Applied Sciences, Computing and Energy, 2025, 2(2), 345-352

Assessment of Heavy Metals in Agroecosystems in Otuoke, Bayelsa State, South South Nigeria

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Received: 23 December 2024/accepted: 16 March 2025/Published: 04 April 2025

Abstract: *This study assessed heavy metal contamination in agricultural soils from Otuoke, Bayelsa State, Nigeria. Soil samples from two sites (with and without pesticide application) were analyzed for lead (Pb), cadmium (Cd), chromium (Cr), arsenic (As), and mercury (Hg) using Atomic Absorption Spectrophotometry. Lead concentrations were slightly higher in the pesticide-treated site (Site 2), averaging 0.771 mg/kg, compared to 0.741 mg/kg in the untreated site (Site 1). Cadmium levels were 0.066 mg/kg in Site 2 and 0.040 mg/kg in Site 1. Chromium concentrations were 0.036 mg/kg and 0.024 mg/kg in Site 2 and Site 1, respectively. Arsenic and mercury were not detected in either site. While detected levels were below WHO/FAO permissible limits (Pb: 100 mg/kg, Cd: 3 mg/kg, Cr: 100 mg/kg), the trend indicates potential agrochemical-related contamination. The findings highlight the need for ongoing monitoring to prevent future heavy metal accumulation.*

Keywords: *Heavy metals, Soil contamination, Agricultural soils, Pesticides, Bayelsa State*

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1.0 Introduction

Agriculture remains a cornerstone of rural livelihoods and the local economy in Bayelsa State, Nigeria. Predominantly subsistence-based, the agricultural sector in this region supports food security, employment, and socio-economic development. However, in recent decades, the increasing contamination of agricultural ecosystems by heavy metals has emerged as a major global environmental and public health concern. Heavy metals, unlike organic pollutants, are non-biodegradable and persist in the environment for extended periods (Eddy *et al*., 2024). Once introduced into the soil, they can accumulate in plant tissues and subsequently enter the food chain, posing significant risks to human and animal health (Alloway, 2013; Kelle *et al*., 2020; Ogoko *et al*., 2022).

Heavy metals of particular concern in agricultural systems include lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), and chromium (Cr) and could arise through the employment of heavy metal contaminated water for irrigation or through surface runoff from contaminated wastes or ground (Ogoko, 2017) These elements, even at low concentrations, can disrupt soil microbial activities, inhibit plant growth, and reduce crop yield and quality (Wang et al., 2019; Smith et al., 2020). Their toxicity is heightened by their tendency to bioaccumulate and biomagnify, especially in ecosystems with poor regulatory monitoring. While trace amounts of some metals are essential for plant and animal metabolism, they become toxic when concentrations exceed permissible thresholds (Mildvan, 2000). The primary sources of heavy metal contamination in agricultural soils include the use of phosphate fertilizers, pesticides, industrial emissions, waste disposal, oil exploration activities, and atmospheric deposition (Kashem et al., 2008; Ghorani-Azam et al., 2016).

Studies around the world have documented heavy metal contamination in agroecosystems, revealing significant ecological and human health implications. For instance, research in China, India, and parts of Africa has shown elevated levels of lead and cadmium in farmland soils, often linked to anthropogenic activities (Monisha et al., 2014; Balali-Mood et al., 2021). In Nigeria, especially in regions with high industrial and oil exploration activities such as the Niger Delta, there is growing concern about soil contamination and its impact on food safety (Ghani, 2011). Despite this concern, there is a dearth of localized studies that quantify and assess the levels of heavy metals in specific agricultural communities within Bayelsa State, including Otuoke—a town surrounded by both agricultural land and environmental stressors such as oil-related activities.

This gap in empirical data on soil contamination levels in Otuoke limits informed decision-making and hampers the development of effective land-use policies and environmental health interventions. Therefore, this study was designed to assess the concentrations of selected heavy metals—lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), and chromium (Cr)—in agricultural soils within Otuoke, Bayelsa State. Soil samples were collected and analyzed using standard procedures to determine the presence and concentration of these metals.

