = 276)

Materials and Method

Study areas

The primary emphasis of this investigation was on three distinct regions. Eleme, Ikoku, and Aluu were all notable for their respective sets of economic and industrial pursuits. **Eleme is** Famous across Rivers State, Nigeria, Eleme is one of the state capital's local governments. It's one of the municipalities where several firms are mentioned. There are 138 square kilometers of land there. Over 19 thousand people call this place home. Eleme is also one of the economically viable places in Port Harcourt metropolitan city. Eleme may be found at coordinates 4.7994° N and 7.1198° E. In Aluu, there are many people residing in Aluu, another city in Rivers State. About 141 square kilometers may be found there. The coordinates for Aluu are 4.9331° N and 6.9316° E. Residents of Aluu are notorious for their participation in illicit refineries, often known as bonfires [34-36]. Ikoku is One of the neighborhoods in the city of Port Harcourt is called Ikoku. The coordinates of this location are 4.7996° N and 6.9926° E. Commercially is a well-known.

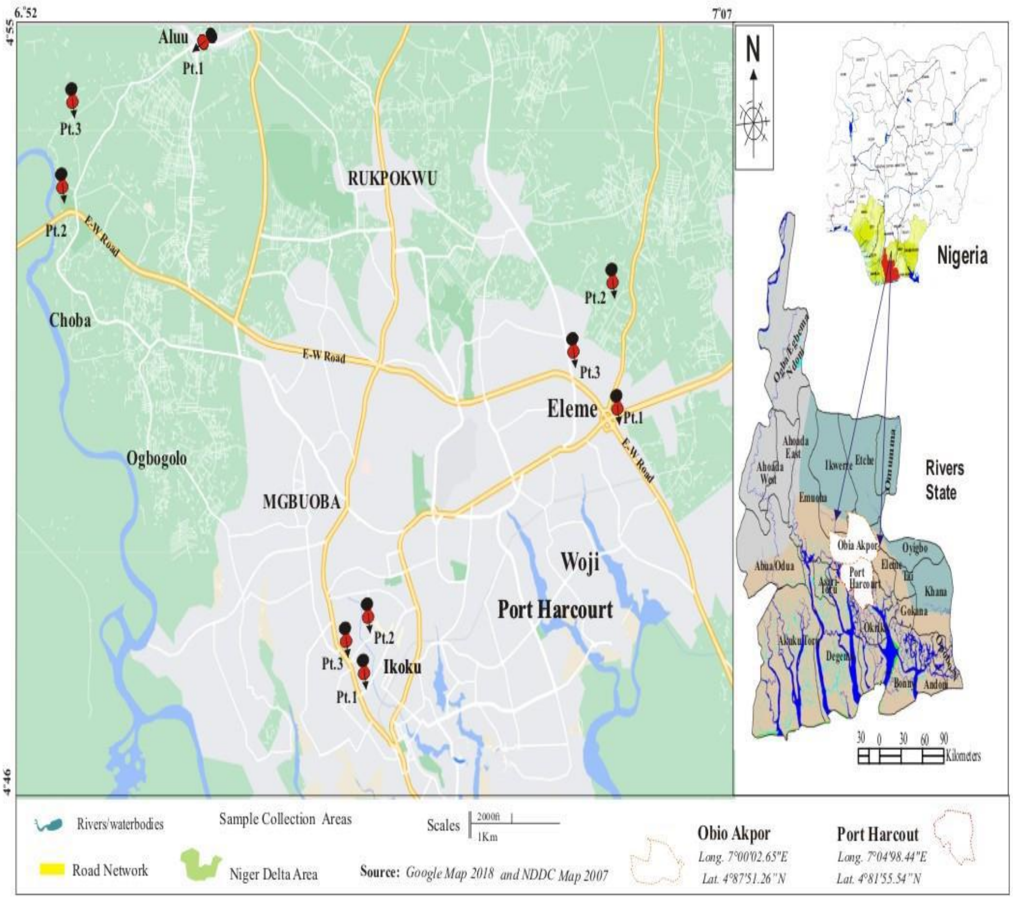


Figure 6. A map showing the different sampling areas and locations

Sample collection

Samples of air were taken using a Minivol (high volume air sampler) which was exposed in the air for a period of time. The samples were trapped with the aid of a glass microfibre filter papers with pore sizes of 2.5 µm and 10.0 µm. After 3 hours, the trapped air samples were collected, tagged, and transported to a laboratory for examination of the concentration of Polycyclic aromatic hydrocarbons (PAHs).

