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DISTRIBUTION OF HEAVY METALS IN AGRICULTURAL SOILS OF THE RIVER BENUE FLOODPLAIN, ADAMAWA STATE, NORTH-EASTERN NIGERIA

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ABSTRACT

This study investigated the influence of location and season on the concentrations of lead (Pb), chromium (Cr), cadmium (Cd), nickel (Ni), and zinc (Zn) in agricultural soils of the River Benue floodplain. Soil samples were collected from upstream (Fufore), midstream (Jimeta), and downstream (Numan) locations during the rainy and dry seasons of 2022 and 2023. Heavy metal concentrations were determined using atomic absorption spectrophotometry after nitric acid digestion. Results showed that Pb concentration (0.69 mg/kg) did not vary with season or location, with a significant interaction effect ($p < 0.05$). The rainy season recorded a mean Pb concentration of 0.54 mg/kg. Similar trends were observed for Cr, Cd, Ni, and Zn. The concentrations of Pb, Cd, and Ni exceeded the World Health Organization (WHO) thresholds for agricultural soils. The order of metal abundance across all samples was Ni > Pb > Cr > Zn > Cd. Despite these exceedances, all values remained below critical tolerance limits for soil contamination, suggesting no immediate risk. The study highlights the need for regular monitoring and sustainable agricultural practices.

Keywords: Heavy metals, floodplain, location, season, River Benue, Nigeria

INTRODUCTION

Heavy metals in soils refer to metallic elements (eg cadmium,lead , arsenic ,copper ,zinc ,chromium, and Nickel) that occur naturally but can accumulate to toxic levels due to human activities posing risk to ecosystem and human heath(Romken *et al*,2024)

.Soils exert direct and indirect effects on agricultural productivity, water quality, and global climate (Lal & Pierce, 1991).Soil can filter contaminants and immobilize them being transported elsewere (for example , to surface waters, towards plants and ground water)Howerver , the accumulation of heavy metals in soils including cadmium ,lead, zinc, can lead to adverse effects on ecosystem health and water quality(EU,2021)

Agricultural soils are increasingly polluted due to rapid urbanization, industrialization, and inappropriate agricultural practices, which facilitate the release of metal contaminants into farmlands (Sidhu, 2016). Heavy metals are metallic elements with relatively high density compared to water (Fergusson, 1990). Metals such as Cr, Cd, Hg, Pb, and Ni are potentially hazardous in both elemental and combined form. Concentrations above allowable limits can negatively affect humans, other organisms, and the environment (Sobhanardakani, 2016; Sobhanardakani *et al*., 2018).

Heavy metal pollution can retard plant growth, impair soil function, and harm human health (Sidhu, 2016). Contamination arises from industrial emissions, mine tailings, waste disposal, leaded gasoline, paints, fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, petrochemical spills, and atmospheric deposition

(Khan *et al*., 2008; Zhang *et al*., 2010). Natural sources include parent material weathering and volcanic eruptions (Cai *et al*., 2009). Soils act as major sinks for these metals, which do not degrade biologically or chemically (Kirpichtchikova *et al.,* 2006), persisting for long periods. Contamination can harm human health, contaminate groundwater, and reduce food quality (McLaughlin *et al*., 2000; Ling, 2007). Routine monitoring of agricultural soils is essential for risk assessment and environmental protection. This study aims to assess heavy metal contamination in the River Benue floodplain and inform policy.

Materials and Methods

Study Area and Sampling Sites

The Gongola Topo-Sheet 156 NE (1:50,000) and Google Earth images were used for field planning. Soil samples were collected from upstream (Fufore, Wuro Boki), midstream (Jimeta, Kukan PRP, Gerio, Jambutu), and downstream (Numan, Demsa, Lamurde) locations. Dry season sampling occurred from March to April 2015, and wet season sampling from July to October 2022. The sampling was repeated at the same locations in 2023. Samples were taken at depths of 0–20 cm and 20–50 cm using auger bores, with additional samples from profile pits.

Heavy Metal Analysis

Soil samples were air-dried at room temperature, ground, sieved, weighed, and stored in labeled polythene bags. Samples underwent nitric acid digestion (ASTM, 2010) and were analyzed for Cd, Cr, Pb, Ni, and Zn using an atomic absorption spectrophotometer (AAS, Buck 210 Model) with an air-acetylene flame in integrated mode.

Data Analysis

Data were analyzed using SPSS for Windows at a 5% significance level. Descriptive statistics (means, standard error, standard deviation) were computed. One-way analysis of variance (ANOVA) was used to determine significant differences within and between groups.

