Assessment of Heavy Metal Concentrations and Textural Properties of Soils in The Southern Part of Kebbi State, Nigeria

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Abstract

Agricultural soils are increasingly vulnerable to heavy metal contamination, which may threaten food security, ecosystem quality and human health. This study assessed heavy metal concentrations and soil textural properties in the southern part of Kebbi State, Nigeria. A multistage sampling technique was used to collect 48 composite soil samples from four Local Government Areas (LGAs): Zuru, Danko Wasagu, Yauri and Shanga. Particle-size distribution was determined using the hydrometer method. Cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), lead (Pb) and zinc (Zn) concentrations were determined using atomic absorption spectrophotometry (AAS). The data were subjected to analysis of variance (ANOVA), and means were separated using Duncan's New Multiple Range Test (DMRT). The soils were generally sandy loam in texture. The overall mean concentrations of the analysed metals were 3.2375 mg/kg for Cd, 0.0597 mg/kg for Cu, 15.435 mg/kg for Fe, 2.8463 mg/kg for Mn, 0.1808 mg/kg for Pb and 0.3056 mg/kg for Zn. The mean Cd concentration exceeded the NESREA limit of 3.00 mg/kg reported in the study, whereas the other reported metal concentrations were below the comparison limits presented. Most of the measured heavy metals were below the comparison limits used in this study. However, the overall mean Cd concentration exceeded the stated NESREA limit, indicating the need for further investigation and regular monitoring. The soils were predominantly sandy loam, although the textural classification reported for Shanga LGA differed from that of the other LGAs.

Keywords: *Heavy metals; soil texture; soil pollution; cadmium; atomic absorption spectrophotometry.*

1. Introduction

Agricultural soils receive various pollutants, among which heavy metals are common contaminants worldwide. Heavy metal pollution in soils has become a major environmental concern because of its potential effects on agricultural productivity, food safety and human health (Ozein, 2018). Heavy metals may pose risks to living organisms and humans when they accumulate in the food chain (Kettkar, 2019).

Unlike many organic compounds, most heavy metals are not readily degraded by microbial or chemical processes and may therefore persist in the environment for extended periods (Ozein, 2018). Their sources may be natural, including parent materials and geological processes, or anthropogenic, including industrial activities, agriculture and mining (Grange, 2021). In Nigeria, the use of phosphate fertilizers and pesticides has been identified as a potential contributor to the accumulation of heavy metals in agricultural soils (Arao *et al*., 2010).

Metals such as arsenic, lead, cadmium and mercury are of particular concern because of their toxicity. Cadmium is persistent in the environment and has been associated with adverse effects, including kidney damage and bone disease (Campbell, 2006). Analytical techniques such as atomic absorption spectrophotometry (AAS) are used to determine heavy metal concentrations in soil samples (Diazzy, 2021). Agriculture is an important livelihood activity in the southern part of Kebbi State. However, information on the concentrations of selected heavy metals and the textural properties of soils in the area is limited. Baseline information is required to support appropriate soil-management practices and sustainable agricultural production. Therefore, this study assessed selected heavy metal concentrations and soil textural properties in the southern part of Kebbi State, Nigeria.

2. Materials and Methods

2.1 Study Area

The study was conducted in the southern part of Kebbi State, Nigeria, between the geographical coordinates reported as latitudes 10°00′–11°00′ N and longitudes 3°30′–60°35′ E. The area covers approximately 11,428 km² and comprises the Yauri and Zuru Emirates, with seven Local Government Areas. The vegetation is described as tropical savannah woodland, and the mean annual rainfall is approximately 1,004 mm. The soils are generally well-drained and sandy loam in texture (Dudu, 2014).

2.2 Sampling Procedure

A multistage sampling technique was used. Two LGAs were selected from each emirate: Yauri and Shanga from Yauri Emirate, and Zuru and Danko Wasagu from Zuru Emirate. Four villages were selected from each LGA, and three composite soil samples were collected from each village, giving a total of 48 composite soil samples.

2.3 Analytical Techniques

The processed soil samples were analysed for selected physical and chemical properties using standard procedures.

Particle-size distribution: Particle-size distribution was determined using the hydrometer method, following Gee and Bauder (1986).

Heavy metal analysis: Ten grams of soil were shaken with 20 mL of extracting solution comprising 0.005 M DTPA, 0.01 M $CaCl_2$ and 0.1 M TEA, buffered at pH 7.3. The filtrate was analysed for Cd, Cu, Fe, Mn, Pb and Zn using an atomic absorption spectrophotometer, following the procedure attributed to Peter *et al*. (2011).

2.4 Data Analysis

The data were subjected to analysis of variance (ANOVA) using SPSS. Where significant differences occurred, means were separated using Duncan's New Multiple Range Test (DMRT) at the 5% probability level.

