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QUANTIFICATION OF HEAVY METALS IN WETLANDS IN BATEREN AND ENVIRONS (OIL BEARING COMMUNITIES) WARRI NORTH DELTA FOR CAGE AQUACULTURE ADOPTION FOR FOOD SECURITY IN NIGERIA

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Abstract

Oil exploitation in Nigeria most often than none leave on it trail of environmental degradation of varying quantum resulting sometimes to unrest in oil producing communities of the Niger Delta. This study was an ex-post facto research that investigated the content of heavy metals in Bateren and environs oil bearing communities for their suitability for the adoption of cage aquaculture for food security. The study answered 6 research questions and tested a hypothesis. In achieving these, the water samples were collected from research area bAteren, Tebu, Tisun, Ugbege and Nana wetlands were mapped into 5 sampling sites and water samples were collected at the depth of 10cm with 125mL. plastic bottles from 5 spots and these were bulked and composites drawn and fixed with HNO3 and stored in cooled flask for analysis. The analytical standard adopted was USEPA 72000 and the instrument for determination does for the metal was Agilent ICP-MS model 7900. The results obtained were; Pb 0.06±0.01 mg/l, Mn, 0.57±0.00 mg/l, Cr, 0.04±0.00 mg/l , V, 0.06±0.10 mg/l and Cd, 0.07±0.01 mg/l . the means of the heavy metals measure were subjected to test of significance using SPSS model 29 and the p value was 0.042 thus rejecting H0. The study concluded that the wetlands were polluted with heavy metals measured above WHO 2018 MPC for the metals investigated. This the wetlands will not be suitable for cage aquaculture adoption as the produce will neither be suitable for human consumption nor be used as concentrate (fish meal) for animal feeds. The produce will also not be exportable. The study recommends that oil companies operating in Bateren and environs should adlpt world best practices in their operation. NESREA and NOSDRA should step up their surveillance roles and the impacted ecosystem should be remediated to allow for cage aquaculture adoption for food security in Nigeria.

Keywords: *oil exploitation, heavy metal, wetland contamination, food security*

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Introduction

A cardinal index of assessment of good governance is having citizens that are food secured. Food security is having access to affordable, nutritious and sufficient quantity of food (Allen, 2018, Betrand, 2020, Thompson, 2021). It is the availability of food to all classes, gender and state or religion (Beron, 2017, Adams, 2021, Bedford, 2021). Food security when people at all time have unhindered, economic and physical access to good quality and quantity to food (Davidson, 2018, Tedwell, 2019), Jones, 2020). Food security is when all people, at all times have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996, Food and Agricultural Organisation, 2020, Stephen, 2023). It is having access to very good quality food desired at any time and at any quantity required for a physical activities and well being (Paulson, 2018, Derrick, 2019). A country is food secured when every citizen has reliable access to affordable, nutritious food at the desired quantity for physical and social activities and for a healthy living (Joel, 2019, Shedrack, 2019, Thomas, 2020). Achieving food security is predicated on investment in sustainable agriculture through researches, advisory service and funding (Paschal, 2019, Samulson, 2020). Nigeria was an agrarian country with agriculture accounting for 80 percent of gross domestic product (GDP) and 90 percent of foreign exchange earning (Nwankwo, 2016, Chukwuma, 2018, Adeboye, 2021, Olatunde, 2021). Agriculture was pushed to the back burner with the emergence of petroleum in the 1970s (Olawale, 2015, Hassan, 2017, Ojikutu, 2019). Oil account for 95 percent of Nigeria foreign exchange, 70 percent of Nigeria budget revenue and 85 percent of the gross domestic product (National Bureau of Statistics, 2023, Riwani, 2023, Oteriba, 2024). Oil international market is susceptible to gluts shocks and recessions, the last instances being 2016 and 2020 leading to high inflation and food scarcity (NBS, 2021, Oteriba, 2022, Lawal, 2022). Nigeria divestment to petroleum and neglect to agriculture is a major threat to achieving food security and attain zero hunger status as enshrined in United Nations Sustainable Development Goals in 2030 (Haruna, 2020, Tsav, 2022, Ochu, 2023). Food security can only be achieved if Nigeria go back to its bases and reinvest in agriculture (Okoroji, 2016, Etuk, 2018, Ogagaoghene, 2019). Nigeria is enjoined to venture into aquaculture in crop production into agriculture in crop production, livestock, poultry and aquaculture (Ogwu et al., 2022, Ogwu et al., 2023, Sodje, 2021). Aquaculture is fish farming (Ogwu et al., 2022). Aquaculture is a very veritable means in youths and adult empowerment, wealth creation and food security (Ojoko, 2020, Fashina, 2021, Ogwu et al., 2023). Nigeria fish annual demand is 3.00 million metric tonnes and the local production is 850,000 metric tonnes the gap is bridged through importation (NBS, 2023, Ruwani, 2023, Abubaka 2023). Nigerians are enjoined to venture into adopting cage aquaculture due to low initial investment capital outlay (Ogwu et al., 2022, Ogwu et al 2023, Ogwu et al., 2024). Cage aquaculture is the practice of building a cage and anchoring it in a natural water (Jewel, 2018, Sampson, 2019, Ogwu et al., 2022) and adoption is the process of accepting and implementing a new technology or technique (Bello, 2015). A decision to make use of an innovation (Simpson, 2016). Adpting cage aquaculture requires water analysis for presence of toxicants to avoid bioaccumulation and biomagnification (Atshana and Atshana, 2017, Osunkwo, 2018). Possible toxicants in water include pesticides, microplastic, polychlorinated biphenyls (PCBs) polycyclic aromatic hydrocarbons (PAHs), heavy metals (United State Environmental Protection Agency, 2015, World health Organisation, 2018, Ogwu et al., 2023). Heavy metals are group of metals and metalloids that have high density and atomic weight and can be toxic at high concentration (USEPa, 2015, WHO, 2018). Heavy metals cause paired cognition, reproductive issues (nkolnonwu et al., 2020, Gont et al., 2020, Rai et al., 2019), brain damage, renal failure (upadhyay et al., 2022, Goswami & Baroliyu, 2023, Abedi et al., 2023), liver damage, anemia (Alom et al., 2023, Yao et al., 2023, Nighat et al., 2023, Ya et al., 2023, Nighat et a., 2016, Wang et al., 2019), cancer disruption to the nevous system (li et al., 2022, Rahman et al., 2021). Sources of heavy metals include industrial process lines, power plants, natural process, crude oil; petroleum (Benhorff, 2012, Marigo et al., 2022, Hossini et al., 2022). Sources of petroleum in the wetland environment include spillages, pipeline rupture, wellhead blowout, sabotage and vandalism equipment failure (Ogwu et al., 2021, Yan et al., 2023, Desmarais & Costa, 2019, Chem & Lee, 2023, Zhang et al., 2020). A wetland is an area of land that can havour water for three to six months in a year or al the year round (Ogwu et al., 2022, Genchi, 2020, Zhang et al., 2020).

