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Full Length Research Article

GEOSPATIAL QUANTIFICATION OF THE POLYCYCLIC AROMATIC HYDROCARONS (PAHs) IN THE WETLANDS OF KOLOKOLO AND ENVIRONS (OIL BEARING COMMUNITIES), WARRI NORTH, DELTA, NIGERIA

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ABSTRACT

This study was an ex-port factor research that investigated the content of PAHs in the wetlands in Kolokolo and environs. The study answered 5 research questions and tested a hypothesis. To achieve these, the wetlands in the 5 settlements were mapped into 5 sampling grids of 50 meters apart and water samples were collected from 5 spots with 125mL plastic sampling bottles at 10cm depth and covered sub surface. The samples from each grid were bulked, composites drawn and fixed with HNO_3 and stored in ice cooled flasks for analysis. The analytical standard adopted was EU 1881/2014 while the instrument of determination deployed was Agilent GC/MS Triple Quadruple model 7000. The mean result obtained were; pyrene 1.02 ± 0.01µg/l, chrysene, 1.02±0.01 µg/l, BaP; 1.03 ± 0.01µg/l BaA; 1.02 ±0.02ug/l and BbF, 1.03 ± 0.02µg/l. The mean results were subjected to test of significance with ANOVA using SPSS IBM model 29 at 0.05 level of significance and the *p* value was 0.042 thus rejecting H_o. The study concluded that the wetlands are contaminated with PAHs above EU 1881/2014 MPC for wetlands thus the produce are not fit for human and animal consumption. They are equally not exportable. The study recommended that the oil companies should be compelled to adopt world best practices in their operational activities, the monitoring agencies NESREA and NOSDRA should scale up their surveillance and the impacted ecosystem should be remediated and restored.

Keywords: aromatic hydrocarbons (PAHs), Wetlands, Oil production, polycyclic contamination.

INTRODUCTION

Wetlands are complex, delicate and highly valuable ecosystem that exist in varying degrees in virtually all countries on the planet earth. It is an ecosystem that is saturated or flooded with water permanently or partially for decades, or years (Sabastine 2021, Cole 2022, Ogwu *et al.,* 2022) Wetlands are areas where water is present near the surface of the soil in most period of the year (Thompson 2016, Dell 2018, Sodiq 2023). They are transitional lands between aquatic and terrestrial lands with high water table usually near the surface and in most times covered by shallow water (Shingle 2019, Doff 2021, Spence 2018) Wetlands are areas of land covered by swamp, bog, fen or mash (Benson 2015 Betrand 2018). They are low lying lands with soil spongy in nature with high moisture content all year round. (Onwuka 2017, Ogwu *et al.,* 2022, Ogwu *et al.,* 2021).

Wetland ecosystem is the habitat for numerous species of fauna and flora (Ogwu 2021, Bamgboye 2022, Adeeko 2021), they provide shore protection, prevent coastal erosion and purify run off water (Surrel 2019, Maxwell 2018, Afocabi 2020). Wetlands provide breeding place for fish and wetland animals (Osodeke 2019), and provide recreation and tourists destination (Duru 2018, Odili 2020), they recharge the rivers, cool the higher grounds and balance redox reaction. (Ogwu *et al.,* 2023 Okpako 2023, Maduka 2024).

Wetlands globally have been subjected to various abuses from industrial effluents discharges containing heavy metals, pesticides, detergents, styroforms, (Ogwu *et al.,* 2022, Ogwu *et al.,* 2021), micro plastics, polycyclic aromatic hydrocarbons (PAHs) Benson *et al.,* 2014, Beriro *et al.,* 2016, Chen *et al.,* 2015, Chang *et al.,* 2016). Polycyclic aromatic hydrocarbons (PAHs) are a class of organic compounds that are composed of simple to complex benzene rings (Canozzi *et al.,* 2016, Caruso *et al.,* 2015, Celeiro *et al.,* 2014). PAHs occur naturally in coal, gasoline and crude oil (Cili *et al.,* 2014, Dela-Rosa *et al.,* 2016, Chropenova *et al.,* 2016). Oil spillage into and wetland occur via pipelines rupture; well head blow out, tank wash equipment failure (Ogwu *et al.,* 2022, Abubakar 2020, Nurudeen 2022). Bioavailability of PAHs in wetland ecosystem results in bioaccumulation and biomultiplication in wetland fauna and flora (Coronas *et al.,* 2016, Corrotea *et al.,* 2014, Dellarulle *et al.,* 2016, Deng *et al.,* 2014) and PAHs have been fingered in cateracts, liver problems, renal complications, cancer of the gastrointestinal tract. (El-Saeid *et al.,* 2015).