3. Results and Discussion

3.1 Particle-Size Distribution and Soil Texture

The particle-size distribution results indicated that the soils of the southern part of Kebbi State were generally sandy loam in texture. The reported overall mean values were 680.10 g/kg sand, 172.36 g/kg silt and 140.55 g/kg clay.

Table 1. Mean particle-size distribution of soils in four Local Government Areas in the southern part of Kebbi State

LGA	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Textural class
Zuru	753.00	171.10	75.90	Sandy loam
Danko Wasagu	725.60	176.80	97.60	Sandy loam
Shanga	631.10	106.73	262.17	Loamy sand
Yauri	638.70	234.78	126.52	Sandy loam
Overall mean	680.10	172.36	140.55	Sandy loam

The results show that sandy loam was the dominant textural class across the study area. Such soils may provide favourable drainage and aeration for crop production when managed appropriately. The findings are consistent with the description of the area's soils as generally well-drained (Dudu, 2014). The textural class reported for Shanga should, however, be checked against its sand, silt and clay percentages before publication.

3.2 Heavy Metal Concentrations

The overall mean concentrations of the selected heavy metals across the four LGAs are presented in Table 2.

Table 2. Overall mean heavy metal concentrations across the four LGAs

Heavy metal	Overall mean (mg/kg)	NESREA standard (mg/kg)	WHO limit (mg/kg)	Status as reported
Cadmium (Cd)	3.2375	3.00	—	Exceeded
Copper (Cu)	0.0597	36	36	Within limit
Iron (Fe)	15.435	—	20	Within limit
Manganese (Mn)	2.8463	—	2,000	Within limit
Lead (Pb)	0.1808	40	—	Within limit
Zinc (Zn)	0.3056	—	50	Within limit

Cadmium (Cd): The overall mean Cd concentration was 3.2375 mg/kg, exceeding the NESREA standard of 3.00 mg/kg cited in this study. The highest concentration was reported in Shanga LGA (4.0350 mg/kg), followed by Danko Wasagu (3.0825 mg/kg). Possible sources of Cd accumulation include phosphate fertilizers, sewage sludge and manure application (Campbell, 2006). These potential sources were not directly tested in the present study.

Copper (Cu): The overall mean Cu concentration was 0.0597 mg/kg, below the NESREA and WHO comparison limits of 36 mg/kg presented in Table 2. Copper is an essential micronutrient

for plant growth; however, concentrations should be interpreted in relation to the extraction method and the applicable soil-quality guideline.

Iron (Fe): The overall mean Fe concentration was 15.435 mg/kg, below the WHO comparison limit of 20 mg/kg reported in Table 2. This value is higher than the range of 1.23–2.28 mg/kg reported by Augie *et al*. (2020) for other areas of Kebbi State. Differences in location and analytical procedures may affect comparisons between studies.

Manganese (Mn): The overall mean Mn concentration was 2.8463 mg/kg, below the WHO comparison value of 2,000 mg/kg presented in Table 2. This result is comparable to the value of 3.13 mg/kg reported by Onwudike *et al*. (2016) for soils in Rivers State.

Lead (Pb): The overall mean Pb concentration was 0.1808 mg/kg, below the NESREA value of 40 mg/kg presented in Table 2. Based on this comparison, the measured mean concentration was within the stated limit.

Zinc (Zn): The overall mean Zn concentration was 0.3056 mg/kg, below the WHO comparison value of 50 mg/kg presented in Table 2. This is lower than the concentration of 0.58 mg/kg reported by Mustapha *et al*. (2010) in soils of Yamaltu-Deba Local Government Area, Gombe State.

4. Conclusion and Recommendations

4.1 Conclusion

The soil physical-property results indicate that sandy loam is the dominant textural class in the southern part of Kebbi State. The overall mean concentrations of Cu, Fe, Mn, Pb and Zn were below the comparison limits presented in this study. In contrast, the overall mean Cd concentration of 3.2375 mg/kg exceeded the stated NESREA standard of 3.00 mg/kg. This finding warrants further investigation because cadmium can persist in soils and may enter the food chain.

4.2 Recommendations

1. Further assessment should be conducted in areas with comparatively high Cd concentrations, particularly Shanga and Danko Wasagu LGAs, to identify possible sources and determine the extent of contamination.
2. Regular monitoring of heavy metal concentrations, especially Cd, should be undertaken across the four LGAs to establish changes over time.
3. Farmers should receive guidance on the responsible use of phosphate fertilizers and other agricultural inputs, and on avoiding irrigation with untreated wastewater.
4. Where elevated Cd concentrations are confirmed, site-specific remediation options, including suitable phytoremediation approaches and the use of amendments such as biochar or lime, should be evaluated before implementation.

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