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The Role of Earthworms as Bioindicators of Heavy Metal Concentrations in Soil Fauna within Mubi North Local Government Area, Adamawa State

Bode A. S[1], Adamu M. Y[2], Abdulnasir M[3]

[1,3]Adamawa State University, Mubi, Adamawa State, Nigeria

[2]Modibbo Adama University, Yola, Adamawa State, Nigeria

saiduahmedbode@gmail.com

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Abstract

Heavy metal contamination in agricultural soils poses ecological and public health concerns, requiring reliable biological indicators for monitoring soil quality. This study examines the role of earthworms as bioindicators of heavy metal contamination in Mubi North Local Government Area, Adamawa State, Nigeria. Earthworm samples were collected from two farms and analyzed for concentrations of chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), and zinc (Zn). The results revealed that copper had the highest concentration, followed by nickel and zinc, while manganese and chromium were comparatively lower. Pearson correlation analysis showed that chromium and nickel exhibited moderate positive correlations across both farms, suggesting possible common sources or similar uptake mechanisms. Manganese showed a weak correlation in Farm 1 but a stronger correlation in Farm 2, indicating site-specific environmental influences. In contrast, copper and zinc showed consistently weak correlations, suggesting that their accumulation may be influenced by localized environmental factors. Comparisons with World Health Organization permissible limits indicated

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that copper and nickel concentrations were relatively high, raising concerns about potential ecological risks and human health impacts through bioaccumulation in the food chain. These findings support the use of earthworms as reliable bioindicators of soil contamination because of their sensitivity to environmental pollutants and capacity to accumulate heavy metals. The study contributes to environmental monitoring and soil quality assessment by demonstrating the relevance of earthworm-based biomonitoring in agricultural ecosystems and highlights the need for regular environmental surveillance and sustainable agricultural practices in Mubi North to protect soil health and public welfare.

Keywords: Earthworms; Bioindicators; Heavy Metals; Soil Contamination; Agricultural Soil.

INTRODUCTION

Earthworms are recognized as valuable bio indicators of soil health because of their ecological roles and ability to bio accumulate heavy metals from their surroundings. They ingest large amounts of soil during feeding, exposing their tissues to contaminants, which makes them reliable proxies for monitoring metal pollution in terrestrial ecosystems (Khatun *et al.,* 2023). Their sensitivity to pollutants and their position at the base of the soil food web allow them to reflect the degree of contamination, providing insights into risks to higher trophic levels, including humans (Nunes, *et al*., 2021**)**. Research has shown that heavy metals accumulate differently in earthworm species depending on soil composition, metal type, and exposure level, which makes them important tools in Eco toxicological studies (Aparicio, *et al.,* 2022).

Soil contamination by heavy metals is a pressing environmental issue due to the persistence, non-biodegradability, and bio accumulative nature of these elements. Unlike organic pollutants, heavy metals such as chromium (Cr), nickel (Ni), manganese (Mn), and zinc (Zn) do not degrade naturally and can remain in soil for decades, thereby altering soil quality and threatening ecosystem balance (Munir *et al*., 2020). These metals may enter the environment through natural processes such as weathering of rocks and volcanic activity, but anthropogenic activities including agriculture, mining, waste disposal, and industrial emissions are the dominant contributors to elevated concentrations in soils (Asefa *et al*., 2020). In Nigeria, poor waste management practices, intensive use of agrochemicals, and

increasing urbanization have contributed significantly to soil pollution, raising concerns about the transfer of toxic metals into the food chain (Salem *et al.*, 2020).

Some heavy metals such as iron, copper and zinc are essential micronutrient for living organism's others including lead, mercury, cadmium and arsenic are toxic even at low concentrations. These metals can accumulate in biological tissues leading to harmful effects on metabolism, organ function and overall health (Fu and Xi, 2020). The presences of heavy metals in the environment is influenced by both natural and anthropogenic source (Akhtar *et al.*, 2021).