Results

3.1 Effect of Location on Heavy Metal Concentrations

Fig 1 shows the mean concentrations of heavy metals at different locations. Pb was highest upstream (0.59 mg/kg) and lowest downstream (0.50 mg/kg). Cr followed a similar pattern (0.28 mg/kg upstream, 0.15 mg/kg downstream). Cd was highest midstream (0.09 mg/kg). Ni was highest upstream (0.69 mg/kg). Zn peaked midstream (1.37 mg/kg). Pb, Ni, and Zn showed significant differences with location ($p < 0.05$). Pb, Cd, and Ni exceeded WHO thresholds.

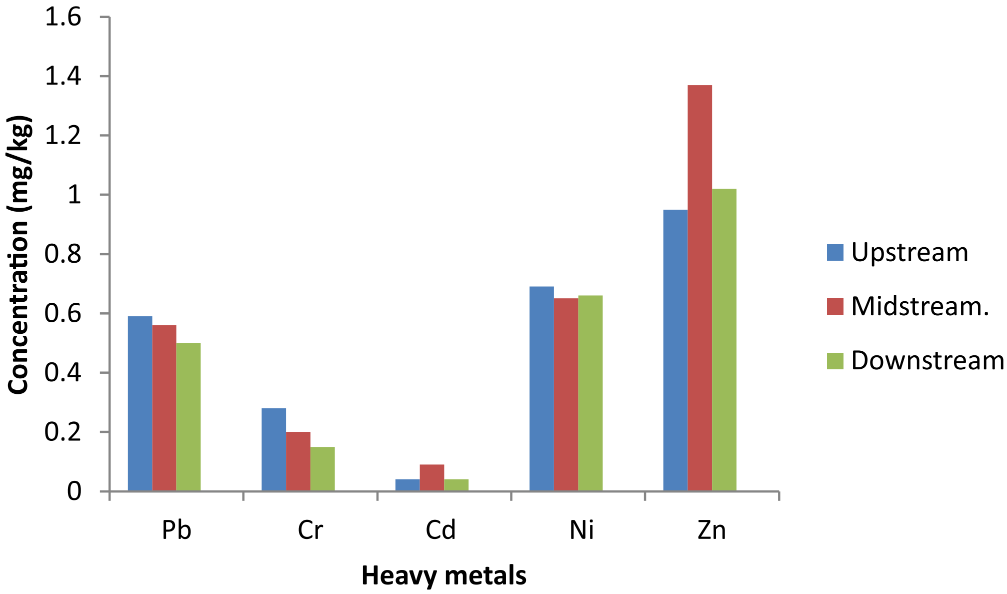
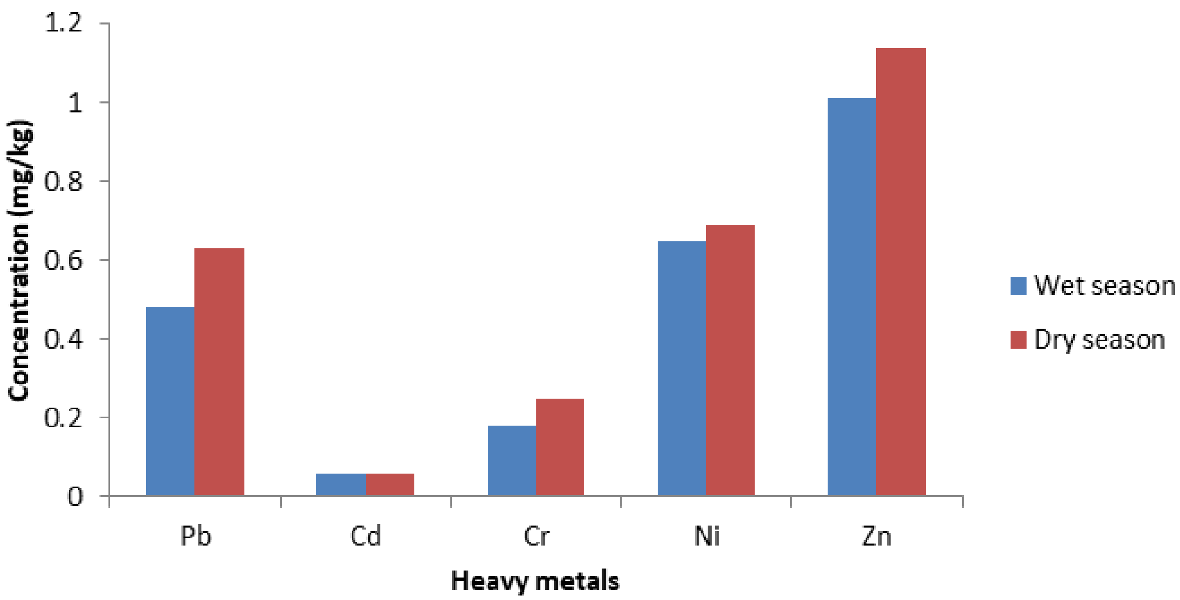