The significance of this study lies in its potential to provide baseline data for environmental monitoring and policy formulation in Bayelsa State. It will also enhance awareness among farmers, agricultural extension workers, and local communities about the risks associated with heavy metal contamination and the need for sustainable soil management practices. Ultimately, the findings will contribute to safeguarding food safety, protecting soil health, and supporting long-term agricultural productivity in the region.

2.0 Materials and Methods

2.1 Materials

The materials and equipment used in this study include: soil auger, hand gloves, Whatman No. 42 filter paper, volumetric flasks, crucibles, distilled water, Bunsen burner, concentrated hydrochloric acid (HCl), 5 M nitric acid (HNO_3), 2 M HCl, and a Varian Spectra A100 Atomic Absorption Spectrophotometer (AAS). All chemicals used were of analytical grade and obtained from reputable suppliers.

2.2 Study Area

The study was conducted in Otuoke, a semi-urban community located in Ogbia Local Government Area of Bayelsa State, Nigeria (latitude 4.7897° N, longitude 6.3241° E). The region is characterized by its rich alluvial soils, making it a notable agricultural hub in the Niger Delta. Residents engage primarily in farming and fishing, with crops such as cassava, plantain, and vegetables commonly cultivated. However, ongoing urbanization and increasing industrial activity pose environmental concerns, including the potential for soil contamination by heavy metals (Eli & Agusomu, 2015).

2.3 Sample Collection and Preparation

Soil samples were collected from two distinct farmland sites within the Otuoke metropolis. Using a soil auger, samples were taken from the topsoil at a depth of 0–30 cm. Samples from each site were composited, labeled, and transported to the laboratory under standard conditions.

In the laboratory, the samples were air-dried at room temperature, homogenized, and passed through a 2.0 mm mesh sieve to remove debris. Approximately 2 g of each sieved sample was placed in a clean crucible and pre-heated in a muffle furnace at 200°C for 30 minutes, followed by ashing at 480°C for 4 hours. After cooling, each sample was digested using a dry ashing method with concentrated nitric acid.

Specifically, 2 ml of 5 M HNO_3 was added and the mixture evaporated to dryness on a sand bath.

The residue was further heated in the furnace at 400°C for 15 minutes, allowed to cool, and moistened with four drops of distilled water. Subsequently, 2 ml of concentrated HCl was added and the solution evaporated to dryness again. Finally, 5 ml of 2 M HCl was added, the sample swirled to dissolve the contents, and filtered through Whatman No. 42 filter paper into a 25 ml volumetric flask, and made up to volume with distilled water.

2.4 Heavy Metal Analysis

The prepared soil extracts were analyzed for heavy metals—lead (Pb), cadmium (Cd), chromium (Cr), mercury (Hg), and arsenic (As)—using a Varian Spectra A100 Atomic Absorption Spectrophotometer (AAS) following standard analytical procedures (APHA, 2017; USEPA, 1996). Prior to analysis, samples were digested with aqua regia (a mixture of HNO_3 and HCl in a 1:3 ratio) for 1 hour, cooled, and filtered into 50 ml volumetric flasks.

To ensure data quality, blanks, duplicates, and certified standard reference materials (SRMs) were included in each batch of analysis. Calibration was performed using standard solutions of known concentrations for each metal. The detection limits and precision of the instrument were confirmed to be within acceptable analytical standards.

3.0 Results and Discussion

3.1 Heavy Metal Concentrations in Soil Samples

The concentrations of selected heavy metals, namely lead (Pb), cadmium (Cd), chromium (Cr), arsenic (As), and mercury (Hg), in soil samples collected from two different farmlands in Otuoke, Bayelsa State, are presented in Table 1.