Bateren, Tebu, Tisun, Ugbege and Nana are oil bearing wetland settlements in Warri north local government Delta Nigeria. The focus of this research is the assessment of the heavy metal content in the wetlands in Bateren, Tebu, Tisun, Ugbege and Nana for it suitability for cage aquaculture adoption for food security in Nigeria. The heavy metals investigated were lead (Pb), manganese (Mn), chromium (Cr), vanadium (V) and cadmium (Cd).

The study was guided by research questions as

i. What are the contents of Pb, Mn, Cr, V and Cd in the wetlands in Bateren and environs?
ii. Are the contents of the heavy metals with the WHO 2018 permissible concentration (MPC)?
iii. Can cage aquaculture be implemented in the wetlands
iv. Will the produce be fit for human consumption
v. Can the produce be used for ivestock feeds?
vi. Can the produce be exported considering Codex Allimentarius Commision 1963.

Hypothesis

The study was guided by a hypothesis as:

Ho: There is no significant difference bweteen the concentration of the heavy emtals in the wetland water in Bateren and and environs and WHO MPC for heavy metals in wetland water.

Study Area

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Figure 1: Map of Warri North Source: https://upload.wikimedia.org/wikipedia/commons/9/9c/Map_of_Warri_State.jpg

Bateren, Tebu, Tisu, Ugbege and Nana are wetland settlements in Warri North local government area, Delta state, Nigeria. They lie within the coordinates of 5 31' north and 5 45' E in geographical positioning. The inhabitants of bateren and environs are mainly farmers and fishermen. Some are artisans while some other petty traders, some are teachers and some work in dispensary with a very insignificant few working in oil companies operating in the area as janitors, messengers and security guards. The wetlands in Bateren and environs are the recipients of wastes generated by oil exploitation companies in the course of their operations.

Materials and Methods

Ethical statement

Water samples were collected from the wetlands. They are not life so there were no consideration for being endangered or threatened, so permit was not sought. However, permission were sought from the heads of federating settlement before water samples were collected.

Sample collection

The research was conducted between September 2024 and January 2025. Five (5) research assistance were enganged to help in samples collection in each of the settlements. Each wetland was mapped into 5 and water samples were collected with clean plastic 125mL samples bottles from 5 spots at 10cm depth adopting grab sampling technique (Manaisi and Zacharidis, 2020). Samples from each sample partition were bulked and composites drawn and fixed with nitric acid and stored in ice cooled flasks for laboratory analysis.

Analysis

The analysis of the wetlands water samples were carried out at National Institute for Oceanography and Marine Research, Victoria Island, Lagos. Water pollution laboratory by the Chief Laboratory Technologist Dr. Uyimadu J. P. The samples were first filtered using Lxm fibre filter membrane to expel the suspended solids. Nitric acid ($HN0_3$) were added again to increase the pH to 2 and keep the temperature at 4 degree Celsius (4°C). the heavy metals Pb, Mn, Cr, V and Cd were determined deploying Agilent Inductively Coupled Plasma Spectroscopy System (ICP-MS) model 7900. The validation of the accuracy of the determination was carried out using Agilent reference standard material AFS 9620 and AI OMR 6200. The recovery rate was 98 percent.

Results

The results of the heavy metals content in the wetlands in Bateren and environs were as in Figures 2-6 and the comparative mean of the heavy metals in Figure 7.

The results of the heavy metals content in the wetlands of Bateren were as in Figure 2.

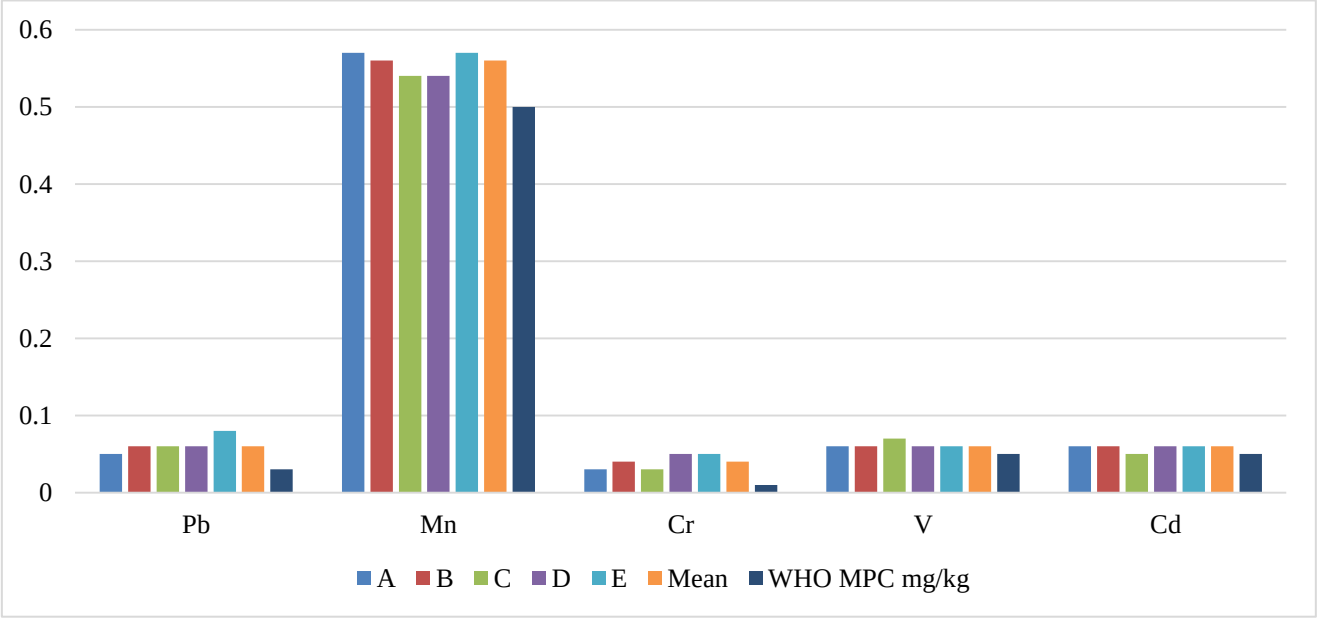


Figure 2: results of the heavy metals in the wetlands in Bateren and WHO MPC for heavy metals in water in mg/l.

The results of the heavy metals in the wetlands in Tebu were as in Figure 3.