Kolokolo and the adjoining villages are wetland oil bearing communities whose wetlands are the recipients of the spills that occur during oil extraction and loading. The focus of this study is the analysis of the wetlands water in Kolokolo, Ayogboro, Daghele, Eghoro and Dudu Town for the contents of polycyclic aromatic hydrocarbons as concomitant effect of oil production in the area.

The PAHs investigated are pyrene, chrysene, Benzo(a)pyrene (BaP), benzo(a) anthracane (BaA), and benzo(a) fluorathene (BbF)

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Research Questions

The study was guided by research questions as:

1. what are the concentrations of pyrene, chrysene BaP, BaA and BbF in the wetlands of Kolokolo and environs?
2. are the concentrations of the PAHs in the wetlands within the maximum Permissible Concentration(MPC) of 1.00µg/l as espoused by EU code1881/2014?
3. are the produce from the wetlands fit for human consumption?
4. will the produce be fit for animal feeds formulation?
5. will the produce be exportable considering Codex 1963 commission standards for produce export?

Hypothesis

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

H_0: there is no significant difference between the concentrations of PAHs in the wetlands in Kolokolo and environs and EU 1881/2014 MPC for PAHs in wetlands.

Study Area

Kolokolo, Ayogboro, Daghele, Egboro and Dudu Town are oil bearing Itsekiri settlements in Warri North local government area Delta state Nigeria. They are within latitude 6° 45' 31"N and longitude 5° 4" E. The inhabitants of these wetlands settlement are predominantly fishermen and farmers. Some are artisans while some are petty traders. A very few are public servants teaching in public primary and secondary schools and some work in the oil companies operating in the area.

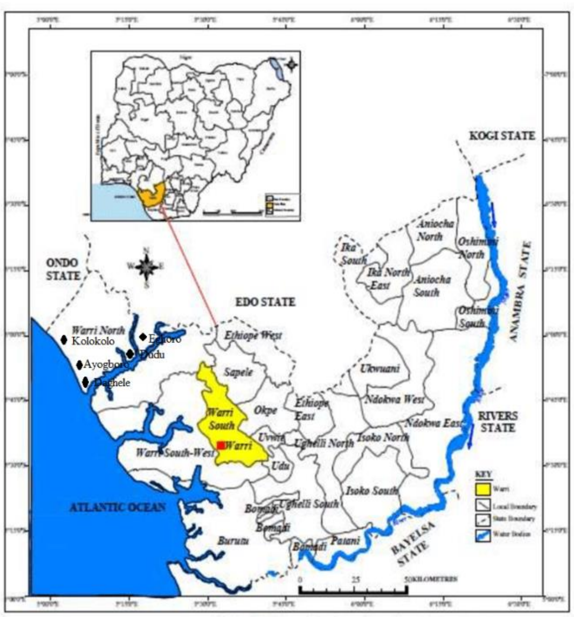

Figure 1: Map of Warri North Showing Kolokolo and environs) Adapted from: Ogeleka et al. (2016)

MATERIALS AND METHODS

This study was conducted within a period of six (6) months spanning from October 2023 to march 2024. Five (5) research assistants were enlisted for the samples collection, one in each of the 5 settlements. Grab hydrological sampling technique was adopted, and the wetlands were mapped out into 5 sampling grids and Samples were collected from 5 spots in each grid using 125mL plastic sampling bottle at 10cm depth, bulked and composites taken fixed with nitric acid and stored in ice cooled sample boxes for analysis. 125 samples were collected for the study.

Analysis

The samples were analyzed using gas chromatography with mass spectrometry adopting EU 1881/2014 as describe in (Dudghagara *et al.,* 2016, Dong *et al.,* 2015 Ganna *et al.,* 2014) 5ml of the wetlands water samples were measured into beakers into which 2g of sodium sulphate (anhydrous) were added. They were agitated vigorously for good mixing. The mixtures were then transferred into extraction beakers with tight lids and allowed to settle for 30minutes. Dicafluorabiphenyl were added and also sodium hydrosulphate and the beakers were again vigorously agitated until free flowing flurry appears. The beakers were allowed to settle again for about 30 minutes to 1 hour. The mixtures produced were aspirated into gas chromatography and mass spectrometry (GC/MS) chambers of Agilent Triple Quadruple 7000 model for the reading of the concentrations of PAHs under investigation.