Fig1: Effect of locations on Heavy Metals

Pb = lead, Cr = chromium, Cd = cadmium, Ni = nickel, Zn = zinc; NS = not significant; * = significant
Effect of Season on Heavy Metal Concentrations

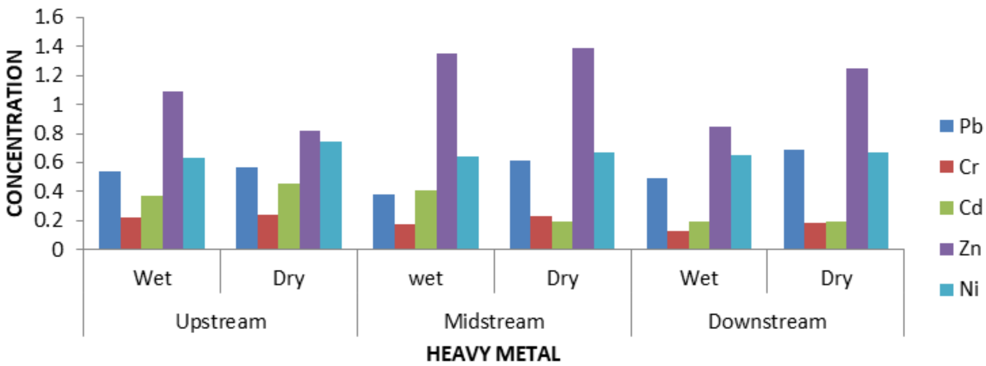
Dry season concentrations were generally higher than wet season (Fig 2). Pb (0.63 mg/kg), Cr (0.25 mg/kg), Ni (0.69 mg/kg), and Zn (1.14 mg/kg) were higher in dry season. Cd showed no seasonal variation (0.06 mg/kg). Pb and Cr differed significantly with season ($p < 0.05$).

Fig 2: Effect of Season on Heavy Metal Concentrations (mg/kg)



Interactive Effect of Location and Season

The interaction between location and season was significant only for Pb ($p < 0.05$). The highest Pb concentration was recorded downstream during the dry season (0.69 mg/kg). Cr, Cd, Zn, and Ni showed no significant interaction effects (Fig 3).



Discussion

The spatial variation in heavy metal concentrations may be attributed to differences in agricultural activities, fertilizer and pesticide use, and environmental factors across the floodplain (Akan *et al.,* 2013). Higher metal levels in dry season compared to wet season likely result from rainfall-induced leaching, erosion, and plant uptake during the rainy season (Tautsch *et a*l., 1999). This agrees with findings from southwestern Nigeria (Monsurat & Gregory, 2015) and flood-affected farmlands (Abeh *et al*., 2007). The persistence of metals above WHO thresholds for Pb, Cd, and Ni warrants attention, although overall levels remain below critical contamination limits. The lack of significant interaction for most metals suggests that location and season act independently. The overall order of heavy metal abundance in soils was Ni > Pb > Cr > Zn > Cd.

Conclusion

This study revealed spatiotemporal variation in heavy metal distribution in the River Benue floodplain soils. Dry season recorded higher concentrations than wet season. Concentrations of Pb, Cd, and Ni exceeded WHO safe limits for agricultural soils, though no immediate contamination risk was indicated. The abundance order was Ni > Pb > Cr > Zn > Cd. Regular monitoring and farmer education on best practices are recommended. Further studies should investigate upstream sources of elevated metal concentrations. Routine inspection and monitoring of agricultural soil pollution should be done

REFERENCES

Abeh, T., Gungfshik, J., Adams, M.M. (2007). Speciation studies of trace element levels in sediments from Zaramaganda stream in Jos, Plateau State, Nigeria. *Journal of Chemical Society of Nigeria*, 32(2), 218-225

Akan, J., Kolo, B.G., Yikala, B.S., Chellube, Z.M. (2013). Levels of some agricultural pollutants in soil samples from Biu Local Government Area of Borno State, Nigeria. *Merit Research Journal of Environmental Science and Toxicology*, 1(3), 7.

