Int. j. adv. multidisc. res. stud. 2025; 5(2):1118-1124

Received: 08-02-2025
Accepted: 18-03-2025

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Characterization of the Polycyclic Aromatic Hydrocarbons (PAHS) in the Wetlands of Ogbinbiri and Environs for the Adoption of Cage Aquaculture as a Recipe for Achieving Zero Hunger in Nigeria

[1] Ogwu C, [2] Adinkwu OM

[1] Department of Environmental Management and Toxicology, Delta State University of Science and Technology, Ozoro, Nigeria

[2] Department of Plant Science and Biotechnology, Delta State University of Science and Technology, Ozoro, Nigeria

DOI: https://doi.org/10.62225/2583049X.2025.5.2.3954

Corresponding Author: **Ogwu C**

Abstract

This study investigated the concentrations of PAHs in the wetlands of Ogbinbiri and environs for the deployment of cage aquaculture. For achievement of zero hunger in Nigeria. The study answered 5 research questions and tested a hypothesis. In accomplishing these, the wetlands in Ogbinbiri, Ugbo-Rado, Ogbudogbodu Okoromado and Opuama were mapped out into 5 sampling units each water sample were collected from 5 spots with plastic sample bottles in each unit, bulked and composite drawn and fixed with $HN0_4$ and stored in ice cool flask for analysis. The analytical standard adopted was EU 1881/2014 MPC and the instrument of determination used was Agilent spectrometry GC/MS and the results obtained were; pyrene 0.73±0.01 µg/l, chrysene 0.74±0.11 µg/l, BaP, 0.32±0.01 µg/l, BaA, 0.72±0.01 µg/l and BbF, 0.73±0.00 µg/l. the mean results obtained were subjected to test of significance with ANOVA using SPSS IBM model 29 at 0.05 and the *p* value was 0.06, thus accept H_0. The Study concludes that the wetlands were not polluted above EU 1881/2014 recommended standards and thus cage aquaculture can be implemented in the wetland. The produce will be fit for human and animal consumption and are equally exportable. The study recommends that oil companies operating in Ogbinbiri and environs should continue with the standard practice adopted, the monitoring agencies NESREA and NOSDRA should continue with their standard mandate of surveillance of the oil companies operation for the sustenance of the purity of the wetlands for continued ecosystem services such as the adoption of cage aquaculture for zero hunger in Nigeria.

Keywords: Wetlands, polycyclic Aromatic Hydrocarbon, Cage Aquaculture Adoption, Zero Hunger

Introduction

THE United Nations in 2012 in Rio de Janeiro articulated and produced a set of universal goals seventeen in number that meet world urgent political, environmental and economic challenges and tagged it Sustainable Development Goals, goal number 2 is zero hunger. Zero hunger requires that all people have unhindered access to healthy diet for healthy living (United Nations Organisation, 2012, Jones, 2018, Maxwell, 2019) [79, 39, 45]. Zero hunger means ending hunger globally by the year 2030 through increased access to nutritious food to meet physiological and physical needs (Samuelson, 2019 [70], Patrick, 2019, Maxmillian, 2019 [44]). Zero hunger is geared towards ending all forms of hunger and malnutrition by 2030 (Soul, 2020, Davidson, 2020, Drake, 2021) [73, 15, 23]. It is putting an end to global hunger by making food available at the right quantity and quality (Benson, 2018, Johnson, 2019 [38]). Zero hunger is the worlds ability to end global hunger through unhindered access to good quality and nutritious food for all especially for nursing and lactating mothers, aged and infants (Pedro, 2019, Jackson, 2021, McDoff, 2021) [67, 36, 46]. Zero hunger as enshrined in United Nations Organisations sustainable development number 2 is to ensure that everyone has access to safe, sufficient and nutritious food that will satisfy their dietary preferences and needs without compromising quantity and quality (UNO, 2015, Johnbul, 2021 [37], Shedrack, 2022 [71], Alexander, 2022). Zero hunger is all about ensuring that all people especially the poor, vulnerable, weak and aged, nursing and lactating mother have unhindered access to the food quality food and the required quantity (Betrand, 2018, Daniel, 2019, Saint, 2019, Christopher, 2020) [12, 14, 69, 13].

Zero hunger is achievable through courting global participation and cooperation and through increasing agricultural productivity (UNO, 2015).