Natural source includes volcanic eruptions, rock weathering and geothermal activities which release heavy metals into the soil, water and atmosphere. Anthropogenic activities such as industrial emission, mining, waste disposal and agricultural practices, have significantly increased heavy metal concentrations, contributing to environmental pollution (Daripa *et al.*, 2023).

Heavy metals exhibit varying degrees of mobility and bioavailability which influence their impact on ecosystem (Liu *et al.*, 2023). Factors such as soil pH, organic matter content and citation exchange capacity determine metal speciation and bioavailability (Parvin *et al.*, 2022). Toxic metals can persist in the environment for long periods leading to bioaccumulation in plant and animals (Okereafor et al., 2020). This poses significant risks to human health through food chain contamination, emphasizing the need for effective monitoring and remediation strategies (Sarker et *al.*, 2022).

Understanding heavy metals toxicity mechanisms is crucial for assessing their ecological and health effects. Heavy metals interfere with enzymatic activity disrupt cellular functions and induce oxidative stress in organism (Ghuge *et al.*, 2023). Research has demonstrate that chronic exposure to heavy metals can lead to developmental disorder, neurological impairment, and immune system suppuration in both humans and wildlife. Addressing heavy metals contamination requires multi-disciplinary approaches including environmental monitoring, pollution control measures and sustainable land management practices (Hou *et al.*, 2020).

In the context of Mubi North Local Government Area, Adamawa State, the growing use of agrochemicals, improper waste disposal, and other human activities may contribute to the release of heavy metals into the soil environment. However, scientific evidence on the extent of heavy metal accumulation in soil fauna within this region is still

limited. Since soil contamination not only affects fertility and agricultural productivity but also poses health risks through bio magnification in the food chain, it is crucial to evaluate the degree of exposure in soil organisms. Earthworms, being abundant and ecologically relevant, provide a cost-effective and reliable means of monitoring such contamination. This study therefore investigates the concentrations of selected heavy metals (Cr, Ni, Mn, and Zn) in earthworms from Mubi North and compares them with World Health Organization (WHO) permissible limits, with the aim of providing baseline data for environmental monitoring and public health protection in the area.

The significance of this study lies in its contribution to understanding the role of earthworms as reliable bio indicators of heavy metal contamination in agricultural soils. By assessing the concentrations and correlation patterns of selected heavy metals, the study provides valuable insights into the extent of soil pollution and its potential ecological and health implications. Furthermore, the study offers a scientific basis for environmental monitoring and sustainable agricultural practices, particularly in regions like Mubi North where soil contamination from anthropogenic activities is a growing concern.

MATERIALS AND METHODS

Study area

Mubi North is one of the 21 Local Government Areas in Adamawa State. Mubi north lies between latitude 9°50' N and 10°50' N and longitude 10°10° E (Adebayo and Tukur 2018). The temperature regime of the area is warm to hot throughout the year, because of high radiation income which is relatively evenly distributed throughout the year. However, there is usually a slightly cold period between November and February. There is a gradual increase in temperature from January to April with seasonal maximum occurring in April. Temperature drops slightly at the onset of rains due to the effects of cloudiness. It increases again a bit after the cessation of rains (October-November). This is followed by the hamattan period when temperature drops to the possible minimum. Generally, the mean annual temperature is about 27°c, the hottest month is May with about 35°c and the coldest month is January with less than 13°c (Adebayo and Uyi, 2016).

April is a month of transition between the wet and dry seasons in the area. During this period, there is scanty rainfall in most part of the area. The months of May to

September constitute the wet season. Monthly rainfall increases steadily from May to August which has the highest amounts. Rainfall decreases from September to October at a very sharp rate. The mean annual rainfall ranges from 900mm to 1050mm. Generally, planting of crops begins earlier in mountainous areas than the low land areas due to the orographic factor earlier mentioned. Relative humidity between January and March is low. It starts rising as from April and reaches the maximum in August, the peak of the raining season. Relative humidity starts decreasing as from October following the cessation of rainy season (Adebayo *et al.*, 2017).