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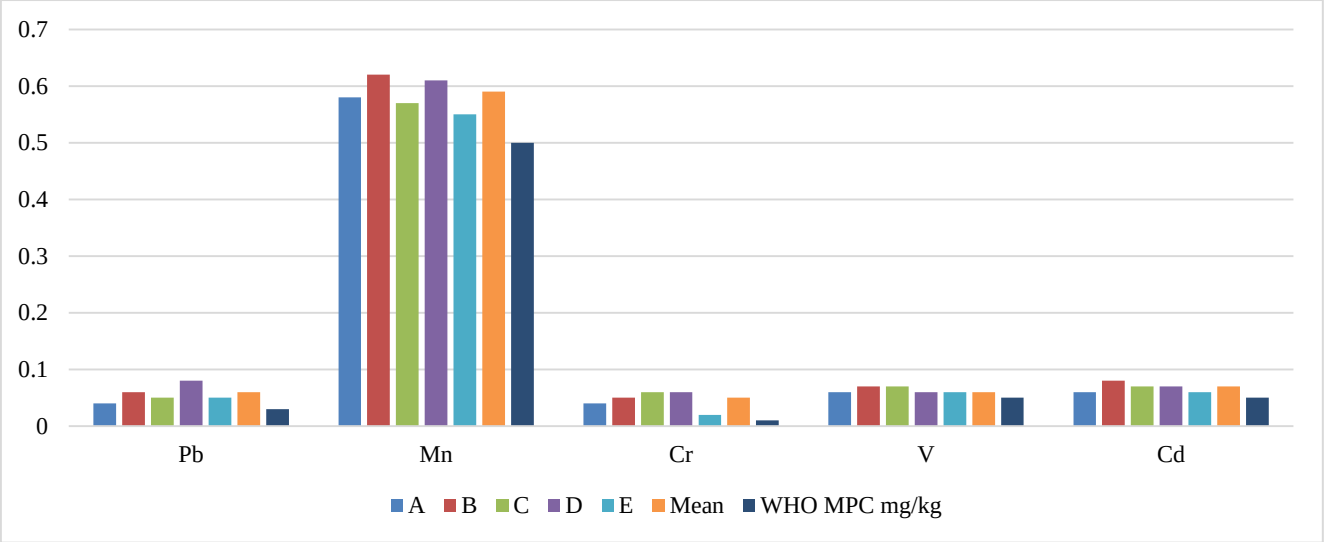


Figure 3: results of the heavy metals in the wetlands in Tebu and WHO MPC for heavy metals in mg/l

The results of the heavy metals in wetlands in Tisun were as in Figure 4.

Figure 4:

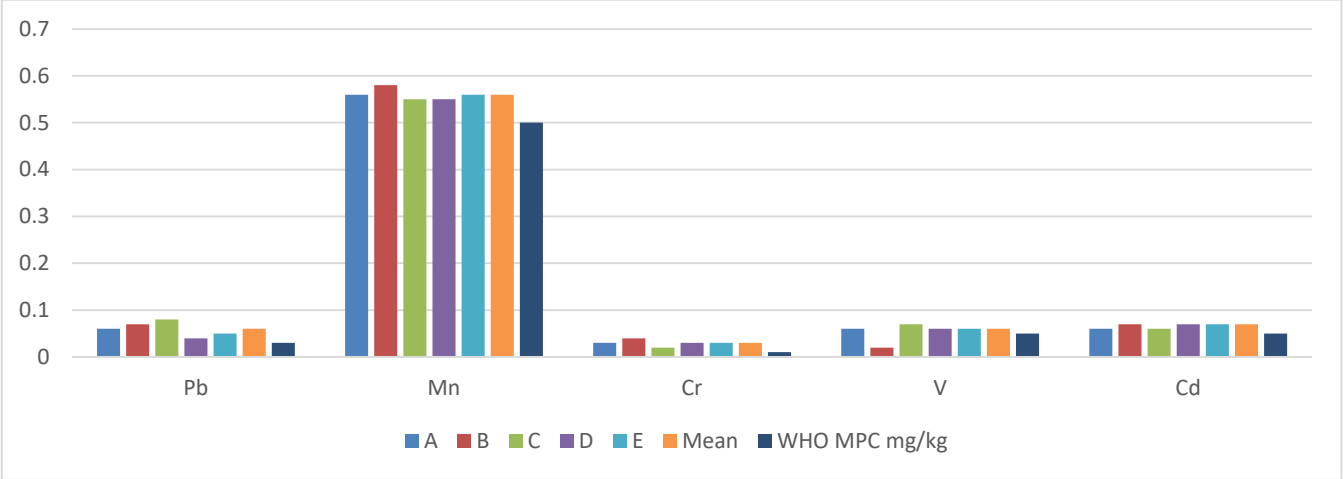


Figure 4: results of the heavy metals in wetlands in Tisun and WHO 2018 MPC for wetlands water in mg/l

The results of the heavy metals in the wetland Ugbese were as in Table Figure 5.

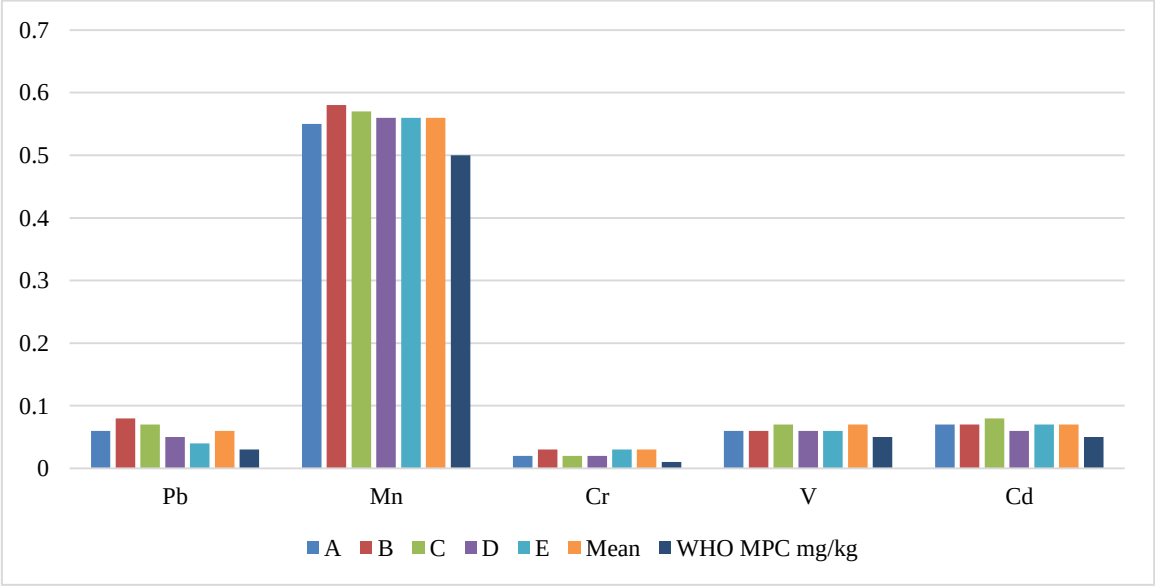


Figure 5: results of the heavy metals in the wetlands in Ugbege and WHO 2018 MPC for heavy metals in wetland water in mg/l

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The results of the heavy metals on the wetlands in Nana were as in Figure 6.