Laboratory Analysis

The collected samples were analysed using the standard analytical method adopted by [37]. The filter papers were carefully transferred into 250 mL extraction bottle using forceps, solvated with 25mL dichloromethane and adequately shaken using a mechanical shaker for a duration of 1 hour at the speed of 120 rpm. Glass wool was used to filter the samples before they were placed in a beaker and coated with sodium anhydrous sulfate.

GC-Ms Analysis

For Gas chromatographic separation of the PAHs and subsequent detection by the Mass spectrometer, 1 mL of the filtrate was concentrated in a fume hood before being transferred to a 2 mL GC vial. The technique analytes were separated using a temperature-programmable GC capillary column, and then MS was used to identify PAHs.

Measured mass spectra and retention durations are compared to those in a reference library database to determine the identity of compounds eluting from the GC columns. Analyses using calibration standards performed under the same circumstances as those employed for sample analysis provided the reference spectra and retention time for the analyte of interest.

Using a multi-point linear regression calibration curve, we were able to calculate the quantity of each detected analyte by correlating the MS response of the quantitation ion generated by that molecule with the MS response of that chemical. The concentration of the analyte may also be calculated by comparing the ion's response to that of an internal standard substance. Compensation for differences in instrument sensitivity or sample heterogeneity was aided by the introduction of an internal standard.

Results and Discussion

Table 2 demonstrates that in comparison to Eleme and Aluu, Anthracene, Phenanthrene, Fluoranthene, Pyrene, Benzo (ah)anthracene, and Total PAH were all found to be statistically substantially higher in Ikoku. Between the three sites, Indeno (1,2,3c-d) Pyrene and Benzo(ghi)Perylene did not vary significantly (p>0.05).

Table 2: Mean concentration of PAHs in the different locations in dry season

	Locations		
PAHs	Eleme (mg/kg)	Aluu (mg/kg)	Ikoku (mg/kg)
Naphthalene	-	-	-
Acepnaphthylene	-	-	-
Acepnapthene	-	-	-
Fluorene	0.313±0.015	0.203±0.055	BDL
Anthracene	$0.460±0.137^{a}$	$0.283±0.147^{a}$	$2.175±2.159^{b}$
Phenanthrene	$0.447±0.161^{a}$	$0.238±0.058^{a}$	$0.858±0.654^{b}$
Fluoranthene	$0.600±0.132^{b}$	$0.122±0.048^{a}$	$0.617±0.393^{b}$
Pyrene	$0.588±0.281^{a}$	$0.288±0.086^{a}$	$2.220±2.183^{b}$
	-	-	-
Benzo(a)anthracene			
Benzo a h anthracene	$0.137±0.016^{a}$	$0.127±0.054^{a}$	$0.360±0.267^{b}$
Chrysene	-	-	-
Benzo(b) Fluoranthene	-	-	-
Benzo(k) Fluoranthene	-	-	-
Benzo(a)pyrene	-	-	-
Indeno (123)cd Pyrene	$0.122±0.065^{a}$	$0.407±0.282^{a}$	$0.432±0.343^{a}$
Benzo(ghi)Perylene	$0.335±0.171^{a}$	$0.113±0.037^{a}$	$0.915±1.072^{a}$
Total PAH	$\mathbf{2.852±0.433^{a}}$	$\mathbf{1.825±0.636^{a}}$	$\mathbf{7.577±6.938^{b}}$

Similar superscriptletter a means not significantly different (p>0.05)in a group while different superscript letter b means significantly different (p<0.05) in a group .PAHs not reported in the tables are those below detectable limits. NA- Not applicable