Sample collection

The mature earthworms were manually collected at each study site and was brought to the zoology laboratory. The earthworms were placed immediately into petri dishes (one per dish). They were thoroughly rinsed with distilled water in the laboratory as soon as possible and were placed in petri dishes with one Whatman No. 1 filter paper and few drops of distilled water to maintain them. The earthworms were sacrificed by freezing and then oven dried at 800ºC to constant weight and then left in the desiccator to cool.

Earthworm Samples Treatment

The collected earthworm samples were oven-dried, after which they were homogenized into fine powder using a clean mortar and pestle. A portion of 300 mg of the powdered sample was digested with a mixture of 12 ml concentrated nitric acid (HNO_3) and 6 ml concentrated hydrochloric acid (HCl). The digestion was carried out in a closed Teflon vessel and progressively heated for twelve hours until a temperature of 1500 °C and a pressure of 800 kPa is reached in a microwave digestion system. The digestion process continued for two hours to ensure complete mineralization of organic matter. After cooling to ambient temperature, the digest was quantitatively transferred and diluted to 250 ml with deionized water. A procedural blank was prepared alongside all samples using distilled deionized water to account for potential contamination during the digestion process. The concentrations of heavy metals in the digested solutions was determined using an Atomic Absorption Spectrophotometer (AAS), following the method described by Corte *et al.*, (2019).

Statistical analysis

Statistical analysis for all the parameters tested**,** comparison of the means were analyzed Statistically, using descriptive analysis of variance (ANOVA) and Pearson statistic at probability of $p>0.05$ relation was then tested using the Pearson correlation index at the same probability, all statistical analysis was performed using SPSS Version 23 .

RESULTS

Mean concentration in heavy metals in earthworm

Table 1 below shows that copper (Cu) recorded the highest concentration in earthworms from both farms, followed by nickel (Ni) and zinc (Zn), whereas manganese (Mn) and chromium (Cr) were present in comparatively lower amounts. The concentrations were generally close between Farm 1 and Farm 2, with only slight variations, suggesting that earthworms accumulated these metals in a relatively consistent manner across the two sites.

Table 1 shows the Mean concentration of Mn, Zn, Ni, Cr, Cu, in earthworm in Mubi North farm 1 and 2

Heavy metals	Mean concentration (mg/g) F1	Mean concentration (mg/g) F2
Chromium (Cr)	1.515 ± 0.060^{a}	1.532 ± 0.057^{a}
Copper (Cu)	16.472 ± 0.338^{c}	16.498 ± 0.347^{a}
Manganese (Mn)	3.025 ± 0.139^{b}	3.012 ± 0.142^{c}
Nickel (Ni)	13.502 ± 0.218^{a}	13.488 ± 0.298^{b}
Zinc (Zn)	7.566 ± 0.129^{c}	7.589 ± 0.133^{a}

Key: F1 = Farm 1 F2 = Farm 2

Table 2 below indicates the Pearson correlation of heavy metals in earthworms from both farms, where chromium (Cr) and nickel (Ni) showed moderate positive correlations across the two sites, suggesting possible similarities in their sources or uptake mechanisms. Copper (Cu) and zinc (Zn) recorded weak correlations in both farms, reflecting limited association in their accumulation. Manganese (Mn), however, displayed a very low correlation in Farm 1 but a comparatively stronger correlation in Farm 2, which may indicate site-specific influences on its bioaccumulation. Overall, the results suggest that Cr and Ni tend to follow more consistent accumulation patterns across the study locations, while other metals vary depending on environmental conditions.

Table 2 shows the Pearson correlation of heavy metals in earthworm

Heavy metals	Farm one	Farm two
Chromium (Cr)	0.632	0.502
Copper (Cu)	0.205	0.118
Manganese (Mn)	0.124	0.547
Nickel (Ni)	0.516	0.582
Zinc (Zn)	0.351	0.152

Correlation co-efficient of chromium (Cr), Copper (Cu), Nickel (Ni), found in earthworm for the 2 samples location showed correlation.