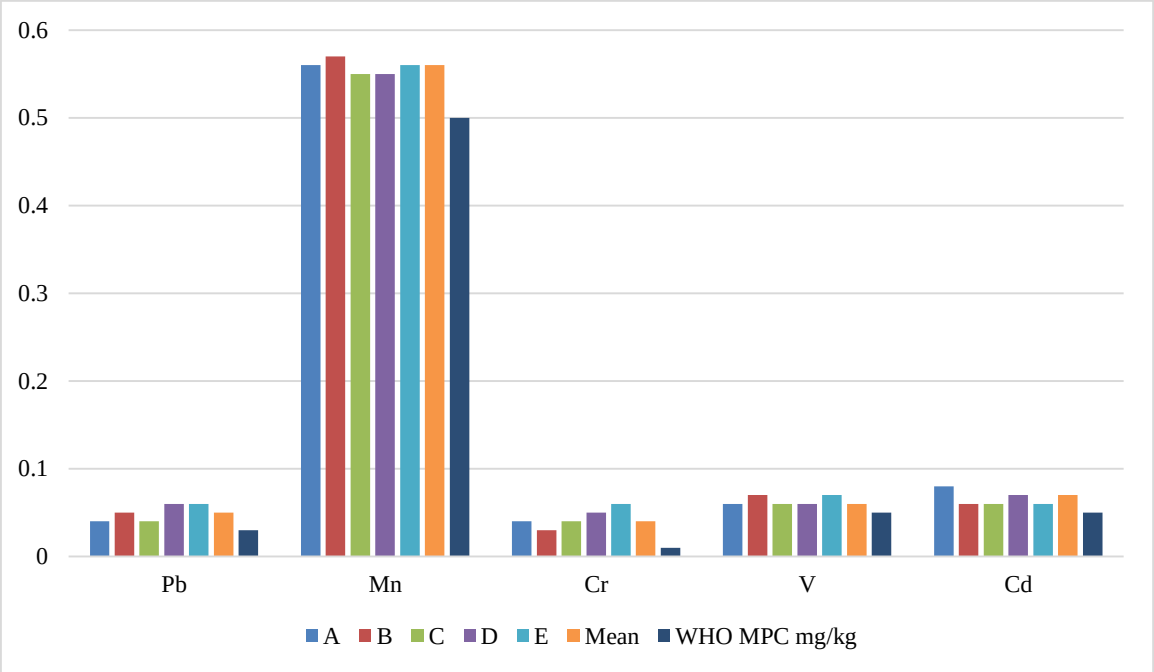


Figure 6: results of the heavy metals in the wetlands in Nana and WHO 2018 MPC for heavy metals in wetland water in mg/l.

The comparative results of the heavy metals in the wetlands in Bateren and environs were as in Figure 7.

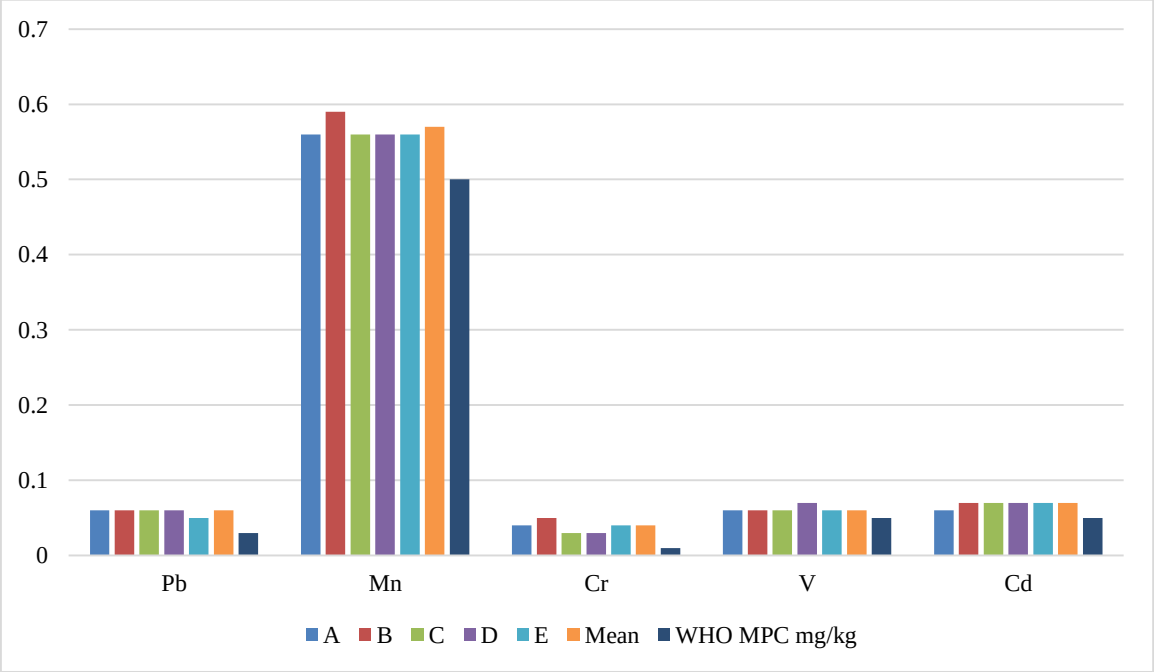


Figure 7: results of the comparative means of the heavy metals in Bateren and environs in mg/l.

The results of the mean of the heavy metals in Bateren, Tebu, Tisun, Mgbege and Nana were subjected to test of significance using analysis of variance (ANOVA) deploying special package for social science SPSS model 29 and the *p* value was 0.042 thus rejecting H_0.

Discussion of Findings

Environmental degradation resulting from activities of extractive industries is replete in. The research of the analysis of the heavy metals content of the wetland in Bateren and environs is an affirmation of already existing facts. The analysis of the wetland water in Bateren and environs showed varying concentrations of the variables measured. The analysis of the wetlands water in Bateren for the content of Pb revealed that the concentrations of lead range from 0.05 mg/l in Nana to 0.06 mg/l in Bateren, Tebu, Tisun and Ugbege with a mean of 0.06 mg/l. the WHO 2018 MPC for Pb in water is 0.03 mg/l. this high content is anthropogenic. This result is in agreement with the results in (Wilscheski & Baxter, 2019, Li et al., 2019, Elgamail et al., 2019). Epidemiological studies have revealed that Pb contamination results in brain damage, behaviours problems (Rem et al., 2012, Song et al., 2022), Cardiovascular problem, kidney damage (Oreste, 2021).

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The wetland water analysis of Bateren and environs for the content of manganese showed the value of Mn to range from 0.56 mg/l in Bateren, Tisun and Ugbege to 0.59 mg/l in Tebu with a group mean of 0.57 mg/l. this increased concentration of Mn is human effect in the environment. This result is similar to the reports in Bansort et al., 2017, Scaeteanu et al., 2021) but at variance with the reports in (Pacanac et al., 2023). Human prolonged exposure to Mn leads to brain damage including manganim (Amer et al., 2019, Khan et al., 2015), muscular spasm speech defects (Ercilla-Mantserrat et al., 2018, de-Oliveira et al., 2017).