Nigeria was an agrarian country with agriculture engaging over 80 percent of its population and accounting for 90 percent of its Gross Domestic Product and 85 percent of its foreign exchange earning (Halilu, 2016 [33], Oteriba, 2018, Nwakwo, 2018, Ochu, 2018 [50]). The coming of petroleum wealth in early 70's pushed agriculture to the back burners, stimulated rural urban drift and dislocated the old or Nigeria is the 11th oil producing country and 71th in natural gas deposit (Upstream Petroleum Regulatory Commission, 2023, Natural Bureau of Statistics, 2023, Ruwani, 2023) [48, 47, 68] oil accounts for 90 percent of Nigeria foreign exchange and 80 percent of its GDP (NBS, 2023, Ruwani, 2023 [68]) and International oil market is prone to shocks and uncertainties, Nigeria has witnessed several recessions due to glut, the last two occasions being 2016 and 2021 (Sobowale, 2022 [72], Abubakar, 2023 [1], Dogara, 2023). Nigeria should embrace diversification by reversing to agriculture to ward off recessions to achieve zero hunger by 2023 (Babatunde, 2022, Adewale, 2019 [2], Asuqu, 2019 [6]). Youths and unemployed adults to venture into aquaculture for job and wealth creation and for achieving zero hunger in 2030 (Ogwu *et al*., 2022, Ogwu *et al*., 2022, Babagona, 2023). Nigeria annual fish demand is 3 million metric tons but produces only 850,000 metric tons annually (Ruwani, 2023 [68], Osakwe, 2023 [64], Ogwu *et al*., 2022); the shortfall in demand is bridged through importation thus creating unemployment in Nigeria and employment in country of import (Ododo, 2018 [51], Ojugo, 2019). Youths unemployment in Nigeria is put at 33.5 percent (International Labour Organisation, 2023, International Monetary Fund (IMF), 2023, Oteriba, 2023) [34, 35, 66]. Nigerian should venture into aquaculture adopting cage aquaculture technique due to its low investment outlay and high return on investment (Ogwu *et al*., 2021, Ogwu *et al*., 2022, Ogwu *et al*., 2022, Bamgboye, 2023 [10]). Cage aquaculture is the practice of raising fish in a cage anchored in a natural body of water (Afolabi, 2022 [3], Ogwu *et al*., 2022). Water analysis is highly recommended before cage aquaculture deployment for possible presence of toxicants (Ogwu *et al*., 2022, Babawale, 2022 [9]). Possible water pollutants include heavy metals, pesticides, polychlorinated biphenyl, volatile organic pollutants, Styrofoam, polycyclic aromatic hydrocarbons (PAHs) (United State Environmental Protection Agency (USEPA), 2012 [80], World Health Organisation (WHO), 2018) [81]. PAHs is a group of organic compound that is composed of multiple aromatic benzene rings (USEPA 2012 [80], Atshana & Atshana, 2012). They occur naturally in gasoline coal and crude oil (WHO, 2012, USEPA, 2018, Ogwu *et al*., 2022). PAHs have been implicated in epidemiological studies to cause cancer of the lungs, bone marrow (Deng *et al*., 2014 [18], Deltavalle *et al*., 2016, deOliveira *et al*., 2014 [16]). Mutation of the DNA, skin irritation (Enault *et al*., 2015 [28], Yuan *et al*., 2015).

A wetland is an ecosystem that has the innate propensity to hold water for 3 to 6 months of the year (Ogwu *et al*., 2022, Osawaru, 2023, Eromosele, 2023 [30]), while adoption the acceptance and deployment of a now production technique in agriculture (Babawale, 2023, Ododo 2018 [51], Ojugo, 2019). Oginnbiri, Ugbo-Rodo, Ogbudogbodu, Okoromado and Opuama are wetlands oil bearing communities in Warri north local government area of Delta, Nigeria and oil spillage to the environment occur via ruptures, wellheads blow out, sabotage, accidents, loading, ballast water (Ogwu 2021, Ogwu *et al*., 2022, Ajoko, 2023 [4]). The focus of this study is the analysis of the water in the wetlands in Oginbiri and environs for the contents of PAHs for the adoption of cage aquaculture towards the achievement of zero hunger in Nigeria. The PAHs investigated were pyrene, chrysene, benzo(a)pyrene (BaP) benzo(a)anthracene (BaA) and benzo(b)flourathene (BbF).

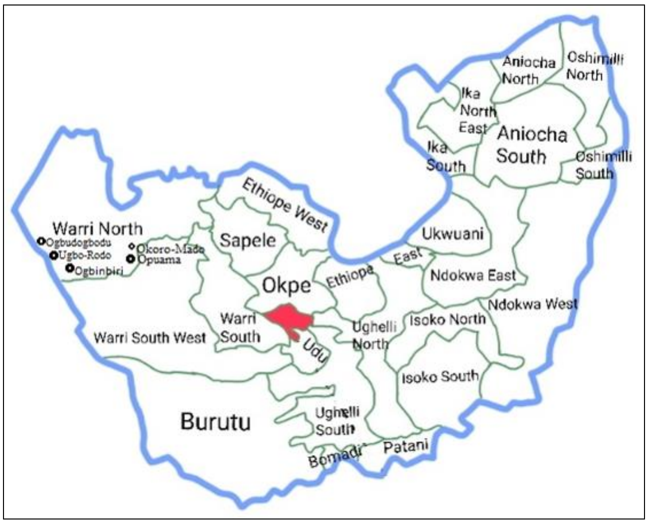
The study was guided by research questions as below:

1. What are the contetns of pyrene, chrysene, BaP, BaA and BbF in the wetlands in Ogbinbiri and environs
2. Are the concentrations of the PAHs with the maximum permissible concentration (MPC) of 1.00 µg/l recommended by EU 1881/2014 for wetlands?
3. Can cage aquaculture be adopted and deployed in the wetlands
4. Can the produce be fit for human consumption?
5. Will the produce be fit for animal feed formulation?
6. Can the produce be exported considering Codex Allimentarious 1963 Commission conditions for produce export?