DISCUSSION

The study assessed the role of earthworms as bio indicators of heavy metal concentrations in soil fauna within Mubi North Local Government Area, in line with the study's aim. The concentrations of selected heavy metals (Cr, Cu, Mn, Ni, and Zn) detected in earthworms from the two farms showed that copper (Cu) had the highest mean concentration, followed closely by nickel (Ni) and zinc (Zn), while manganese (Mn) and chromium (Cr) remained comparatively lower. This finding indicates that earthworms effectively accumulate metals present in their habitat, which is consistent with the reports of Terekhova, (2022)., who highlighted the sensitivity of earthworms to environmental pollutants, making them reliable bio indicators of soil contamination. The relatively high levels of Cu and Ni could be attributed to anthropogenic influences such as agricultural inputs, waste disposal, and soil amendments within the area, factors previously emphasized by Ahmed and Al-Mutairi, (2022) as contributors to heavy metal accumulation in Nigerian soils.

Furthermore, the correlation analysis (Table 2) demonstrated that chromium (Cr) and nickel (Ni) exhibited moderate positive correlations in both farm locations, suggesting a possible common source or similar mechanisms of uptake by earthworms. Manganese (Mn), however, showed weak correlation in Farm 1 but a stronger correlation in Farm 2, which may be linked to differences in soil composition or localized farming practices. Similar observations were made by Kuppan, *et al.*, (2024), who reported that variations in heavy metal accumulation in earthworms can be influenced by both soil characteristics and metal bioavailability. The weak correlations recorded for copper (Cu) and zinc (Zn) in this study further suggest that their accumulation may be controlled by site-specific

environmental factors, thereby supporting the second objective of comparing concentration patterns across farms.

Comparing the concentrations obtained in this study with the World Health Organization (WHO) permissible limits indicates that the levels of Cu and Ni were relatively high, suggesting potential ecological and health risks if bioaccumulation progresses through the food chain. This aligns with the findings of Singh *et al.*, (2020), who emphasized that excessive heavy metal concentrations in soil organisms can have cascading effects on higher trophic levels, including humans. Therefore, the results of this research not only validate the use of earthworms as bio indicators of heavy metal contamination but also highlight the need for regular environmental monitoring in agricultural areas like Mubi North. The study objectives have thus been achieved, as both the mean concentrations and correlation patterns of the metals were determined and compared with international safety standards, revealing significant insights into the bioaccumulation of heavy metals in the study area.

CONCLUSION

This study demonstrated that earthworms in Mubi North Local Government Area accumulated varying concentrations of heavy metals, with copper (Cu) showing the highest levels, followed by nickel (Ni) and zinc (Zn), while chromium (Cr) and manganese (Mn) were comparatively lower. The correlation analysis further revealed that chromium (Cr) and nickel (Ni) exhibited moderate positive associations across both farms, suggesting common sources and similar mechanisms of uptake. In contrast, manganese (Mn) displayed weak correlation in Farm 1 but stronger correlation in Farm 2, reflecting possible site-specific influences on its accumulation, while copper (Cu) and zinc (Zn) showed consistently weak correlations. When compared with WHO permissible limits, the concentrations of Cu and Ni were relatively high, indicating potential ecological and health risks if bioaccumulation continues through the food chain. These findings confirm the role of earthworms as effective bio indicators of soil heavy metal pollution and underscore the importance of continuous monitoring to ensure sustainable soil quality and protect public health.

Recommendations

i. based on the findings of this study, it is recommended that regular monitoring of heavy metal concentrations in soils and soil fauna should be carried out in Mubi North to detect early signs of pollution.

ii. awareness programs should be organized for farmers and residents on the risks of heavy metal accumulation and the safe use of agrochemicals, fertilizers, and pesticides.

iii. local authorities should enforce proper waste disposal practices and regulate industrial and agricultural inputs that may introduce heavy metals into the environment.

iv. further research should be conducted to assess the bioaccumulation of heavy metals in crops and other soil organisms, to determine potential risks along the food chain.

adoption of soil remediation strategies, such as phytoremediation and organic soil amendments, should be encouraged to reduce heavy metal concentrations and improve soil health in the study area.

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