The analysis of wetlands in Bateren and environs for the concentrations of Cr presented a concentration of 0.03 mg/l in Tisun, Ugbege to 0.05 mg/l in Tebu with a mean of 0.04 mg/l. this elevated concentration of Cr is a result input to the environment resulting from oil activities. High content of Cr in oil producing wetlands were in oil producing wetlands were in (Rosca et al., 2021, Streen et al., 2016), human health complication arising from prolonged exposure to Cr include asthma, eye irritation (Niedvedeva et al., 2021, Ozbay et al., 2023, Dageilar & Gezar, 2021), damages eardrum, kidney damage, irritation of the respiratory tract (Heghedus et al., 2023, Elkady & Abdel-Wahhab, 2018), cancer and skin lessions (Meshref et al., 2014, Benitez-Rojas et al., 2023).

Analyzing the wetland waters in Bateren and environs for the concentration of V revealed the contents of V to be between 0.66 mg/l in Bateren, Tebu, Tisun and Nana to 0.07 mg/l in Ugbege with a group mean of 0.06 mg/l. the WHO 2018 MPC for V in wetland dis 0.05 mg/l. this increased concentration is attributable to oil exploitation activities in the wetlands similar results of high content of V in wetlands. Subjected to oil activities was reported in (Jaafazadeh et al., 2023, Ali et al., 2023, Ogwu et al., 2022). Human health complication associated with prolonged exposure to V include lung irritation, cough, phlegun (Dibello et al., 2020, Barone et al., 2020), asthma attach, shortness of breath, chest tightness (Hoha et al., 2014, Han et al., 2022), liver problem and renal failure (Ogwu et al., 2021).

The analysis of wetlands in Bateren and environs for the concentration of Cadmium showed that Cd content was 0.06 mg/l in Bateren to 0.07 mg/l in Tebu, Tisun, Ugbege and Nana with a group mean of 0.07 mg/l. the maximum permissible concentration stipulated by WHO 2018 is 0.05 mg/l, this increased content of Cd in the environments were as a result of oil activities in the wetlands. A corroboration of this result was in (Salim et al., 2023, Xia et al., 2021, Trindade et al., 2015, Bateota et al., 2015). Literature revealed that exposure to Cd is responsible for lung cancer, tetratogenic disorder (Luka & Akum, 2019, Oner et a., 2021, Taghizadeh et al., 2020), DNA mutation, nervous disorder (Yang et al., 2016, Wroniak & Rekas, 2017, Talebi-Ghane et al., 2022, Ampem et al., 2022). Reduction of bone density especially in children (Hag et al., 2022, Zhuravlev et al., 2015, Drosalki and Anthemidis, 2022, Szyczewski et al., 2016).

Conclusion and Recommendation

The results showed that the concentrations of all the heavy metals measured were above WHO 2018 MPC for heavy metals in wetland water thus the wetlands are contaminated making the adoption of cage aquaculture for food security unfeasible as the produce will not be fit for human consumption, they will also not be fit as concentrate for animal feeds neither will they be exportable because of failure to meet Codex Alimentarius 1963 condition for produce export. Consequent upon the foregoing, the study recommends that oil companies operating in Bateren and environs be made to deploy world best practices in oil exploitation, the environmental monitoring agencies, National Environmental Standards Regulations and Enforcement Agency (NESREA) and National Oil Spills Detection and Response Agency (NODRA) should be made to live up to their mandate of policing spilages for pristine wetland environment and the impacted ecosystem should be remediated to allow for the adoption and implementation of cage aquaculture for food security in Nigeria.

References

1. Abedi, A., Hoseini, H., Mohammadi-Nasrabadi, F., Rostami, N., & Esfarjani, F. (2023). Consumer health risk assessment of arsenic and mercury in hen eggs through Monte Carlo simulations. *BMC Public Health, 23*, 1320. https://doi.org/10.1186/s12889-023-14620-x
2. Abubaka, Q.B. (2023 August 9). Fish importation and Nigeria economy in 2022 Tribune News, pp. 50 – Economy.
3. Adam, F. (2021). What is food security. Https://wwwers.org. Retreived December, 2024.
4. Adegboye, M. T. (2021 March 16). Nigeria economy with agriculture was robust. Punch News pp. 41 – Economy.
5. Alam, M. A., Mukherjee, A., Bhattacharya, P., & Bundschuh, J. (2023). An appraisal of the principal concerns and controlling factors for arsenic contamination in Chile. *Scientific Reports, 13*, 11168. https://doi.org/10.1038/s41598-023-38014-y
6. Ali, H. R., Ame, M. M., Sheikh, M. A., & Bakari, S. S. (2023). Levels of lead (Pb), cadmium (Cd) and cobalt (Co) in cow milk from selected areas of Zanzibar Island, Tanzania. *American Journal of Analytical Chemistry, 14*(4), 287–304.
7. Allen, T. (2018). Food security. https://www.wikipedia.com. Retrieved November, 2024.
8. Amer, M., Sabry, B. A., Marrez, D. A., Hathout, A. S., & Fouzy, A. S. M. (2019). Exposure assessment of heavy metal residues in some Egyptian fruits. *Toxicology Reports, 6*, 538–543. https://doi.org/10.1016/j.toxrep.2019.05.014
9. Ampem, G., Gresley, A. L., Grootveld, M., Mars, S., & Naughton, D. P. (2022). The impact of partial oil substitution and trace metal ions on the evolution of peroxidation products in thermally stressed culinary oils. *Food Chemistry, 375*, 131823.
10. Atshana, D. & Atshana, L. (2017). Chemistry of the environment. New Delhi: Old Publisher Ltd.
11. Bakota, E. L., Winkler-Moser, J. K., Dunn, R. O., & Liu, S. X. (2015). Heavy metals screening of rice bran oils and its relation to composition. *European Journal of Lipid Science and Technology, 117*(9), 1452–1462.
12. Bansod, B. S., Kumar, T. J., Thakur, R., Rana, S., & Singh, I. (2017). A review on various electrochemical techniques for heavy metal ions detection with different sensing platforms. *Biosensors and Bioelectronics, 94*, 443–455. https://doi.org/10.1016/j.bios.2017.03.031
13. Barone, G., Storelli, A., Quaglia, N. C., Garofalo, R., Meleleo, A. B., Busco, A., & Storelli, M. M. (2020).