Table 1: Mean concentration of heavy metals in soil samples from Otuoke farmland

Sample Site	Lead (Pb) (mg/kg)	Cadmium (Cd) (mg/kg)	Chromium (Cr) (mg/kg)	Arsenic (As) (mg/kg)	Mercury (Hg) (mg/kg)
Site 1 (soil without pesticide application)	0.741	0.040	0.024	ND	ND
Site 2 (soil with pesticide application)	0.771	0.066	0.036	ND	ND

*****ND = Not Detected.***

The analysis revealed that lead, cadmium, and chromium were detected in both soil samples, whereas arsenic and mercury were not detected, indicating either their absence or presence at concentrations below the detection limit of the analytical method used. Lead concentrations were found to be slightly higher in Site 2, with a mean value of 0.771 mg/kg, compared to 0.741 mg/kg in Site 1. Although the difference is relatively small, the elevated lead level in the pesticide-treated farmland suggests a potential contribution from agrochemical use, as many pesticides historically contained lead-based compounds (Alloway, 2013). Cadmium levels also exhibited an increase in Site 2, with a concentration of 0.066 mg/kg compared to 0.040 mg/kg in Site 1. Cadmium is recognized as highly toxic even at low concentrations, and its increased presence in the pesticide-treated soil indicates that agricultural inputs could be a significant source of contamination (Loganathan & Hedley, 1997). Similarly, chromium concentrations were higher in Site 2 at 0.036 mg/kg compared to 0.024 mg/kg in Site 1. Chromium contamination in soils is often linked to anthropogenic activities, including the use of certain pesticides and contaminated irrigation water (Kabata-Pendias, 2011).

Comparatively, the detected levels of lead, cadmium, and chromium in both sites are substantially lower than the permissible limits set by international standards. The WHO/FAO recommended maximum levels for lead, cadmium, and chromium in agricultural soils are 100 mg/kg, 3 mg/kg, and 100 mg/kg respectively. The observed lead concentration (0.741–0.771 mg/kg) represents less than 1% of the allowable limit, while cadmium and chromium levels also remain well within safe margins. This suggests that the extent of heavy metal contamination in Otuoke farmlands is currently minimal and unlikely to pose immediate toxicological risks.

However, the environmental implications warrant careful consideration. Globally, about 10% of cultivated soils are estimated to be contaminated with heavy metals (FAO, 2015), and studies within Nigeria have reported that agricultural soils, particularly in industrial areas, can reach lead concentrations exceeding 300–500 mg/kg (Ogunlana et al., 2016; Oladeji and Ayodele, 2018). Although the levels in Otuoke are comparatively low, the trend of higher concentrations in pesticide-treated soils relative to untreated soils points to a risk of gradual accumulation over time.

Of particular concern is the risk of bioaccumulation. Research has shown that cadmium concentrations as low as 1–2 mg/kg in soils can result in detectable uptake by crops (Kabata-Pendias, 2011), while crops have been reported to bioaccumulate lead from soils with concentrations as low as 5 mg/kg (Zhuang et al., 2009). Although the current soil concentrations are below these critical thresholds, continuous application of agrochemicals without monitoring could eventually elevate soil heavy metal levels to bioaccumulative or toxic concentrations.

From an environmental and public health perspective, even low levels of chronic exposure to lead and cadmium can cause serious adverse effects such as kidney dysfunction, neurological impairments, bone demineralization, and increased cancer risk (Jarup, 2003). The potential entry of these metals into the food chain through bioaccumulation in edible crops could impact the health of local consumers and compromise food security.

Ecologically, the persistence of heavy metals in soils can disrupt soil microbial communities, reduce fertility, impair nutrient cycling, and affect plant biodiversity, all of which are essential for sustainable agriculture. Over time, elevated heavy metal levels could lead to decreased agricultural productivity and economic hardship for the farming communities that rely on these lands.

The absence of detectable levels of arsenic and mercury in both sites is encouraging and suggests that current agricultural practices have not significantly introduced these particularly hazardous elements. However, historical experiences have shown that with increased agricultural intensification, heavy metal pollution can escalate rapidly if proper controls are not maintained (Bhattacharya et al., 2002).