The study was guided by a null hypothesis at 0.05 level of significance as

H_0: There is no significant different between the concentrations of the PAHs in the wetlands in Ogbinbiri and environs and EU/1881/2014 MPC for PAHs in wetlands.

Study Area



Adapted from: https://en.wikipedia.org/wiki/Uvwie#/media/File:Uvwie,_Delta_State.jpg

Fig 1: Map showing the study area

Ogbinbiri, Ugbo-Rodo, Ogbudogbodu Okoro-Mado and Opuama are wetland oil bearing settlements in Warri North local government area, Delta state Nigeria. They lie within the geographical positioning systems of latitude 5°.8824 and longitude 5°.27687. The pople of Ogbinbiri, Ugbo-Rado, Ogbudogbodu, Okoromado and Opuama are mainly farmers and fishermen, some are petty traders and artisans while some are civil servants teaching in the primary and secondary schools with a very few working in the oil companies mainly as janitors, security men and messengers. The wetlands are the recepients of the effluent discharges and spills from oil production activities.

Materials and Methods

This study was conducted between October 2023 to March 2024. The researcher engaged the services of 5 local domiciled in the study area to carry out the sampling. The research sites in the settlements were mapped out into 5 sampling grids and samples were collected from 5 spots in each employing grab sampling technique. The samples collected from each grid were bulked, composite were collected and stored in iced cooled flasks fixed with nitric acid to stamp out oxidation and taken to the laboratory for analyss. The samples were 125.

Samples Preparation and Analysis

The samples were analyzed using gas chromatography fixed with mass spectroscopy EU 1881/2014 method as described in (Devi *et al*., 2016, Zheng *et al*., 2016, Zhao et la., 2016) [19, 90, 89]. 5ml of the wetland water samples were measured out into beakers and 2g of anhydrous sodium sulphate ($NaSO_4$) added and shook vigorously for effective mixing. They were transferred into clean extraction beakers with tight cap and allowed to settle for 30 minutes. Dicafluorabiphenyl 20g were introduced into the beaker and also 5g of sodium hydrosulphate and the beakers were also vigorously agitated to a point when slurry flows freely. The beakers were then allowed to settle for 30 minutes to 1 hour and were then feed into the chambers of GC/MS Agilent Tripple Quadrupole model 7000 for the determination of pyrene chrysene, BaP, BaA and BbF.

Results

The results of the PAHs characterization in Ogbinbiri and environs wetlands were as in figures 2 to 6 and the comparative means of the contents of the PAHs in the wetlands in Fig 7.

The PAHs content in the wetlands in Ogbinbiri were as in Fig 2.

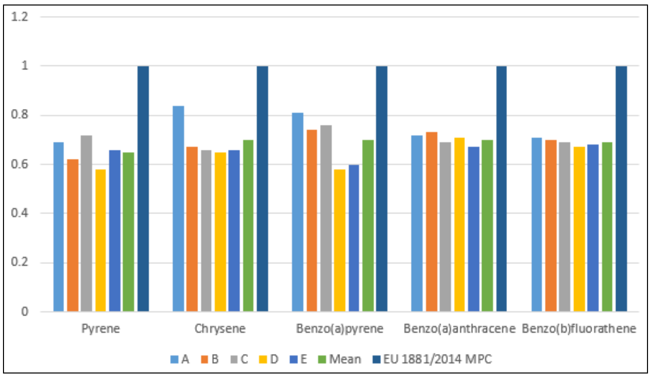


Fig 2: Results of the PAHs in the wetlands in Ogbinbiri and the EU 1881/2014 MPC for PAHs in wetland in µg/l

The result of the PAHs content of the wetlands in Ugbo-Rodo were as in Fig 3

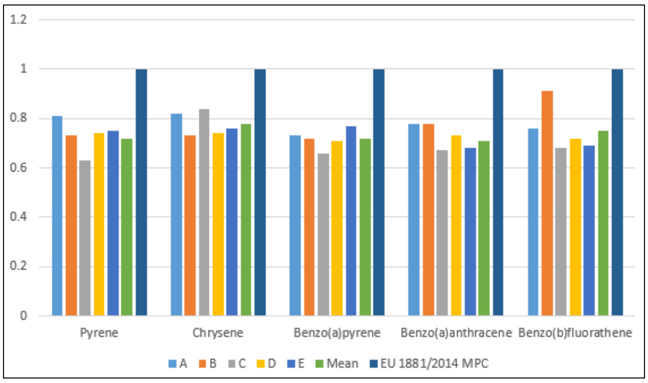


Fig 3: Results of the PAHs content in the wetlands in Ugbo-Rodo and EU 1881/2014 MPC for PAHs in wetland in µg/l

The results of the PAHs content in the wetlands in Ogbudogbodu were as in Fig 4.