The mean concentration of PAHs in ambient air from Eleme and Ikoku for wet season are presented in table 3. Result in Table 3 shows that there was no significant difference in PAHs between Eleme and Aluu ($p>0.05$)

Table 3: Mean concentrations of PAHs in the different locations in wet season

PAH	Eleme	aluu	Ikoku
Naphthalene	-	-	-
Acepnaphthylene	-	-	-
Acepnapthene	--		-
Fluorene	0.347±0.072	-	BDL
Anthracene	0.363±0.129[a]	-	2.383±2.126[a]
Phenanthrene	0.397±0.092[a]	-	0.992±0.702[a]
Fluoranthene	0.737±0.108[a]	-	0.635±0.381[a]
Pyrene	0.605±0.290[a]	-	2.393±2.179[a]
Benzo a anthracene	-	-	-
Benzo a h anthracene	0.137±0.016[a]	-	0.398±0.284[a]
Chrysene	-	-	-
Benzo(b) Fluoranthene	-	-	-
Benzo(k) Fluoranthene	-	-	-
Benzo(a)pyrene	-	-	-
Indeno 123 d Pyrene	0.118±0.081[a]		0.470±0.378[a]
Benzo ghi Perylene	0.318±0.250[a]		0.922±0.925[a]
Total PAH	2.848±0.591[a]		8.198±6.950[a]

superscript letters a mean not significantly different ($p>0.05$) in each location while superscriptletters b mean significantly different ($p<0.05$) in a group. PAHs not reported in the tables are those below detectable limits. No result for Aluu during wet season.

The Distribution of PAHs in dry season in the different locations is presented in Figure 7.

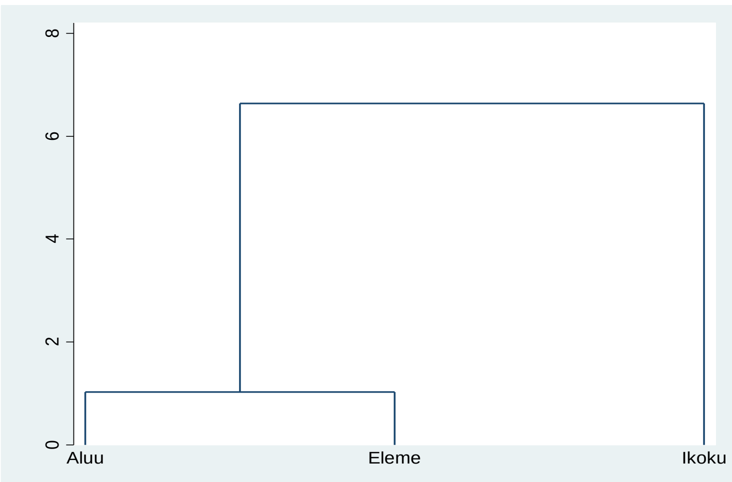


Figure7. Distribution of PAHs in dry season in the different locations.

The spatial distribution of PAHs in dry season is presented in Figure 7. The figure 7 shows that the spatial distribution of PAHs can be grouped into 2 distinct clusters with Aluu and Eleme in cluster 1 and Ikoku in cluster 2 which implies that Aluu and Eleme have similar spatial distribution of PAHs. The Spatial distribution of PAH in dry season is presented in Figure 8.