Therefore, while the findings indicate that the present contamination levels are low, they underscore the critical need for proactive measures. These should include continuous soil monitoring, the adoption of environmentally friendly farming practices such as organic agriculture, and public education programs to minimize future heavy metal buildup. Sustained vigilance is necessary to safeguard soil quality, protect public health, and maintain the environmental integrity of Otuoke and its surrounding ecosystems.

The bar graph given in Fig.1 represents the mean concentrations of three heavy metals – lead (Pb), cadmium (Cd), and chromium (Cr) –

in soil samples collected from two different farmlands in Otuoke, Bayelsa State. The light blue bars represent Site 1, where no pesticides were applied, while the salmon-colored bars represent Site 2, where pesticides were used. The y-axis shows the concentration in milligrams per kilogram (mg/kg).

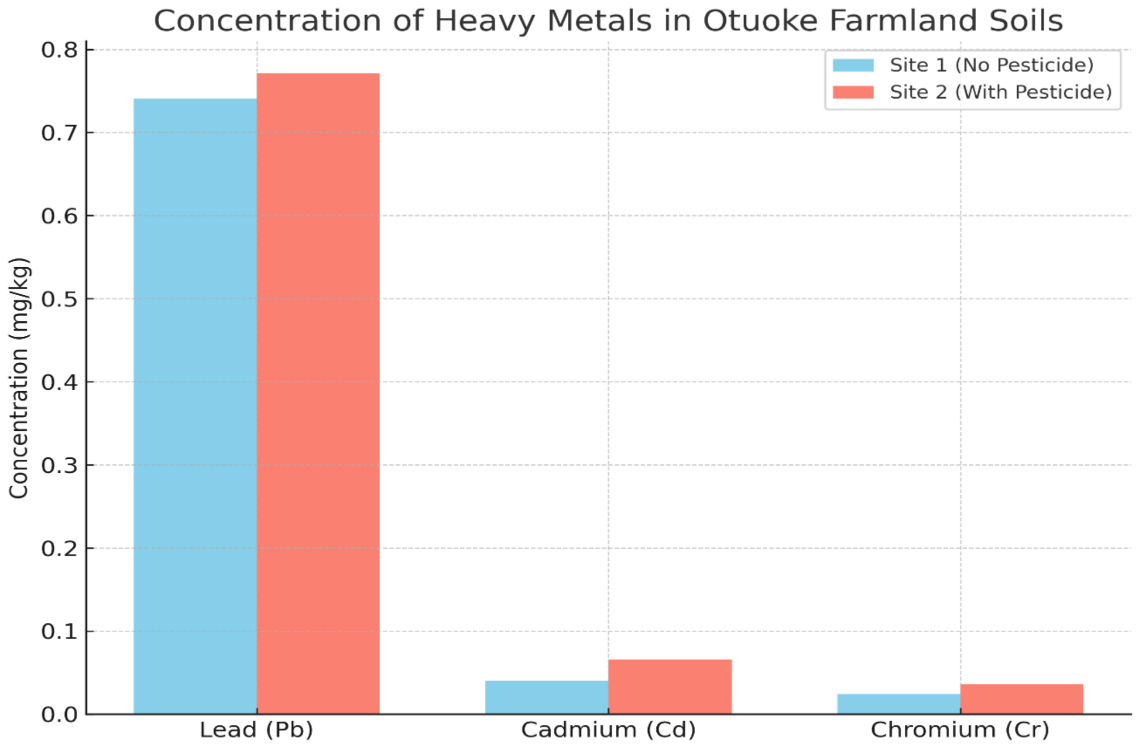

Fig. 1: Histogram showing concentrations of heavy metals in sites 1 and 2

The graph shows that lead concentrations are slightly higher in Site 2 (with pesticide application) at approximately 0.77 mg/kg compared to Site 1 (without pesticide application) at around 0.74 mg/kg. This aligns with the information provided in the text, suggesting a potential link between pesticide use and slightly elevated lead levels.