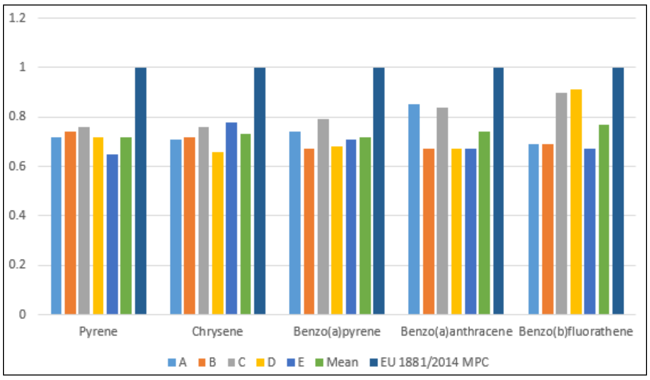


Fig 4: Results of the PAHs in the wetlands in Ogbudogbodu and the EU 1881/2014 MPC for PAHs in wetland in µg/l

The results of the PAHs content in the wetlands in Okoromado were as in Fig 5.

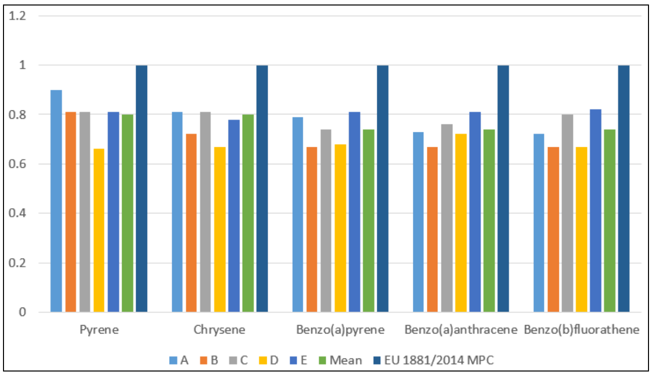


Fig 5: Results of the PAHs content in the wetlands in Okoromado and the EU 1881/2014 MPC for PAHs in wetland in µg/l

The results of the contents of the PAHs in the wetlands in Opuama were as in Fig 6.

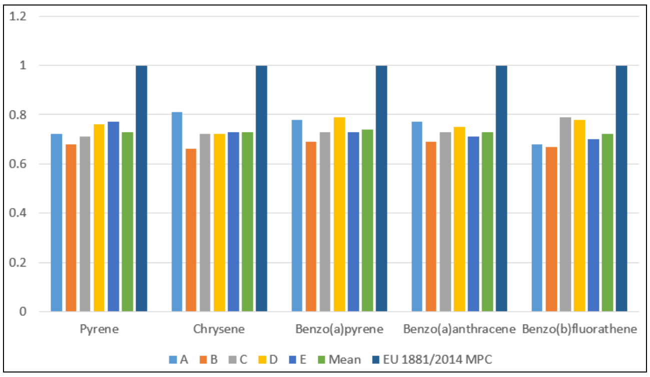


Fig 6: Results of the PAHs content in the wetlands in Opuama and the EU 1881/2014 MPC for PAHs in wetland in µg/l

The means comparison of the PAHs is the wetlands in Ogbinbiri and environs wetlands were as in Fig 7.

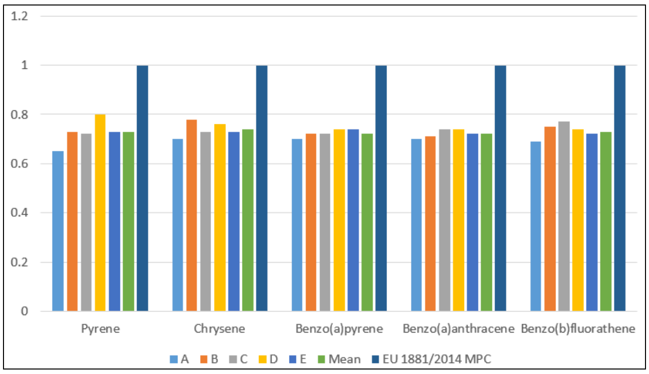


Fig 7: Results of the comparative MEANS of the PAHs in the wetlands in Ogbinbiri and environs and the EU 1881/2014 MPC for PAHs in wetland in µg/l

The means of the PAHs in the wetlands in Ogbinbiri, Nana, Ogbudogbodu, Okoromado and Opuama were then subjected to test of significance with analysis of variance (ANOVA) deploying special package for social sciences (SPSS) model 29 IBM at 0.05 and the *p* value was 0.061 thus accepting H_0.

Discussion of Findings

The analysis of the wetland waters in Ogbinbiri, Nana, Ogbudogbodu, Okoromado and Opuama wetlands presented varying concentrations of the variables investigated. The concentrations of pyrene in Ogbinbiri and environs wetlands were between 0.65 mg/l in Ogbinbiri to 0.80 µg/l in Okoromado with a mean concentrations of 0.73 µg/l. This result within acceptable threshold is similar to reports in (Ekandary *et al*, 2014, Fadiel *et al*., 2013 [32], El-Saeid *et al*., 2015 [27]). It is however at variance with the report in (Sun *et al*, 2016, Sumen *et al*., 2016) [76, 75].

The PAHs content analysis of Ogbinbiri and environs wetlands for the content of chrysene showed that chrysene concentrations in the wetlands range from 0.70 µg/l in Ogbinbiri to 0.78 µg/l in Ugbo-Rado with a mean concentration of 0.74 µg/l. This report is similar to the reports in (Yuanker *et al*., 2015, Zhai *et al*., 2016 [88], Zamani *et al*., 2015) who report low content of chrysene in wetland.