RESULTS

The results of the PAHs content in the wetlands in Kolokolo and environs were as in Figures 2 to 6 and comparative means result in Figure 7.

The values obtained from Kolokolo were as in Figure 2.

Table 1: results of the PAHs content in Kolokolo and EU 1881/2014 MPC for PAHs in wetlands in µg/l

	A	B	C	D	E	Mean	EU 1881/2014 MPC µg/l
Pyrene	1.03	1.03	1.02	1.02	1.03	1.03	1
Chrysene	1.01	1.04	1.07	0.97	1.03	1.01	1
Benzo(a)pyrene	1.02	1.03	1.02	0.98	1.04	1.02	1
Benzo(a)anthracene	1.01	0.98	1.03	1.02	1.02	1.01	1
Benzo(b)fluorathene	1.03	0.99	1.04	1.03	1.03	1.02	1

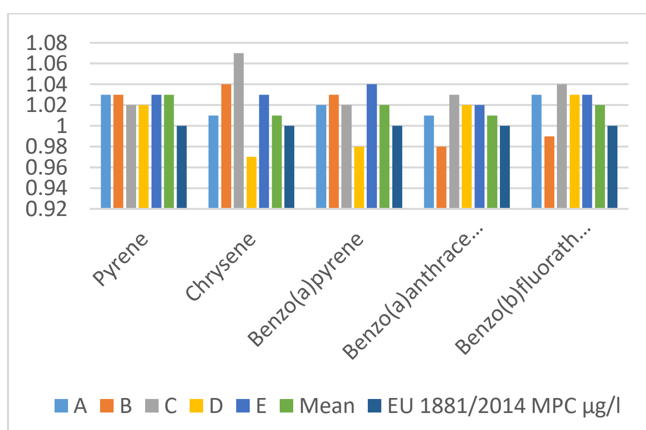

Figure 2: results of the PAHs content in Kolokolo and EU 1881/2014 MPC for PAHs in wetlands in µg/l

The values obtained from Ayogboro were as in Figure 3.

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Table 2: results of the PAHs content of the wetland in Ayogboro and EU 1881/2014 MPC for PAHs in wetland in µg/l

	A	B	C	D	E	Mean	EU 1881/2014 MPC µg/l
Pyrene	0.98	1.01	1.03	1.02	1.01	1.01	1
Chrysene	1.03	1.02	1.02	1.02	1.04	1.03	1
Benzo(a)pyrene	1.03	1.03	1.04	1.03	1.01	1.03	1
Benzo(a)anthracene	1.02	1.01	1	1.03	1.02	1.02	1
Benzo(b)fluorathene	1.01	1.03	1.03	1.02	1.03	1.03	1

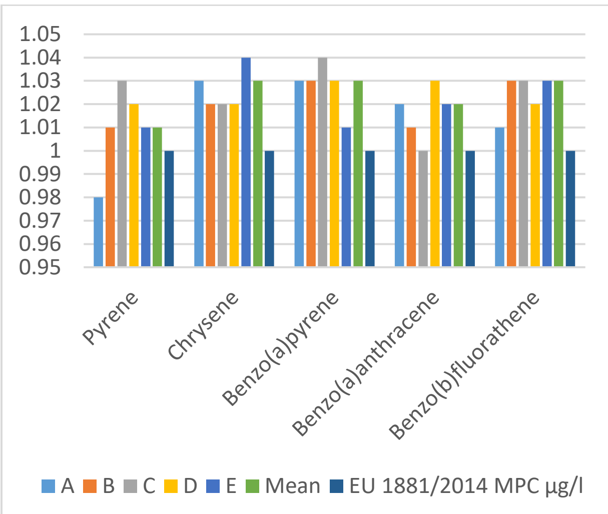

Figure 3: results of the PAHs content of the wetland in Ayogboro and EU 1881/2014 MPC for PAHs in wetland in µg/l

The values obtained from Daghele were as in Figure 4.

Table 3: results of the PAHs content in wetlands in Daghele and EU 1881/2014 MPC for PAHs in wetlands in µg/l.