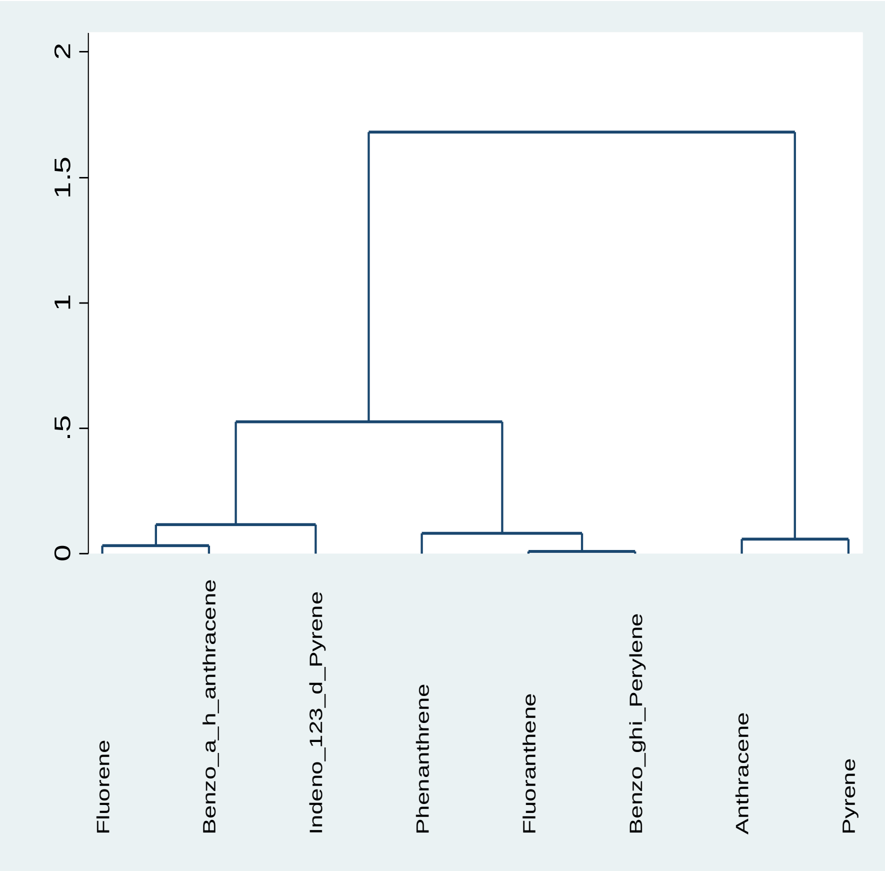


Figure 8. Spatial distribution of PAH in dry season

The spatial distribution of PAHs in dry season is presented in Figure 8. The figure shows that the spatial distribution of PAHs can be grouped into 3 distinct clusters with Fluorene, Benzo a h anthracene, Indeno 123 d Pyrene in cluster 1, Phenanthrene, Fluoranthene and Benzo ghi Perylene in cluster 2 while Anthracene and Pyrene are in cluster 3. The dendogram reveals that PAHs in the same cluster has similar spatial distribution. The Spatial distribution of PAH in wet season is presented in Figure 9.

Analyses for the determination of the concentration of Polycyclic aromatic hydrocarbons were also carried out during the dry season. The results obtained are presented in tables 2 and figures 8. The analyses were carried out in the same three different locations under study.

In the study location, 16 PAHs were analysed for, but the result showed that some of the PAHs were below detection limit, while some were detected. The PAHs detected include: fluorene, anthracene, phenanthrene, fluoranthene, pyrene, benzo(a,h)anthracene, indeno(1,2,3-cd)pyrene and benzo(ghi)perylene. The mean concentrations of the PAHs detected range from 0.122 ± 0.065 mg/kg to 0.600 ± 0.132 mg/kg, 0.113 ± 0.037 mg/kg to 0.407 ± 0.282 mg/kg and 0.360 ± 0.267 mg/kg to 2.220 ± 2.183 mg/kg for Eleme, Ikoku and Aluu respectively. The total mean concentration was reported to be 2.852 ± 0.433 mg/kg, 1.825 ± 0.636 mg/kg and 7.577 ± 6.938 mg/kg for Eleme, Aluu and Ikoku This research revealed the presence of polycyclic aromatic hydrocarbons in the atmospheric region of the three locations under study during the dry season. The mean values and the concentrations of the polycyclic aromatic hydrocarbons reported are all above WHO standard/ acceptable limit which is 0.0002 mg/kg [38]. This clearly indicates that the air around the study areas are quite polluted and poses a serious threat to human health regarding the presence of PAHs in the air. Similar observation was also reported by [39].