The wetland in Ogbinbiri and environs analysis for BaP concentration revealed that the BaP content vary from 0.70 µg/l in Ogbinbiri to 0.74 µg/l in Okoromado with a mean of 0.74 µg/l. This results of low concentration of BaP in wetland is in corroboration of the reports in the studies in (Liu *et al*., 2004, Liu *et al*., 2016) but desimilar to the reports in (Lim *et al*., 2015, Liang *et al*., 2016) [41, 40].

The report of the analysis of the wetlands in Ogbinbiri and environs revealed that the content of BaA was between 0.70 µg/l in Ogbinbiri to 0.74 µg/l in Ogbudogbodu and Okoromado with a mean of 0.72 µg/l. This report of low content of BaA in wetland is in agreement with the reports in (Dong *et al*., 2015, Duan et la., 2015, Taghawaee *et al*., 2015) [22, 25, 78], the report however disagrees with the reports in (storey *et al*., 2014, Zafra *et al*., 2015, Zafra *et al*., 2015) [74, 86, 85].

The analysis of the wetlands in Ogbinbiri and environs for the content of BbF presented the concentrations of BbF to range from 0.69 µg/l in Ogbinbiri to 0.77 µg/l in Ogbudogbodu with a mean content of 0.73 µg/l. This report of acceptable BbF in wetland is in consonance with the reports in (Eriksson *et al*., 2014 [29], Dudhagora *et al*., 2016, Zena *et al*., 2015 [87], Sungthong *et al*., 2015 [77]) but dissimilar to the reports in Domingos *et al*., 2015 [21], Duan *et al*., 2015 [25], Lin *et al*., 2016 [42]).

Conclusion and Recommendation

Sustainable economic development entails the utility of the environmental resources without jeopardizing the opportunity of the generation yet to come the enjoyment and utility of some resources and that is the mantra of the United Nations Organisation global goals. The analysis of the wetlands in Ogbinbiri and environs oil bearing communities for the content of the PAHs for the adoption of cage aquaculture for zero hunger has revealed that the wetlands are not polluted and contaminated by PAHs investigated above the EU 1881/2014 MPC for PAHs in wetlands and thus they are in healthy state for utility. Cage aquaculture can be adopted in The wetlands and the produce will be fit for human and animal consumption. The produce can equally be exported because they will scale codex Alimentarius conditions and standards for produce export.

Consequence upon these, the study recommended that the oil companies operating in Ogbinbiri and environs should continue to operate with the world best practices, the Federal governmental agencies charged with monitoring oil companies activities: National Environmental Standard Regulation and Enforcement (NESREA) and National Oil Spills Detection and Response Agency (NOSDRA) should continue with the standard surveillance of the oil company operations so as to sustain the health of the wetlands for the deployment of cage aquaculture for the attainment of zero hunger in Nigeria.

References

1. Abubakar Q. Economic recession in Nigeria, 2023. https://www.worldbank.org retrieved January 2024.
2. Adewale BC. Nigeria should revert to agriculture. Vanguard News pp. 50 – Economy, 18 September, 2019.
3. Afolabi JC. Evaluation of the adoption rate of cage aquaculture in Ondo state. Sahel Journal of Agriculture. 2022; 6(2):12-18.
4. Ajoko BA. Oil exploitation and the Ogoni environment. Discover Environment. 2023; 70(3):53-59.
5. Alexandra BT. SDG: 2 End hunger achieve food security, 2022. https://www.unwomen.org>infocus