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DOI: 10.5281/zenodo.23725056

Trace metals in pork meat products marketed in Italy: Occurrence and health risk characterization. *Biological Trace Element Research, 199*(8), 2826–2836.
14. Bedford, M. (2021). Food security – meaning. Https://www.fori.org. retrieved January 2025.
15. Bello, J. (2015). Assessment of the adoption rate of cage aquaculture in Yelva and Adodo Old areas of Ogun State Nigeria. *Journal of Agricultural Extension 20*(2), 19-25.
16. Benítez-Rojas, A. C., Jaramillo-Flores, M. E., Zaca-Moran, O., Quiroga-Montes, I., & Delgado-Macuil, R. (2023). A study of the interactions of heavy metals in dairy matrices using Fourier transform infrared spectroscopy, chemometric, and in silico analysis. *Foods, 12*(1919).
17. Benson, C. (2017). Food security defined. https://www.pmc.ncb.nih.gov Retrieved November, 2024.
18. Bernhoft, R. A. (2012). Mercury toxicity and treatment: A review of the literature. *Journal of Environmental and Public Health, 2012*, 460508. https://doi.org/10.1155/2012/460508
19. Betrand, A. (2020). Food security. https://www.handbookse.com Retrieved November, 2024.
20. Chen, R. J., & Lee, V. R. (2023). *Cobalt toxicity*. StatPearls Publishing. Available online: https://www.ncbi.nlm.nih.gov/books/NBK587403 (accessed on August 25, 2023).
21. Chukwuma, S. S. (2018 12 August). Nigeria was better with agriculture. Tribune pp. 38.
22. Ciont, C., Epuran, A., Kerezsi, A. D., Coldea, T. E., Mudura, E., Pasqualone, A., Zhao, H., Suharoschi, R., Vriesekoop, F., & Pop, O. L. (2022). Beer safety: New challenges and future trends within craft and large-scale production. *Foods, 11*, 2693. https://doi.org/10.3390/foods11172693
23. Dağcilar, K., & Gezer, C. (2021). Heavy metal residues in milk and dairy products produced in Northern Cyprus. *Progress in Nutrition, 23*, e2021019.
24. de Oliveira, L. M., Suchismita, D., Gress, J., Rathinasabapathi, B., Chen, Y., & Ma, L. Q. (2017). Arsenic uptake by lettuce from As-contaminated soil remediated with *Pteris vittata* and organic amendment. *Chemosphere, 176*, 249–254. https://doi.org/10.1016/j.chemosphere.2017.02.109
25. Derrick, B. (2019). What is food security? https://www.feedingamerica.org Retreived November, 2024.
26. DesMarais, T. L., & Costa, M. (2019). Mechanism of chromium-induced toxicity. *Current Opinion in Toxicology, 14*, 1–7. https://doi.org/10.1016/j.cotox.2019.03.002
27. Di Bella, C., Traina, A., Giosuè, C., Carpintieri, D., Lo Dico, G. M., Bellante, A., Del Core, M., Falco, F., Gherardi, S., Uccello, M. M., et al. (2020). Heavy metals and PAHs in meat, milk, and seafood from Augusta area (Southern Italy): Contamination levels, dietary intake, and human exposure assessment. *Frontiers in Public Health, 8*, 273.
28. Drosaki, E., & Anthemidis, A. N. (2022). A novel automatic flow-batch extraction induced by emulsion breaking platform for on-line copper determination in edible oil samples by atomic absorption spectrometry. *Talanta, 244*, 123423.
29. Elgamal, S. M., Khorshed, M. A., & Ismail, E. H. (2019). Determination of heavy metal content in whey protein samples from markets in Giza, Egypt, using inductively coupled plasma optical emission spectrometry and graphite furnace atomic absorption spectrometry: A probabilistic risk assessment study. *Journal of Food Composition and Analysis, 84*, 103300. https://doi.org/10.1016/j.jfca.2019.103300
30. Ercilla-Montserrat, M., Muñoz, P., Montero, J. I., Gabarrell, X., & Rieradevall, J. (2018). A study on air quality and heavy metals content of urban food produced in a Mediterranean city (Barcelona). *Journal of Cleaner Production, 195*, 385–395. https://doi.org/10.1016/j.jclepro.2018.05.172
31. Etuk, C. (2018). Agriculture and food security: A review. *Journal of Technical and Vocational Education and Training 18*(2), 31-36.
32. Fasina, B. (2021). Agriculture, climate change and food security. A keynote at the Social Science Associate Animal Conference , Uyo, 2020.
33. Food and Agricultural Organisation (2020). Food security meaning. https://www.fao.org Retrieved December 2020.
34. Genchi, G., Carocci, A., Lauria, G., Sinicropi, M. S., & Catalano, A. (2020). Nickel: Human health and environmental toxicology. *International Journal of Environmental Research and Public Health, 17*, 679. https://doi.org/10.3390/ijerph17020679
35. Goswami, A. K., & Baroliya, P. K. (2023). *Heavy metals adsorption*. Walter de Gruyter GmbH. https://doi.org/10.1515/9783110993742
36. Haruna, J. (2020 June 7). Nigeria mild attention to agriculture a threat to food security. Vanguard News pp. 45 – Economy.
37. Hassan, B. C. (2017). Oil and Nigeria economy. Https://www.oil_and_nigeria_economy. Retreived November 2024.
38. Heghedűș-Mîndru, G., Negrea, P., Trașcă, T. I., Ștef, D. S., Cocan, I., & Heghedűș-Mîndru, R. C. (2023). Food intake of macro and trace elements from different fresh vegetables taken from Timisoara Market, Romania—Chemometric analysis of the results. *Foods, 12*, 749. https://doi.org/10.3390/foods12040749
39. Hoha, G. V., Costăchescu, E., Leahu, A., & Păsărin, B. (2014). Heavy metals contamination levels in processed meat marketed in Romania. *Environmental Engineering and Management Journal, 13*(10), 2411–2415.
40. Hossini, H., Shafie, B., Niri, A. D., Nazari, M., Esfahlan, A. J., Ahmadpour, M., Nazmara, Z., Ahmadimanesh, M., Makhdoumi, P., & Mirzaei, N. (2022). A comprehensive review on human health effects of chromium: Insights on induced toxicity. *Environmental Science and Pollution Research, 29*, 70686–70705. https://doi.org/10.1007/s11356-022-20761-3
41. Jaafarzadeh, N., Tari, K., Samarghandi, M. R., Fard, M. P., Jorfi, S., Feizi, R., & Mehrbakhsh, M. (2023). Non-carcinogenic risk assessment of cadmium and lead in raw milk from dairy production farms in Iran, using Monte Carlo simulation approach. *Journal of Food Composition and Analysis, 115*, 104864.