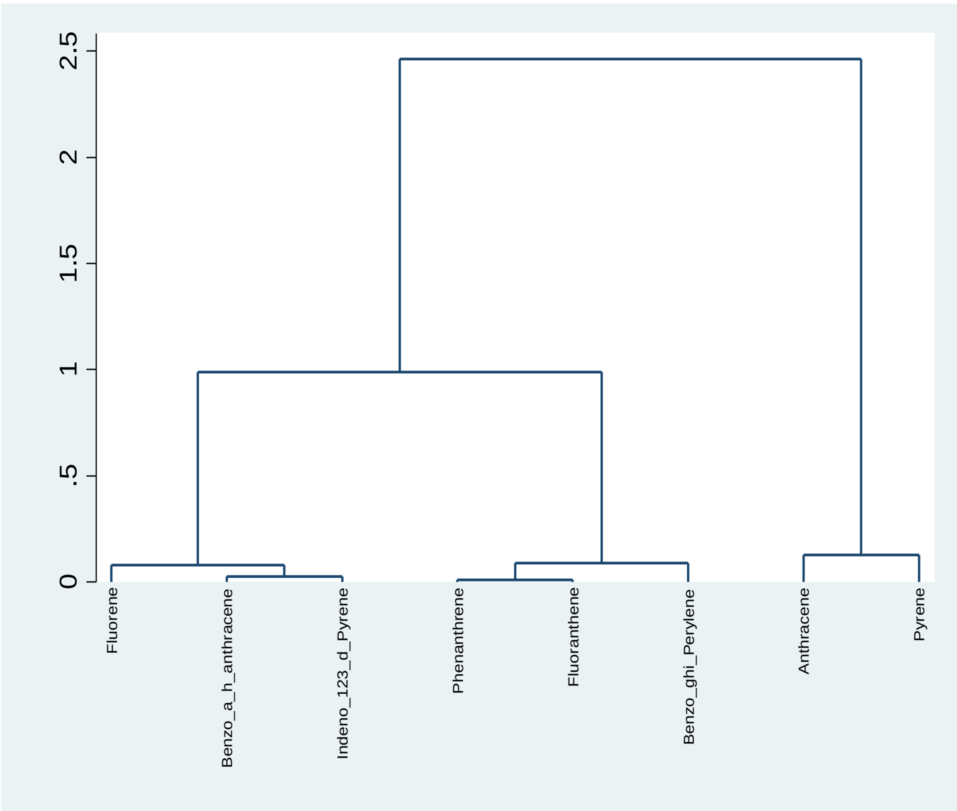


Figure 9. Spatial distribution of PAH in wet season

The spatial distribution of PAHs in wet season is presented in Figure 9. The figure shows that the spatial distribution of PAHs can be grouped into 3 distinct clusters with Fluorene, Benzo (a h) anthracene and Indeno (123) d Pyrene in cluster 1, Phenanthrene, Fluoranthene and Benzo ghi Perylene in cluster 2 while Anthracene and Pyrene are in cluster 3. The dendogram reveals that PAHs in the same cluster has similar spatial distribution. This implies that for both seasons, the spatial distribution of PAHs was the same.

Analyses for the determination of the concentration of Polycyclic aromatic hydrocarbons were also carried out during the wet season. The results obtained are presented in tables 3and figures 9. The analyses were carried out in the same three different locations under study. During the wet season, 16 PAHs were analysed for, but the result showed that some of the PAHs were below detection limit, while some were detected The PAHs detected include: fluorene, anthracene, phenanthrene, fluoranthene, pyrene, benzo(a,h)anthracene, indeno(1,2,3-cd)pyrene and benzo(ghi)perylene. The mean concentrations of the PAHs detected range from 0.118 ± 0.081 mg/kg to 0.737 ± 0.108 mg/kg and 0.398 ± 0.284 mg/kg to 0.992 ± 0.702 mg/kg for Eleme and Ikoku respectively. The total mean concentration was reported to be 2.848 ± 0.591 mg/kg and 8.198 ± 6.950 mg/kg for Eleme and Ikoku. This research revealed the presence of polycyclic aromatic hydrocarbons in the atmospheric region of the two locations under study during the wet season. The mean values and the concentrations of the polycyclic aromatic hydrocarbons reported are all above WHO standard/ acceptable limit which is 0.0002 mg/kg [40]. This clearly indicates that the ambient air around the studied areas are quite polluted and poses a serious threat to human health regarding the presence of PAHs in the air. Similar observation was also reported by [41].