6. Asuquo PN. Evaluation of the rural economy of the south-south littoral communities. Journal of Extension Agriculture. 2019; 13(2):41-46.
7. Babagana. Solve youths employment with youth agriculture. Punch news pp. 45 – Economy, 17 October, 2023.
8. Babatunde S. Nigeria economy will be stable with agriculture as mainstay. Punch News pp. 45 – Economy, 4 January, 2023.
9. Babawale PO. Pollution chemistry of Olomoge lagoon Lagos Nigeria. Journal of Water Pollution and Sanitation. 2022; 4(2):26-32.
10. Bamgboye J. Cage aquaculture adoption in Ogun state Nigeria. Journal of Agriculture Education. 2023; 12(3):40-46.
11. Benson S. SDG – Zero hunger, 2015. https://www.unicef.org retrieved January 2024.
12. Betrand C. World food programme – Zero hunger, 2018. https://www.wfp.ending.hunger retrieved January 2024.
13. Christopher P. Zero hunger, 2020. https://www.academy.org>goals Retrieved February, 2024
14. Daniel A. What do we mean by zero hunger, 2019. https://concernusa.org.new zero hunger
15. Davidson M. Sustainable food solution, 2020. https://www.nationalgeographicsociety.org.
16. de Oliveira Galvão MF, de Melo Cabral T, de André PA, de Fátima Andrade M, de Miranda RM, Saldiva PHN, *et al*. Cashew nut roasting: Chemical characterization of particulate matter and genotocixity analysis. Environmental Research. 2014; 131:145-152.
17. DellaValle CT, Deziel NC, Jones RR, Colt JS, De Roos AJ, Cerhan JR, *et al*. Polycyclic aromatic hydrocarbons: Determinants of residential carpet dust levels and risk of non-Hodgkin lymphoma. Cancer Causes and Control. 2016; 27(1):1-13.
18. Deng Q, Dai X, Guo H, Huang S, Kuang D, Feng J, *et al*. Polycyclic aromatic hydrocarbons-associated micrornas and their interactions with the environment: Influences on oxidative dna damage and lipid peroxidation in coke oven workers. Environmental Science and Technology. 2014; 48:4120-4128.
19. Devi NL, Yadav IC, Shihua Q, Dan Y, Zhang G, Raha P. Environmental carcinogenic polycyclic aromatic hydrocarbons in soil from Himalayas, India: Implications for spatial distribution, sources apportionment and risk assessment. Chemosphere. 2016; 144:493-502.
20. Dogora KT. Nigeria economic recessions 2016 and 2021, 2023. https://www.theeable.org
21. Domingos M, Bulbovas P, Camargo CZS, Aguiar-Silva C, Brandão SE, Dafré-Martinelli M, *et al*. Searching for native tree species and respective potential biomarkers for future assessment of pollution effects on the highly diverse Atlantic Forest in SE-Brazil. Environmental Pollution. 2015; 202:85-95.
22. Dong C, Bai X, Sheng H, Jiao L, Zhou H, Shao Z. Distribution of PAHs and the PAH-degrading bacteria in the deep-sea sediments of the high-latitude Arctic Ocean. Biogeosciences. 2015; 12:2163-2177.
23. Drake F. World food concern, 2021. https://www.education.org retrieved February 2024.
24. Duan X, Shen G, Yang H, Tian J, Wei F, Gong J, *et al*. Dietary intake polycyclic aromatic hydrocarbons (PAHs) and associated cancer risk in a cohort of Chinese urban adults: Inter- and intra-individual variability. Chemosphere. 2016; 144:2469-2475.
25. Duan Y, Shen G, Tao S, Hong J, Chen Y, Xue M, *et al*. Characteristics of polycyclic aromatic hydrocarbons in agricultural soils at a typical coke production base in Shanxi, China. Chemosphere. 2015; 127:64-69.
26. Dudhagara DR, Rajpara RK, Bhatt JK, Gosai HB, Sachaniya BK, Dave BP. Distribution, sources and ecological risk assessment of PAHs in historically contaminated surface sediments at Bhavnagar coast, Gujarat, India. Environmental Pollution. 2016; 213:338-346.
27. El-Saeid MH, Al-Turki AM, Nadeem MEA, Hassanin AS, Al-Wabel MI. Photolysis degradation of polyaromatic hydrocarbons (PAHs) on surface sandy soil. Environmental Science and Pollution Research. 2015; 22:9603-9616.
28. Enault J, Robert S, Schlosser O, de Thé C, Loret JF. Drinking water, diet, indoor air: Comparison of the contribution to environmental micropollutants exposure. International Journal of Hygiene and Environmental Health. 2015; 218:723-730.
29. Eriksson AC, Nordin EZ, Nyström R, Pettersson E, Swietlicki E, Bergvall C, *et al*. Particulate PAH emissions from residential biomass combustion: Time-resolved analysis with aerosol mass spectrometry. Environmental Science and Technology. 2014; 48:7143-7150.
30. Eromosele C. Heavy metals content of Ikpoba River Benin City. Total Environment. 2023; 72(3):103-109.
31. Eskandary S, Hoodaji M, Tahmourespour A, Abdollahi A. Bioremediation of PAHs from contaminated soils by Festuca aroundiacea in the presence of Bacillus licheniformis and Bacillus mojavensis. Journal of Residuals Science and Technology. 2014; 11:99-105.
32. Fadiel A, Epperson B, Shaw MI, Hamza A, Petito J, Naftolin F. Bioinformatic analysis of benzo-α-pyrene-induced damage to the human placental insulin-like growth factor-1 gene. Reproductive Sciences. 2013; 20:917-928.
33. Halilu MC. Nigeria economy can rebound through backward integration to agriculture. Vanguard news pp. 43 – Economy, 16 May, 2016.
34. International Labour Organisation. Unemployment in sub-Saharan Africa. ILO Publication Geneva Switzerland, 2023.
35. International Monetary Fund. Unemployment in Nigeria. IMF publication Washington USA, 2023.
36. Jackson MN. Zero hunger sustainable development, 2021. https://www.MonashUniversity.edu.about
37. Johnbull JA. Zero hunger – private sector pledge, 2021. https://www.gainhealth.org>about
38. Johnson T. Zero hunger, 2019. https://www.sustainability.org retrieved January 2024.
39. Jones A. Zero hunger, 2018. https://www.datatopic.org. Retrieved February 2024.
40. Liang X, Guo C, Wei Y, Lin W, Yi X, Lu G, *et al*. Cosolubilization synergism occurrence in codesorption of PAH mixtures during surfactant-enhanced remediation of contaminated soil. Chemosphere. 2016; 144:583-590.
41. Lim H, Mattsson A, Jarvis IWH, Bergvall C, Bottai M,