ASTM. (2010). Standard practice for nitric acid digestion of solid waste (ASTM D5198). West Conshohocken.

Cai, Q., Long, M.L., Zhu M., Zhou Q.Z, Zhang L,Liu. J. . (2009). Food chain transfer of cadmium and lead to cattle in a lead-zinc smelter in Guizhou, China. *Environmental Pollution*, 157(11), 3078-3082.

Chiroma, T.M., Ebewele, R.O., Hymore, F.K. (2014). Comparative assessment of heavy metal levels in soil, vegetables and urban grey water used for irrigation in Yola and Kano. *International Reference Journal of Engineering and Science*, 3(2), 1-9.

EC,(2021).Communication from the Commission to the European Parliaments ,the Council,the European Economic and Social Committee And he the committee for Regional Pathway to a Healthy planet for All(SWD(2021)140 Final)

Fergusson, J.E. (1990). The heavy metals: Chemistry, environmental impact and health effects. Oxford Press.

Hong, A.H., Lau, P.L., Salamen, O.S. (2014). Heavy metal concentration levels in soil at Lake Geriyo irrigation site, Yola, Adamawa State, North-Eastern Nigeria. *International Journal of Environmental Monitoring and Analysis*, 2(2), 106-111.

Khan, S., Cao, Q., Zheng, Y.M., Huang, Y.Z., Zhu, Y.G. (2008). Health risks of heavy metals in contaminated soil and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution*, 152(3), 686-692.

Kirpichtchikova, T.A., Manceau, A., Spadini, L., Panfili, F., Marcus, M.A., Jacquet, T. (2006). Speciation and solubility of heavy metals in contaminated soil using X-ray microfluorescence, EXAFS spectroscopy, chemical extraction, and thermodynamic modeling. *Geochimica et Cosmochimica Acta*, 70(9), 2163-2190.

Lal, R., Pierce, F.J. (1991). Soil management for sustainability. Soil and Water Conservation Society.

Ling, W.Q., Shan, Y., Gao, X., Gu, Z., Zhang, Z. (2007). Use of bentonite to control the release of copper from contaminated soils. *Australian Journal of Soil Research*, 45(8), 618-623.

Mansouri, G., Madani, M. (2016). Examination of the level of heavy metals in wastewater of Bandar Abbas Wastewater Treatment Plant. *Open Journal of Ecology*, 6, 55-61.

McLaughlin, M.J., Hamou, R.E., McLaren, R.G., Speir, T.W., Roger, S.L. (2000). Review: Bioavailability-based rationale for controlling metal and metalloid contamination of agricultural land in Australia and New Zealand. *Australian Journal of Soil Research*, 38(6), 1037-1086.

Monsurat, T.O., Gregory, O.A. (2015). Levels of heavy metals in soil: Effects of season, agronomic practice and soil geology. *Journal of Agricultural Chemistry and Environment*, 4, 1-9.

Romkens ,P.F.A.M.,Kros,H.,Voogd,J.C.H., and Jeurissen(2024).Balanced and critical concentrations for nutrients and metls in Arabia Soils in EU.Wageningen Evanronmental Research(WENR). Reports of the European topics center Data Integration and digitization (ETC/DI)

Sidhu, G.S. (2016). Heavy metal contamination in agricultural soils: Sources, impacts, and remediation. *International Journal of Environmental Sciences*, 7(2), 89-102.

Sobhanardakani, S. (2016). Potential health risk assessment of heavy metals via consumption of caviar of Persian sturgeon. *Marine Pollution Bulletin*, 123(1-2), 34-38.

Sobhanardakani, S., Tayebi, L., Hosseini, S.V. (2018). Health risk assessment of arsenic and heavy metals (Cd, Cu, Co, Pb, and Sn) through consumption of caviar of *Acipenser persicus* from the Southern Caspian Sea. *Environmental Science and Pollution Research*, 25, 2664-2671.

Tautsch, N.S., Erel, Y., Halicz, L., Chadwick, O.A. (1999). The influence of rainfall on metal concentration and behaviour in soil. *Geochimica et Cosmochimica Acta*, 63, 3499-3511.

Zhang, M.K., Liu, Z.Y., Wang, H. (2010). Use of single extraction methods to predict bioavailability of heavy metals in polluted soils of rice. *Communications in Soil Science and Plant Analysis*, 41(7), 820-831.