Copyright © ISRG Publishers. All rights Reserved.
DOI: 10.5281/zenodo.23725056

42. Jewel, D. (2018). Cage culture. Https://www.aquanet.com.
43. Joel, S. (2019). Food security: definition and measurement. https://www.springer.com.
44. Jones, E. A. (2020). Food security definition. https://www.study.com Retreived December, 2024.
45. Khan, A., Khan, S., Khan, M. A., Qamar, Z., & Waqas, M. (2015). The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: A review. *Environmental Science and Pollution Research, 22*, 13772–13799. https://doi.org/10.1007/s11356-015-4881-0
46. Lawal, N. (2022). Recessions in Nigeria 2016 and 2020. https://www.recessions_in_nigeria.com Retreived December, 2024.
47. Lee, J. G., Hwang, J. H., Lee, H. E., Kim, T. H., Choi, J. D., & Gang, G. J. (2019). Effects of food processing methods on migration of heavy metals to food. *Applied Biological Chemistry, 62*, 64. https://doi.org/10.1186/s13765-019-0467-2
48. Li, J., Cao, D., Huang, Y., Chen, B., Chen, Z., Wang, R., Dong, Q., Wei, Q., & Liu, L. (2022). Zinc intakes and health outcomes: An umbrella review. *Frontiers in Nutrition, 9*, 798078. https://doi.org/10.3389/fnut.2022.798078
49. Luka, M. F., & Akun, E. (2019). Investigation of trace metals in different varieties of olive oils from Northern Cyprus and their variation in accumulation using ICP-MS and multivariate techniques. *Environmental Earth Sciences, 78*, 578.
50. Manousi, N., & Zacharidis, G. A. (2020). Development and application of an ICP-AES method for the determination of nutrient and toxic elements in savory snack products after autoclave dissolution. *Separations, 7*, 66. https://doi.org/10.3390/separations7040066
51. Marrugo-Madrid, S., Pinedo-Hernández, J., Paternina-Uribe, R., Marrugo-Negrete, J., & Díez, S. (2022). Health risk assessment for human exposure to mercury species and arsenic via consumption of local food in a gold mining area in Colombia. *Environmental Research, 215*, 113950. https://doi.org/10.1016/j.envres.2022.113950
52. Medvedeva, Y., Kucher, A., Lipsa, J., & Hełdak, M. (2021). Human health risk assessment on the consumption of apples growing in urbanized areas: Case of Kharkiv, Ukraine. *International Journal of Environmental Research and Public Health, 18*, 1504. https://doi.org/10.3390/ijerph18041504
53. Meshref, M. S., Moselhy, W. A., & Hassan, N. (2014). Heavy metals and trace elements levels in milk and milk products. *Journal of Food Measurement and Characterization, 8*, 381–388. https://doi.org/10.1007/s11694-014-9203-6
54. National Bureau of Statistics (2021). Economy. Recession in Nigeria 2020. An NBS Bulletin 16 2021. Abuja Nigeria.
55. National Bureau of Statistics (2023). Contribution of oil to Nigeria budget 2022. NBS Bulletin 20 2023. Abuja Nigeria.
56. National Bureau of Statistics (2023). Nigeria fish production. A NBS bulletin 12, 2022 Abuja, Nigeria.
57. Nighat, S., Nadeem, M. S., Mahmood, T., Kayani, A. R., Mushtaq, M., & Ul Hassan, M. M. (2016). Estimation of heavy metals in Indian flying fox *Pteropus giganteus* (Brünnich, 1782) from Punjab, Pakistan. *Pakistan Journal of Zoology, 48*, 1787–1792.
58. Nkwunonwo, U. C., Odika, P. O., & Onyia, N. I. (2020). A review of the health implications of heavy metals in food chain in Nigeria. *The Scientific World Journal, 2020*, 6594109. https://doi.org/10.1155/2020/6594109
59. Nwankwo, C. A. (2016 May 16). Nigeria was better as agrarian economy. Guardian News pp. 53 – Economy
60. Ochi, A. N. (2023 June 14). The youths go back to agriculture. Thisday News pp. 40 – Agriculture.
61. Ogagaoghene, B. (2019 August 12). Solve youths unemployment and food security with agriculture. Vanguard News pp. 51 – Economy
62. Ojikutu, A. (2019). Oil politics and Nigeria economy. Https://www.oil_economy.com Retrieved January 2025.
63. Ojoko, J. (2020). Threats to food security. https://www.threat_to_food_security.earth.org retrieved December, 2024.
64. Okoroji, H. (2016 November 8). Agriculture the only way to achieve food security in Nigeria. Nation News pp. 50 – Agriculture.
65. Olatunde, A. (2021 August 10). Agriculture was Nigeria comparative advantage. Vanguard News pp. 45 – Economy.
66. Olawale, F. N. (2015). Oil in Nigeria was a curse not a blessing. https://www.oil_in_nigeria_a_curse.com retrieved December, 2024.
67. Öner, M., Bodur, S., Demir, C., Yazıcı, E., Erarpat, S., & Bakirdere, S. (2021). An effective and rapid magnetic nanoparticle-based dispersive solid phase extraction method for the extraction and preconcentration of cadmium from edible oil samples before ICP-OES measurement. *Journal of Food Composition and Analysis, 101*, 103978.
68. Oreste, E. Q., de Souza, A. O., Pereira, C. C., Bonemann, D. H., Vieira, M. A., de Moura Fontes, L., Pasquini, C., & Ribeiro, A. S. (2021). Microwave induced plasma optical emission spectrometry (MIP OES) and laser-induced breakdown spectroscopy (LIBS) for multi-element determination and location in ceramic tableware. *Microchemical Journal, 168*, 106452. https://doi.org/10.1016/j.microc.2021.106452
69. Osunkwo, S. (2018). Heavy metals content of Omambala River, Anambra State. *Journal of Total Environment* 25(2), 41-48.
70. Oteriba, M. (2022). Recessions in Nigeria. Lagos: Oteriba Consultants.
71. Oteriba, M. (2024). Oil and Nigeria Gross Domestic Product. Lagos: Oteriba Consults Ltd.
72. Özbay, S., Dikici, E., & Soylukan, C. (2023). Evaluation of biological (feed, water), seasonal, and geological factors affecting the heavy metal content of raw milk. *Journal of Food Composition and Analysis, 121*, 105401. https://doi.org/10.1016/j.jfca.2023.105401
73. Paschal, J. P. (2019 April 12). Invest on agriculture to achieve food security. Vanguard News. Pp. 52 – Economy.

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DOI: 10.5281/zenodo.23725056