Morales DA, *et al*. Detection of benz[j]aceanthrylene in urban air and evaluation of its genotoxic potential. Environmental Science and Technology. 2015; 49:3101-3109.
42. Lin M, Ning XA, An T, Zhang J, Chen C, Ke Y, *et al*. Degradation of polycyclic aromatic hydrocarbons (PAHs) in textile dyeing sludge with ultrasound and Fenton processes: Effect of system parameters and synergistic effect study. Journal of Hazardous Materials. 2016; 307:7-16.
43. Liu L, Chen L, Shao Y, Zhang L, Floehr T, Xiao H, *et al*. Evaluation of the ecotoxicity of sediments from Yangtze River estuary and contribution of priority PAHs to Ah receptor-mediated activities. PLoS ONE. 2014; 9(8).
44. Maxmillian G. Global goals – zero hunger, 2019. https://www.globalgoals.com
45. Maxwel BC. Zero hunger – meaning, 2019. https://www.un.org.goal_2. Retrieved DEember 2023.
46. McDoff B. UN goal 2 – sustainable development, 2021. https://www.sdgs.un.org Retrieved January 2024.
47. National Bureau of Statistics. National oil production volume 2022. A NBS bulletin, Abuja, Nigeria, 2023.
48. Nigeria Upstream Petroleum Regulatory Commission. Nigeria oil production. An UPRC bulletin Abuja, 2023.
49. Nwankwo SA. Nigeria economy before oil. Vanguard news pp. 38 – Economy, 17 December, 2018.
50. Ochu BN. Oil wealth curse or blessing to Nigeria. Tribune News pp. 32 – Economy, 12 June, 2018.
51. Ododo PC. Fish production and the economy of the riverine communities in Delta state, Nigeria. Journal of Agricultural Science. 2018; 61(2):90-95.
52. Ogwu C, Imobighe M, Okofu S, Attamah F. Speciation of heavy metals in fish species in the wetlands of oilbearing communities of the Niger Delta; IJB, V21, N2, August, 2022, 169-178.
53. Ogwu C. Heavy metals loadings of Telfairia occidentalis (Fluted pumpkin) grown in Ekpan (Host community of Warri Refinery and Petrochemical) Nigeria. Quest Journals: Journal of Research in Agriculture and Animal Science. 2021; 8(1):16-20.
54. Ogwu C, Azonuche JE, Okumebo VO. Heavy metals content of Telfairiaoccidentalis (fluted pumpkin; order: Violales, Family: Cucurbitacea) grown in Ebedei (An oil and gas bearing community) Niger Delta, Nigeria. Quest Journals: Journal of Research in Humanities and Social Science. 2021; 9(4):74-78.
55. Ogwu C, Azonuche J, Achuba F. Heavy metals quantification of Telfairia occidentalis (Fluted pumpkin, Order: Violales, family: Cucurbitaceae) grown in Niger Delta oil producing areas. International Journal of Biosciences. 2021; 13(2):170-179.
56. Ogwu C, Ideh Victor, Imobighe Mabel. Bioaccumulation of heavy metals in some pelagic and benthic fish species in selected wetlands in oil-bearing communities of the Niger Delta; International Journal of Biosciences. 2022; 20(6):128-139.
57. Ogwu C, Azonuche JE, Okeke M. Heavy metals contamination status of Telfairiaoccidentalis (Fluted pumpkin) grown in Uzere oil rich community, Niger Delta. Quest Journal: Journal of Research in Agriculture and Animal Science. 2020; 7(7):12-17.
58. Ogwu C, Abvbunudiogba RE, Ogune P, Aloamaka TA. Analysis of the heavy metals content of Lagos Lagoon Lagos Nigeria. International Journal of Recent Research in Physics and Chemical Sciences. 2023; 10(1):1-6.
59. Ogwu C, Obi-Okolie F, bvbunudiogba RE. Quantification of the heavy metals in the groundwater of Ikeja industrial estate, Ikeja Lagos. Quest Journal of Research in Environmental and Earth Science. 2023; 9(3):69-73.
60. Ogwu C, Ossai AC, Ejemeyovwi DO, Unuafe SE. Characterisation of the heavy metals in the aquifer of Matori Industrial estate Lagos Nigeria. Quest Journal of Research in Environmental and Earth Science. 2023; 9(3):20-26.
61. Ogwu C, Ossai AC, Ejemeyovwi DO, Unuafe SE. IOSR Journal of Environmental Science, Toxicology and Food Technology. 2023; 17(issue 3, sir 1):01-06.
62. Ogwu C, Ukpene AO, Ekpe IN, Aregbor O. Bioaccumulation of heavy metals in the tissues of some fishes species in selected wetlands in Lagos Nigeria. Journal of Innovation. 2023; 72:1407-1418.
63. Ogwu C, Ukpene AO, Ekpe IN, Umukoro BOJ, Onuelu JE. Quantification of heavy metals and metalloid in cassava roots (manihot esculenta crantz; family: Euphorbiaceae) grown in oil bearing communities of the Niger Delta. Innovation Journal. 2023; 73:89-101.
64. Osakwe CA. Fishery and aquaculture production in Delta state, Nigeria. Asian Journal of Agriculture. 2023; 28(3):120-125.
65. Osawuru JO. Pollution chemistry in Ovia wetlands. Journal of Environmental Monitoring. 2023; 62(2):142-148.
66. Oteriba OO. Nigeria unemployment rate in 2023. Lagos: Oteriba Economic Consultants, 2023.
67. Pedro JC. Zero hunger meaning, 2019. https://www.sdgresources.org. retrieved December, 2023.
68. Ruwani B. Nigeria food demand and production 2022. Lagos: Financial Derivatives Ltd, 2023.
69. Saint F. Zero hunger, 2019. Https://www.datatopic.org retrieved December, 2023
70. Samuelson C. Zero hunger meaning and definition, 2019. https://www.e045dg https://www.04sdg.org retrieved December, 2023.
71. Shedrack P. Zero hunger – close the gap, 2022. https://wwwclosethegapfoundation.org retrieved March, 2024.
72. Sobowale M. Nigeria Economic recession, 2022. https://www.reuks.com>finance retrieved January 2024.
73. Soul PA. Zero hunger meaning, 2020. https://www.zerohunger.com retrieved March 2024.
74. Storey S, Ashaari MM, McCabe G, Harty M, Dempsey R, Doyle O, *et al*. Microbial community structure during fluoranthene degradation in the presence of plants. Journal of Applied Microbiology. 2014; 117:74-84.
75. Suman S, Sinha A, Tarafdar A. Polycyclic aromatic hydrocarbons (PAHs) concentration levels, pattern, source identification and soil toxicity assessment in urban traffic soil of Dhanbad, India. Science of The Total Environment, 2016, 545-546, 353-360.
76. Sun H, Wang W, Guo S, Zhang Y. In situ investigation into surfactant effects on the clearance of polycyclic aromatic hydrocarbons adsorbed onto soybean leaf surfaces. Environmental Pollution. 2016; 210:330-337.
77. Sungthong R, van West P, Cantos M, Ortega-Calvo JJ.