	A	B	C	D	E	Mean	EU 1881/2014 MPC µg/l
Pyrene	1.02	1.01	1.03	1.04	1.02	1.02	1
Chrysene	1.03	1.01	1	1.02	1.03	1.02	1
Benzo(a)pyrene	1.03	1.02	1.04	1.03	1.03	1.03	1
Benzo(a)anthracene	1.02	1	1.03	1.04	1.02	1.02	1
Benzo(b)fluorathene	1.03	1.02	1.02	1.04	1.03	1.03	1

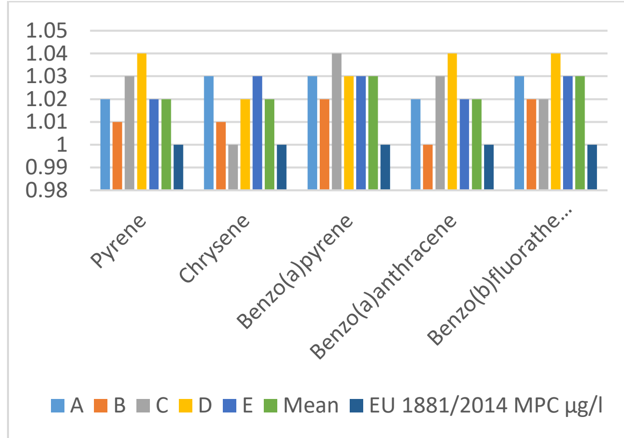

Figure 4: results of the PAHs content in wetlands in Daghele and EU 1881/2014 MPC for PAHs in wetlands in µg/l.

The values obtained from Egboro were as in Figure 5.

Table 4: results of the PAHs content in wetland in Egboro and EU 1881/2014 MPC for PAHs in wetlands in µg/l

	A	B	C	D	E	Mean	EU 1881/2014 MPC µg/l
Pyrene	1.02	1.03	1	1	1.02	1.01	1
Chrysene	1.02	1.02	1.04	1.04	1.03	1.03	1
Benzo(a)pyrene	1.02	1.02	1.03	1.03	1.04	1.03	1
Benzo(a)anthracene	1.02	1.03	1.03	1.04	1.02	1.03	1
Benzo(b)fluorathene	1.03	1.03	1.04	0.99	1.03	1.02	1

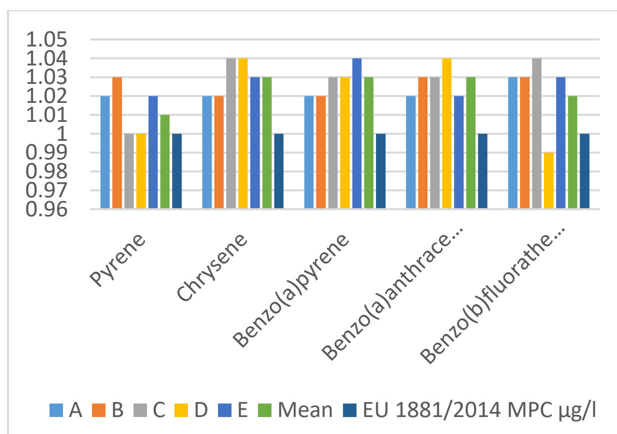

Figure 5: results of the PAHs content in wetland in Egboro and EU 1881/2014 MPC for PAHs in wetlands in µg/l

The values obtained from Dudu Town were as in Figure 6.

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Table 5: results of the PAHs content in wetland in Dudu Town and EU 1881/2014 MPC for PAHs in wetlands in µg/l.

	A	B	C	D	E	Mean	EU 1881/2014 MPC µg/l
Pyrene	1.03	1.04	0.98	1.04	1.04	1.03	1
Chrysene	0.99	1.03	1.03	1.02	1.02	1.02	1
Benzo(a)pyrene	1.02	1.03	1.02	1.03	1	1.02	1
Benzo(a)anthracene	1.03	1.02	1.01	1.03	1.03	1.02	1
Benzo(b)fluorathene	1.04	1.03	1.04	1.03	1.03	1.03	1