Conclusion

This research focused primarily on the concentrations of polycyclic aromatic hydrocarbon in air samples from three different locations (Eleme, Aluu and Ikoku) in Port Harcourt, Rivers state, Nigeria. The results revealed that the concentrations of all the detected polycyclic aromatic hydrocarbons were all higher than WHO permissible limit for PAHs in ambient air. This is a clear indication that the ambient air within the study locations are quite polluted with polycyclic aromatic hydrocarbons which poses a serious health threat to humans dwelling in the City. Due to the high concentrations of PAHs obtained from the studied areas, it is highly recommended that for government to launch an operation to regulate the activities illegal refineries and anyone caught must be made to face the wrath of the law. It is also recommended that monitoring should not only be done seasonal but throughout the year.

References

[1] E.O. Obruche, A. Itodo, R. Wuana, A. Sesugh. Bull. Chem. Soc. Ethiop., 36(4), 1–11 (2022).

[2] M.C. Breitenbach, S.B. Lehrer. Cambridge Journals Online, 310–320 (2002).

[3] W.P. Robert, B.G. Alice, L.D. Robin. Journal on Workshop on Agricultural Air Quality, 1(2), 347–349 (2021).

[4] F. Conen, C.E. Morris, J. Leifeld, M.V. Yakutin, C. Alewell. Journal of Atmospheric Chemistry and Physics, 11(6), 9643–9648 (2011).

[5] P. Gupta, A.S. Christopher, J. Wang, R. Gehring, Y.C. Lee. Journal of Atmospheric Environment, 40, 5880–5892 (2016).

[6] G.D. Ritchie, K.R. Still, W.K. Alexander. Journal of Toxicology and Environmental Health B, 4(3), 223–312 (2001).

[7] J.C. Igwe, P.O. Ukaogo. Journal of Natural Sciences Research, 5(7), 117–126 (2015).

[8] M. Joly, E. Attard, M. Sancelme, L. Deguillaume, C. Guilbaud, C.E. Morris, P. Amato, A.M. Delort. Journal of Atmospheric Environment, 70(12), 392–400 (2013).

[9] H. Swemgba, C.A. Ahiarakwem, G.I. Nwankwor, S.O. Adikwu. International Journal of Environment and Pollution Research, 7(4), 1–20 (2019).

[10] K. Friday. International Journal of Research and Scientific Innovation (IJRSI), 7(5), 117–123 (2020).

[11] I.C. Yadav, N.L. Devi. Encyclopedia of Environmental Health, Second edition, Science Direct, 1(2), 2–12 (2019).

[12] O.E. Ahmed, S.A. Mahmoud, A.E.M. Mousa. Current Science International, 4(1), 27–44 (2015).

[13] R. Jaenicke. Journal of Sciences, 308(20), 73–73 (2005).

[14] C.U. Onuorah, T.G. Leton, O.L.Y. Momoh. Asian Journal of Advanced Research and Reports, 7(2), 1–7 (2019).

[15] E.G. Gregorich, M.H. Beare, U.F. McKim, J.O. Skjemstad. Soil Science Society of America Journal, 70(3), 975–985 (2006).

[16] T.C. Bond. Journal of Geophysical Research: Atmospheres, 118(11), 5380–5552 (2013).

[17] I.A.S. Hussein, S.M.M. Mona. Egyptian Journal of Petroleum, 25(1), 107–123 (2019).

[18] O. Möhler, P.J. DeMott, G. Vali, Z. Levin. Journal of Biogeosciences, 4(2), 1059–1071 (2007).

[19] R. Godec, U.L. Ugljik, U.Z. Cesticama. Journal of Archive and High Radar, 59(4), 309–318 (2008).

[20] U. Pöschl. Journal of Chemistry International Edition, 44(12), 7520–7540 (2005).

[21] I.J. Okpo, S.C. Ekpo. Proceedings of The World Congress on Engineering, 3, 1–5 (2012).