Development of eukaryotic zoospores within polycyclic aromatic hydrocarbon (PAH)-polluted environments: A set of behaviors that are relevant for bioremediation. Science of the Total Environment. 2015; 511:767-776.
78. Taghvaee Z, Piravivanak Z, Rezaei K, Faraji M. Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Olive and Refined Pomace Olive Oils with Modified Low Temperature and Ultrasound-Assisted Liquid-Liquid Extraction Method Followed by the HPLC/FLD. Food Analytical Methods. 2015; 9:1220-1227.
79. United Nations Organisation. Conference on sustainable development Rio de Jeneiro, Brazil, 2012. Retrieved January, 2024.
80. United States Environmental Protection Agency. Water pollutants and toxicants. A USDPA publication Georgia United State of America, 2012.
81. World Health Organisation. Ppolycyclic aromatic hydrocarbons and human health. A WHO publication Geneva Switzerland, 2018.
82. Yuan H, Li T, Ding X, Zhao G, Ye S. Distribution, sources and potential toxicological significance of polycyclic aromatic hydrocarbons (PAHs) in surface soils of the Yellow River Delta, China. Marine Pollution Bulletin. 2014; 83:258-264.
83. Yunker MB, Macdonald RW, Ross PS, Johannessen SC, Dangerfield N. Alkane and PAH provenance and potential bioavailability in coastal marine sediments subject to a gradient of anthropogenic sources in British Columbia, Canada. Organic Geochemistry, 2015, 89-90, 80-116.
84. Zafra G, Cortés-Espinosa DV. Biodegradation of polycyclic aromatic hydrocarbons by Trichoderma species: A mini review. Environmental Science and Pollution Research. 2015; 22:19426-19433.
85. Zafra G, Moreno-Montaño A, Absalón Á, Cortés-Espinosa DV. Degradation of polycyclic aromatic hydrocarbons in soil by a tolerant strain of Trichoderma asperellum. Environmental science and pollution research international. 2015; 22:1034-1042.
86. Zamani J, Hajabbasi MA, Alaie E, Sepehri M, Leuchtmann A, Schulin R. The effect of Piriformospora indica on the root development of maize (Zea mays L.) and remediation of petroleum contaminated soil. International Journal of Phytoremediation. 2016; 18:278-287.
87. Zena R, Speciale A, Calabrò C, Calò M, Palombieri D, Saija A, *et al*. Exposure of sea bream (Sparus aurata) to toxic concentrations of benzo[a]pyrene: Possible human health effect. Ecotoxicology and Environmental Safety. 2015; 122:116-125.
88. Zhai Y, Li P, Zhu Y, Xu B, Peng C, Wang T, *et al*. Source apportionment coupled with gas/particle partitioning theory and risk assessment of polycyclic aromatic hydrocarbons associated with size-segregated airborne particulate matter. Water, Air, and Soil Pollution. 2016; 227.
89. Zhao Z, Zhang L, Cai Y, Chen Y. Distribution of polycyclic aromatic hydrocarbon (PAH) residues in several tissues of edible fishes from the largest freshwater lake in China, Poyang Lake, and associated human health risk assessment. Ecotoxicology and Environmental Safety. 2014; 104:323-331.
90. Zheng H, Xing XL, Gu YS, Gui FK, Qi SH, Huang HF. Distribution characteristics of polycyclic aromatic hydrocarbons in different environmental media from Qingbang Island, Zhoushan, China. Huanjing Kexue/Environmental Science. 2016; 37:513-519.