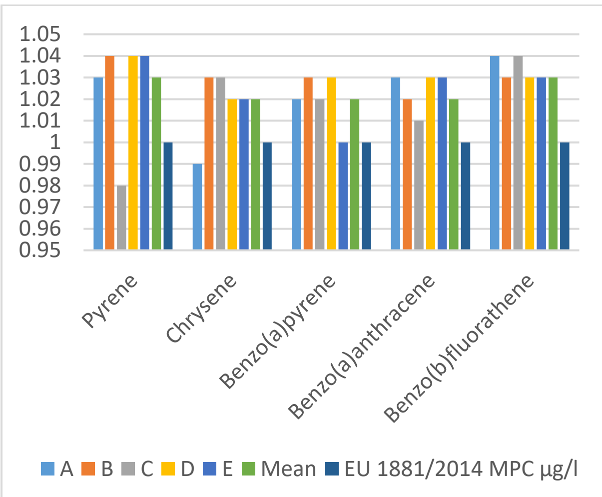

Figure 6: results of the PAHs content in wetland in Dudu Town and EU 1881/2014 MPC for PAHs in wetlands in µg/l.

The comparative mean results are as in Table 7 and Figure 7

Table 6: mean results of the PAHs content of the wetlands in Kolokolo and environ and EU 1881/2014 MPC for PAHs in wetlands in µg/l.

	A	B	C	D	E	Mean	EU 1881/2014 MPC µg/l
Pyrene	1.03	1.01	1.02	1.01	1.03	1.02	1
Chrysene	1.01	1.03	1.02	1.03	1.02	1.02	1
Benzo(a)pyrene	1.02	1.03	1.03	1.03	1.02	1.03	1
Benzo(a)anthracene	1.01	1.02	1.02	1.03	1.02	1.02	1
Benzo(b)fluorathene	1.02	1.03	1.03	1.02	1.03	1.03	1

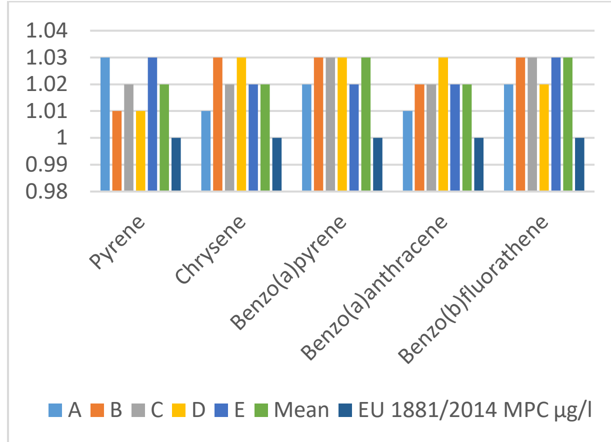

Figure 7: mean results of the PAHs content of the wetlands in Kolokolo and environ and EU 1881/2014 MPC for PAHs in wetlands in µg/l.

The mean results of the PAHs in the wetlands in Kolokolo and environs were subjected to test of significance with analysis of variance using special package for social science (SPSS) IBM model 29 at 0.05 level of significance. The *p* value was 0.042 thus rejecting Ho.

DISCUSSION OF FINDINGS

PAHs contamination of wetlands occasioned by industrial activities is replete in literature but studies of PAHs contamination of wetlands in Kolokolo and surrounding settlements remain unavailable and this underscored the study. The investigation of the PAHs content in Kolokolo and environ presented varying results.

The concentration of pyrene in the wetlands in the Kolokolo and environs showed a range of 1.01µg/l in Ayogbero, and Egboro to 1.03µg/l in Kolokolo and Dudu Town with a group mean of 1.02µg/l. This increased pyrene is anthopogenic. A similar report was in (Ogwu *et al.*, 2022, Fan *et al.*, 2014, Gao *et al.*, 2015). Ingestion of food contaminated by pyrene has been implicated in cancer of the gastro intestinal tract (Goa *et al.*, 2015) skin irritation, osteoporosis (Garrido *et al.*, 2014, Garcia- London *et al.*, 2015).

The wetland water analysis of Kolokolo and environs for the content of chrysene revealed the concentrations to be between 1.01µg/l in Kolokolo to 1.03µg/l in Ayogboro and Egboro with a mean of 1.02µg/l. The elevated concentration of chrysene is traceable to the oil production activities in the area. This report is similar to reports in (Ogwu *et al.*, 2021, Foan *et al.*, 2015, Feng *et al.*, 2015, Guo *et al.*, 2015). Chrysene contamination have been fingered in liver degeneration, kidney failure (Han *et al.*, 2015, Hallare *et al.*, 2016, Grossman *et al.*, 2016), gene mutation (Hashemi *et al.*, 2016, Ogwu *et al.*, 2022).