[22] U.U. Ini, U.U. Uwem, U.U. Etim, U. Roy, I. David. Journal of Environment and Pollution, 4(3), 19–26 (2015).

[23] O.M. Akinfolarin, N. Boisa, C.C. Obunwo. Journal of Environ Anal Chem, 4(4), 224–229 (2017).

[24] N.C. Brady, R.R. Weil. The nature and properties of soils, 11th edition. Upper Saddle River. Prentice-Hall Inc., 1–12 (2007).

[25] E. Vignati, M.C. Facchini, M. Rinaldi, C. Scannell, D. Ceburnis, J. Sciare, M. Kanakidou, S. Myriokefalitakis, F. Dentener, C.D. O'Dowd. Journal of Atmospheric and Environmental, 44(6), 670–677 (2010).

[26] B. Srinivas, M.M. Sarin. Journal of Maritime System, 126(28), 56–68 (2013).

[27] WHO. Non-heterocyclic Polycyclic Aromatic Hydrocarbons. World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 202) (in press), pp. 23–34 (1997).

[28] O.E. Alahmr, M. Othman, N.B.A. Wahid, A.A. Halim, M.T. Latif. Aerosol and Air Quality Resource, 12, 629–642 (2012).

[29] P.D. Kalabokas, J. Hatzianestis, J.G. Bartzis, P. Papagiannakopoulos. Atmospheric Environment, 35(6), 2545–2555 (2001).

[30] J. Peccia, D. Hospodsky, K. Bibby. Journal of Atmospheric Environment, 45(12), 1896–1897 (2011).

[31] S. Szidat, A. Prévôt, J. Sandradewi, M. Alfarra, H. Synal, L. Wacker, U. Baltensperger. Journal of Geophysics and Resources Letter, 34(12), 2–13 (2007).

[32] C.S. Moody, F. Worrall. Journal of Geophysical Research and Biogeosciences, 122(5), 1175–1191 (2017).

[33] V. Vinoj, P. Rasch, H. Wang, J. Yoon, P. Ma, K. Landu, B. Singh. Journal of Nature Geoscience, 7(2), 308–313 (2014).

[34] H.A. Peter. In D.J. Hoffman, B.A. Rattner, G.A. Buston, J. Cairns (Eds.), Handbook of ecotoxicology, Lewis Publishers, pp. 342–359 (2003).

[35] Y.Y. Naumova, S.J. Eisenreich. Environmental Science and Technology, 36(12), 2552–2559 (2002).

[36] M.B. Macaulay, D. Rees. Annals of Environmental Science, 8(2), 9–37 (2014).

[37] M. Sakari, B.S. Hsia, R. Tahir. International Journal of Environment and Bioenergy, 9(1), 1–16 (2014).

[38] F. Amato, F.R. Cassee, H.A.C. Denier van der Gon, R. Gehrig, M. Gustafsson, W. Hafnef, R.M. Harrison, M. Jozwicka, F.J. Kelly, T. Moreno, A.S.H. Prévôt, M. Schaap, J. Sunyer, X. Querol. Journal of Hazard. Materials, 275(10), 31–36 (2014).

[39] M. Jonathan, M.D. Samet, F. D., C. Frank, W.C. Curriero. The New England Journal of Medicine, 343(32), 1742–1749 (2020).

[40] C.M. Moore, M.M. Mills, K.R. Arrigo, I. Berman-Frank, L. Bopp, P.W. Boyd, E.D. Galbraith, R.J. Geider, C. Guieu, S.L. Jaccard. Journal of National Geoscience, 6(2), 701–710 (2013).

[41] H. Ghafur Rauf, S. Majedi, E. Abdulkareem Mahmood, M. Sofi. Chem. Rev. Lett., 2(3), 140–150 (2019).

HOW TO CITE THIS ARTICLE

Obruche Kennedy Erienu**. "Spatial And Temporal Variations In The Concentrations Of Polycyclic Aromatic Hydrocarbon, In Ambient Air From Three Different Locations In River State, Nigeria."**, International Journal of New Chemistry, 2025; 12(4), 567-580. doi: 10.22034/ijnc.2023.2009756.1356.