A more noticeable difference is observed for cadmium. Site 2 exhibits a higher concentration of cadmium, approximately 0.066 mg/kg, compared to Site 1, which has a concentration of about 0.040 mg/kg. This increase in cadmium levels in the pesticide-treated soil, as highlighted in the text, indicates that agricultural inputs could be a source of cadmium contamination. Similar to lead and cadmium, chromium concentrations are also higher in Site 2 (approximately 0.036 mg/kg) than in Site 1 (around 0.024 mg/kg). The text supports this finding and suggests that anthropogenic activities, potentially including the use of certain pesticides or contaminated irrigation water, could contribute to chromium levels in the soil.

The visual representation in the bar graph effectively complements the data presented in Table 1 and the subsequent textual analysis. The graph clearly illustrates the trend of slightly elevated levels of lead, cadmium, and chromium in the farmland where pesticides were applied (Site 2) compared to the site without pesticide application (Site 1).

As the text points out, while the detected levels of these heavy metals are currently substantially lower than the permissible limits set by international standards (WHO/FAO), the trend of higher concentrations in pesticide-treated soils is a cause for environmental concern. The potential for the gradual accumulation of these heavy metals over time with the continuous application of agrochemicals poses a risk.

The absence of detectable levels of arsenic (As) and mercury (Hg), which are not represented in this particular graph, is noted in the provided text as an encouraging sign. However, the text emphasises that without proper monitoring and the adoption of environmentally friendly farming practices, the situation could change with increased agricultural intensification.

The discussion in the text also highlights the potential risks associated with even low levels of chronic exposure to heavy metals like lead and cadmium, including adverse health effects and the possibility of bioaccumulation in crops, which could impact food security and public health. Furthermore, the ecological consequences of heavy metal persistence in soils, such as disruption of soil microbial communities and reduced soil fertility, are important considerations for sustainable agriculture.

In conclusion, the bar graph provides a clear visual summary of the detected heavy metal concentrations in the two farmland sites, reinforcing the findings presented in the table and discussed in the text. While the current levels appear to be within safe limits, the observed trend of higher concentrations in the pesticide-treated site underscores the need for continuous monitoring and the adoption of sustainable agricultural practices to prevent future heavy metal buildup and protect both environmental and public health in the Otuoke region.

4.0 Conclusion

The analysis of soil samples from two farmlands in Otuoke revealed detectable levels of lead, cadmium, and chromium in both sites, with slightly higher concentrations of all three metals observed in the farmland where pesticides were applied compared to the site without pesticide use. Although the measured concentrations of these heavy metals are currently below the permissible limits set by international standards, the trend of elevated levels in pesticide-treated soil suggests a potential contribution from agrochemical use and the risk of gradual accumulation over time. Arsenic and mercury were not detected in either of the soil samples. Based on these findings, it is concluded that while the present heavy metal contamination in Otuoke farmlands is minimal and unlikely to pose immediate toxicological risks, the potential for increased contamination due to agricultural practices warrants careful attention and proactive measures. To mitigate the risk of future heavy metal buildup in agricultural soils, continuous soil monitoring programs should be implemented, environmentally friendly farming practices such as organic agriculture should be adopted, and public education initiatives should be undertaken to promote awareness and minimize potential contamination from agricultural activities. Sustained vigilance and proactive strategies are essential to safeguard soil quality, protect public health, and maintain the environmental integrity of the Otuoke ecosystem.

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Declaration

Ethical Approval

Not Applicable

Competing interests

The authors declare no known competing financial interests

Data Availability

Data shall be made available on request

Conflict of Interest

The authors declare no conflict of interest

Ethical Considerations

Not applicable

Funding

The authors declared no external source of funding.

Authors' Contributions

All aspects of the work were carried out by the author.