The analysis of the wetlands in Kolokolo for the content of BaP presented a concentration of 1.02µg/l in Kolokolo and Dudu Town to 1.03µg/l in Ayogboro, Dughele and Egboro with a group mean of 1.03µg/l; This high content of BaP is the impact of oil production in the area. This report is a corroboration of the reports in (Hassanwand *et al.*, 2015). The effect of BaP in human health include mutation, tetratogenic problems and lung cancer (Hussain *et al.*, 2015, Isaac at al 2015) renal failure, cancer of the bone (Hu *et al.*, 2016).

BaA analysis in the wetlands of Kolokolo and environs presented the concentrations of 1.01µg/l in Kolokolo to 1.03µg/l in Egboro with a mean of 1.02µg/l. This high content of BaA is as a result of man's interaction with the ecosystem via oil activities. High content of BaA was in the reports of (Auang *et al.,* 2015, Hung *et al.,* 2014, Heyderi *et al.,* 2014). BaA in man is associated with skin and lung cancer, eye irritation (Yang *et al.,* 2015, hang *et al.,* 2014, hang *et al.,* 2016).

The analysis of the wetland water in Kolokolo and environs for BbF showed that the concentrations of BbF varied from 1.02µg/l in Kolokolo and Egboro to 1.03µg/l in Ayogboro, Daghele and Dudu Town with a mean of 1.03µg/l. This increased content of BbF in the wetland is the effect of oil extraction activities. This result is in agreement with reports in (Kalwa *et al.,* 2014, Kamal *et al.,* 2015, Ogwu *et al.,* 2023). Health implications of human prolonged exposure to BbF include nephropathy, increases in liver enzymes (Ivshina *et al.,* 2016, Jin *et al.,* 2014, Jimenez *et al.,* 2014).

Conclusion and Recommendation

Contamination of wetlands through industrial activities is a global challenge that require concerted efforts from all concerned to ameliorate. The analysis of the wetlands in Kolokolo and environs has further reaffirmed reports in varying literature of industrial activities and wetlands contamination. The result of the analysis of the wetlands in Kolokolo and environs revealed the contamination of the ecosystems with PAHs above the maximum allowable concentration stipulated in EU 1881/2014 and thus the produce are not suitable for human and animal consumption. The produce will not be exportable for the failure to scale Codex Alimentarius hurdle for produce export.

Against this back drop, the study recommended thus;

The oil companies operating in Kolokolo and environs should be made to keep to standard global practice in oil industry; the monitoring agencies National Environmental Standards Regulation and Enforcement Agency (NESREA) and National Oil Spills Detection and Response Agency should be compelled to do their work efficiently to ensure oil companies compliance to set down standards and the impacted wetlands should be remediated and restored forthwith for continued ecosystem services.

REFERENCES

Adegbye, M. N. (2016). Youths employment and cage aquaculture in riverine communities of Ogun state. *Journal of Extension Services* 20(1), 100-106.

Adegoke, P. A. (2022). Cage aquaculture adoption and the polycyclic aromatic hydrocarbon content of Camp Aduwo Ondo state. *Journal of Environmental Monitoring* 17(2), 201-207.

Adewale, M. (2022). Oil production and Nigeria economy. In Ibironke, E. (Ed). The Economy of Nigeria Present and Future. Lagos: Fredrick Foundation

Afolabi, T. J. (2022). Cage aquaculture adoption in Yewa area of Ogun state. *Journal of Agricultural Extension and Economics* 18(3), 212-217.

Aguelinen, A. O. (2022). Oil spillage and the environment of Niger Delta. *Journal of Total Environment* 22(2), 222-227.

Atshana, D. and Atshana, P. (2012). Water contaminants. New Delhi: EOPA Publishers Ltd.

Audu, O. (2024). Importation creates unemployment and employment in country of ogirin. Channel Television Hardcopy with Audu Ogbe.

Bamgboye, C. N. (2016). Water pollution and cage aquaculture adoption in Ilaje communities of Ondo state, Nigeria. *Journal of Marine Toxicity* 22(2), 192-198.

Bell, J. F. (2020). What is sustainable economic development. https://www.ukindeed.com retrieved January 2024.