74. Paulson, A. A. (2018). Food security: overview. https://www.sciencedirect.com Retrieved December, 2024.
75. Pećanac, B., Golić, B., & Knežević, D. (2023). Assessment of contamination with heavy metals in food of animal origin. In *Proceedings of the XII International Symposium on Agricultural Sciences AgroReS* (Trebinje, Bosnia and Herzegovina, May 24–26, 2023).
76. Rahman, M. A., Kumar, S., Lamb, D., & Rahman, M. M. (2021). Health risk assessment of arsenic, manganese, and iron from drinking water for high school children. *Water, Air, & Soil Pollution, 232*, 269. https://doi.org/10.1007/s11270-021-05217-y
77. Rai, P. K., Lee, S. S., Zhang, M., Tsang, Y. F., & Kim, K. H. (2019). Heavy metals in food crops: Health risks, fate, mechanisms, and managements. *Environment International, 125*, 365–385. https://doi.org/10.1016/j.envint.2019.01.067
78. Ren, T., Zhao, L. J., Zao, J., & Zhong, R. G. (2012). Determination of Pb, Cd, and Cr in food by high-resolution continuum source graphite furnace atomic absorption spectrometry. *Spectroscopy and Spectral Analysis, 32*, 2566–2571.
79. Roșca, M., Hlihor, R. M., Mihalache, M., & Stoleru, V. (2021). Heavy metals contamination of fruits and vegetables in Europe. *Scientific Papers Horticulture Series USV Iasi, 64*, 227–232.
80. Ruwani, B. (2023). Fish production in Nigeria in 2022. Lagos: Financial Derivatives Ltd.
81. Ruwani, B. (2023). Oil and Nigeria Gross Domestic Product and Budget. Lagos: Financial Derivatives Ltd.
82. Salim, S. A., Ov, N. S., Dana, Z., Hashami, Z., Afrah, A., Sadeghi, E., & Bashiry, M. (2023). A comprehensive image of environmental toxic heavy metals in red meat: A global systematic review and meta-analysis and risk assessment study. *Science of the Total Environment, 889*, 164100.
83. Sampson, P. (2019). Cage culture: overview. Https://www.sciencedirect.com
84. Samuelson, C. N. (2020 May 7). Achieve food security adopting modern agricultural practices Federal Government Advised. Punch News. Pp. 41 – Economy.
85. Scaeteanu, G. V., Madjar, R. M., & Mot, A. (2021). An overview of methods used for quantification of heavy metal contents in vegetal samples. *Romanian Journal of Ecology & Environmental Chemistry, 3*, 7–15.
86. Shedrack, T. (2019). Concept of food security. https://www.researchgate.net Retrieved November, 2024.
87. Simpson, J. (2016). What is cage culture. https://www.ncrac.org. Retrieved December, 2024.
88. Sodje, S. T. (2021). Agriculture and rural economy of the Urhobos Delta Nigeria. *Journal of Social Sciences 20*(2), 191-197.
89. Song, Y., Guo, F., Zeng, P., Liu, J., Wang, Y., & Cheng, H. (2022). Simultaneous measurements of Cr, Cd, Hg, and Pb species in ng L−1 levels by interfacing high-performance liquid chromatography and inductively coupled plasma mass spectrometry. *Analytica Chimica Acta, 1212*, 339935. https://doi.org/10.1016/j.aca.2022.339935
90. Stephen S. (2023). Food security meaning. https://www.usda.org. Retrieved December, 2024.
91. Szyczewski, P., Frankowski, M., Zioła-Frankowska, A., Siepak, J., Szyczewski, T., & Piotrowski, P. (2016). A comparative study of the content of heavy metals in oils: Linseed oil, rapeseed oil and soybean oil in technological production processes. *Archives of Environmental Protection, 42*(3), 37–40.
92. Taghizadeh, S. F., Rezaee, R., Boskabady, M., Mashayekhi Sardoo, H., & Karimi, G. (2020). Exploring the carcinogenic and non-carcinogenic risk of chemicals present in vegetable oils. *International Journal of Environmental Analytical Chemistry, 102*(15), 5756–5784.
93. Talebi-Ghane, E., Poormohammadi, A., Khazaei, S., & Mehri, F. (2022). Concentration of potentially toxic elements in vegetable oils and health risk assessment: A systematic review and meta-analysis. *Biological Trace Element Research, 200*(2), 437–446.
94. Tedwel, P. (2019). Food security definition and measurement. https://www.researchgate.net retrieved November 2024.
95. Thanas, P. S. (2020). How can we define food security. https://www.anacademy.org. Retreived December 2024.
96. Thompson, J. (2021). What is food security. https://What is food security. https://worldconcern.net retrieved December, 2024.
97. Trindade, A. S. N., Dantas, A. F., Lima, D. C., Ferreira, S. L. C., & Teixeira, L. S. G. (2015). Multivariate optimization of ultrasound-assisted extraction for determination of Cu, Fe, Ni and Zn in vegetable oils by high-resolution continuum source atomic absorption spectrometry. *Food Chemistry, 185*, 145–150.
98. Tsav FC (2022) March 12). Agriclutre in Nigeria and food security. Guardian News pp. 50 – Economy.
99. United State Environmental Protection Agency (2015)e. List of water contaminants. https://www.epa.gov. Retrieved February 2025.
100. Upadhyay, R. (2022). Heavy metals in our ecosystem. In J. Kumar, S. Gaur, P. K. Srivastava, R. K. Mishra, S. M. Prasad, & D. K. Chaudan (Eds.), *Heavy metals in plants: Physiological to molecular approach* (pp. xx–xx). CRC Press.
101. Wang, X., Zhang, Y., Geng, Z., Liu, Y., Guo, L., & Xiao, G. (2019). Spatial analysis of heavy metals in meat products in China during 2015–2017. *Food Control, 104*, 174–180. https://doi.org/10.1016/j.foodcont.2019.04.029
102. Wilscheski, S. C., & Baxter, M. R. (2019). Inductively coupled plasma mass spectrometry: Introduction to analytical aspects. *Clinical Biochemistry Reviews, 40*, 115–133.
103. World Food Summit (1997). Summit in global food crisis. Retrieved December, 2024.
104. World Health Organisation (2018). Water contaminants. https://www.who.int. Retrieved December, 2024.
105. Xia, Q., Du, Z., Lin, D., Huo, L., Qin, L., Wang, W., Qiang, L., Yao, Y., & An, Y. (2021). Review on contaminants in edible oil and analytical technologies. *Oil Crop Science, 6*, 23–27.
106. Yan, G., Ying-Jun, G., Xue, K., Qi, Y., Fan, Y., Xue, T., Wang, J., Zhao, R., Zhang, P., & Liu, Y. (2023). Toxicity mechanisms and remediation strategies for chromium exposure in the environment. *Frontiers in Environmental*

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DOI: 10.5281/zenodo.23725056

Science, 11, 1131204. https://doi.org/10.3389/fenvs.2023.1131204

107. Yang, Y., Li, H., Peng, L., Chen, Z., & Zeng, Q. (2016). Assessment of Pb and Cd in seed oils and meals and methodology of their extraction. *Food Chemistry, 197*, 482–488.
108. Yao, X., Chen, H., Zhang, B., & Lu, L. (2023). Transcriptome analysis reveals differentially expressed genes involved in aluminum, copper, and cadmium accumulation in tea 'Qianmei 419′ and 'Qianfu 4.' *Plants, 12*, 2580. https://doi.org/10.3390/plants12192580
109. Zhang, Y., Ge, S., Yang, Z., & Dong, C. (2020). Heavy metals analysis in chalk sticks based on ICP-AES and their associated health risk. *Environmental Science and Pollution Research, 27*, 37887–37893. https://doi.org/10.1007/s11356-020-09816-5
110. Zhuravlev, A., Zacharia, A., Gucer, S., Chebotarev, A., Arabadji, M., & Dobrynin, A. (2015). Direct atomic absorption spectrometry determination of arsenic, cadmium, copper, manganese, lead and zinc in vegetable oil and fat samples with graphite filter furnace atomizer. *Journal of Food Composition and Analysis, 38*, 62–68.

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