Benson, N. U., Essien, J. P., Asuquo, F. E., & Eritobor, A. L. (2014). Occurrence and distribution of polycyclic aromatic hydrocarbons in surface microlayer and subsurface seawater of Lagos Lagoon, Nigeria. Environmental Monitoring and Assessment, 186, 5519–5529.

Beriro, D. J., Cave, M. R., Wragg, J., Thomas, R., Wills, G., & Evans, F. (2016). A review of the current state of the art of physiologically-based tests for measuring human dermal in vitro bioavailability of polycyclic aromatic hydrocarbons (PAH) in soil. Journal of Hazardous Materials, 305, 240–259.

Brandson, C. (2019). Economic sustainability: definition, importance and example. https://www.masterclass.com retrieved November 2023.

Brook, G. (2023). Sustainable economic development. https:///glz.de.worldwide retrieved January, 2024.

Caruso, J. A., Zhang, K., Schroeck, N. J., McCoy, B., & McElmurry, S. P. (2015). Petroleum coke in the urban environment: A review of potential health effects. International Journal of Environmental Research and Public Health, 12, 6218–6231.

Celeiro, M., Lamas, J. P., Garcia-Jares, C., Dagnac, T., Ramos, L., & Llompart, M. (2014). Investigation of PAH and other hazardous contaminant occurrence in recycled tyre rubber surfaces. Case-study: restaurant playground in an indoor shopping centre. International Journal of Environmental Analytical Chemistry, 94, 1264–1271.

Chang, Y. T., Lee, J. F., Liu, K. H., Liao, Y. F., & Yang, V. (2016). Immobilization of fungal laccase onto a nonionic surfactant-modified clay material: application to PAH degradation. Environmental Science and Pollution Research, 23, 4024–4035.

Chen, Y., Zhi, G., Feng, Y., Tian, C., Bi, X., Li, J., & Zhang, G. (2015). Increase in polycyclic aromatic hydrocarbon (PAH) emissions due to briquetting: A challenge to the coal briquetting policy. Environmental Pollution, 204, 58–63.

Doris Fovwe Ogeleka, Oghenekohwiroro Edjere, Nwudu Angela, Felix Okieimen (2016). Ecological effects of oil spill on pelagic and bottom dwelling organisms in the riverine areas of Odidi and Egwa in Warri, Delta State, Journal of Ecology and the Natural Environment 8(12):201-211
European Union (2014). Polycyclic aromatic hydrocarbon maximum permissible concentrations in wetland water code 1881.

Frederick, S. A. (2019). Sustainable development: meaning, definition, goals. https://www.byjus.com commerce. Retrieved December, 2023.

Hanson, F. (2022). Sustainable economic development: meaning, history, principles, pillars. https://www.tandton.com retrieved January 2024.

Haruna, M. S. (2023, 16 June). The problem with Nigeria economy. Guardian News pp. 54. Economy

Jone, P. (2018). Sustainable economic development. *International Monetary Fund Library. https://www.elibrary.imf.org.* retrieved November 2022.

Lawal, D. (2023, 20 August). Economic recessions and Nigeria economic policies. Punch news pp. 46 Economy. National Bureau of Statistics (2023). Nigeria oil production and sales 2022. NBS bulletin, Abuja Nigeria.

Nwankwo, J. C. (2022). Diversification, antidote to Nigeria ecnomy. https://www.diversificationnig.com retrieved November 2023.

Ochu, F. T. (2023 17 June). Diversify Nigeria economy to solve youth's unemployment. Punch News pp. 35 – Economy.

Oden, F. T. (2022). Adoption of cage aquaculture in the rural littoral communities of Delta state. *Journal of Agricultural Science* 12(2), 91-96.

Ogwu C, Imobighe M, Okofu S, Attamah F (2022), Speciation of heavy metals in fish species in the wetlands of oilbearing communities of the Niger Delta; IJB, V21, N2, August, P169-178.

Ogwu C. (2021). 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. 8(1), 16-20

Ogwu C. (2024) Characterization of the Polycyclic aromatic hydrocarbon in the wetlands of Gbokoda and environs for pen aquaculture adoption as a recipe for achieving zero hunger in Nigeria

Ogwu C., Azonuche J E and Okumebo V. O. (2021). 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. 9(4), 74-78 [29].

Ogwu C., Azonuche J., and Achuba F (2021). Heavy metals quantification of Telfairia occidentalis (Fluted pumpkin, Order: Violales, family: Cucurbitaceae) grown in Niger Delta oil producing areas. International Journal of Biosciences. 13(2) 170-179.

Ogwu C., Ideh Victor, Imobighe Mabel (2022), 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. 20 (6), 128-139.

Ogwu C.,Azonuche J. E and Okeke, M. (2020). 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. 7(7), 12-17

Ogwu, C., Abvbunudiogba, R. E., Ogune, P., Aloamaka, T. A. (2023). Analysis of the heavy metals content of Lagos Lagoon Lagos Nigeria. International Journal of Recent Research in Physics and Chemical Sciences, 10(1), 1-6.

Ogwu, C., Obi-Okolie, F. and bvbunudiogba, R. E. (2023). Quantification of the heavy metals in the groundwater of Ikeja industrial estate, Ikeja Lagos. Quest Journal of Research in Environmental and Earth Science 9(3), 69-73.

Ogwu, C., Ossai, A. C., Ejemeyovwi, D. O. & Unuafe, S. E. (2023). Characterisation of the heavy metals in the aquifer of Matori Industrial estate Lagos Nigeria. Quest Journal of Research in Environmental and Earth Science 9(3), 20-26.

Ogwu, C., Ossai, A. C., Ejemeyovwi, D. O. and Unuafe, S. E. (2023). IOSR Journal of Environmental Science, Toxicology and Food Technology. 17(issue 3, sir 1), 01-06.

Ogwu, C., Ukpene, A. O., Ekpe, I. N. and Aregbor, O. (2023). Bioaccumulation of heavy metals in the tissues of some fishes species in selected wetlands in Lagos Nigeria. Journal of Innovation 72, 1407- 1418.

Ogwu, C., Ukpene, A. O., Ekpe, I. N., Umukoro B. O. J. and Onuelu, J. E. (2023). 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, 73, 89-101.

Ojo, A. N. (2023). Oil production activities and PaHs polycyclic aromatic hydrocarbons content in wetlands of Okpai. *Journal of Environmental Toxicology* 22(2), 24-29.

Oteriba, A. N. (2022). Concept of economic sustainability and Nigeria economic policies. Lagos: Oteriba Associates Ltd.

Ovie, D. (2022 16 December). Monocultural economy the bane of Nigeria economic growth. Vanguard news, pp. 48 economy retrieved December 2023.

Owolabi, J. F. (2018). Economic policies of the Federal government and growth trajectory. Vanguard news pp. 50 Ecnmy.

Oza, S. A. (2022). Polycyclic aromatic hydrocarbon content of the wetlands in Batere Warri South LGA, Delta Nigeria. *Journal of Environmental Monitoring* 20(2), 90-96.

Ozor, K. C. (2017). Diversify Nigeria economy for sustainable growth. https://www.diversitynigeriaeconomy.com retrieved December 2023.

Pedro, M. (2019). Sustainable economic development defined. https://www.britainical.com retrieved December 2023.

Ramsar Convention (1971). Convention on wetlands of international importance. Ramsar Iran.

Ramsar, Conference of Parties (COP) (2018). Convention on wetland. Dubai UAE.

Rewani, B. (2023). Nigeria economic and oil. Lagos: Financial Derivatives Ltd.

Sandwell, J. (2020). Sustainable economic development: definition, goals, origins. https://www.study.com retrieved November 2023.

Sheffield, B. (2012). What is economic sustainability. https://www.indeed.com retrieved December 2023.

Spear, F. C. (2022). Concept of sustainable economic development. https://www.researchgate.com retrieved December 2023.

Spencer, S. (2022). The concept of sustainable economic development. https://www.jstore.com retrieved December 2023.

Suswan, L. C. (2021). Polycyclic aromatic hydrocarbon content in Ogun River and Cage aquaculture adoption. *Journal of Marine Toxicity* 18(2), 123-128.

Tedwell, M. (2018). Sustainable economic development. https://www.study.com retrieved January 2024.

Thompson, H. (2020). Sustainable economic development, growth and barriers – lesson. https://www.study.com retrieved November 2023.

Thorndike, M. (2018). Economic recession definition and causes. https://www.studygroup.com retrieved January 2024. United States Environmental Protection Agency (USEPA) (2012). Water contaminations. USEPA Bulletin Atlanta Georgia USA. World Health Organisation (WHO). Water contaminants . WHO Bulletin Geneva Switzerland.