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Research Article

# Assessment of Spatial Variability of Heavy Metals (Pb and Al) in Alluvial Soil around Delta State University of Science and Technology, Ozoro, Southern Nigeria

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## ABSTRACT

Soil heavy metals pollution is a major global threat, because of its impact to plants, animals, and the soil geotechnical properties. Geostatistical method was used to investigate the spatial distributions of aluminum and lead within a section of the Delta State University of Science and Technology, Ozoro, Nigeria. A total area of 1 $km^2$ (100 hectares) was covered within the school environment. Twenty -five (25) topsoil samples were collected, at the end of the dry season (March 2021); when the water table in the study area was very low. The lead and aluminum concentrations of the 25 samples were measured by using the Association of Official Analytical Chemists (AOAC) approved methods. Using a geostatistical tool, the lead and aluminum concentrations and distribution in the soil were plotted on predication maps. The maps revealed irregular spatial distributions of lead and aluminum ions within the study area. The lead concentration was highest at the North-central region of the study area; while lead concentration was lowest at the Eastern region of the study area. In terms of the aluminum metal, the highest aluminum concentration was observed in the North eastern region; while aluminum concentration was lowest at the South western region. Data obtained from this study will be useful for agricultural and civil engineering purposes, mainly in the area of decision-making.

**RESEARCH ARTICLE**

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## INTRODUCTION

Soil is a vital component of the ecosystem that is mainly used for agricultural and constructional purposes; hence, it needs to be protected. According to Alloway (1990) the knowledge of the heavy metals and minerals status of the soil is necessary, in order to ascertain the concentrations of the essential micronutrients in the environment. Spatial heterogeneity of heavy metals concentrations in soil is an important factor affecting agricultural productivity and geotechnical properties of the soil (Cemek *et al.*, 2007). Geotechnical properties of soil are one of the major factors to be considered during foundation design of farm structures and other residential buildings. Soil productivity in agricultural technology is influenced by its texture, structure, chemical composition, heavy metals concentration, amongst others. The availability (solubility) of a metal in the soil is a factor of the immediate environmental condition (Ogbaran and Uguru, 2021a); as solubility is higher in fine grained soils with high moisture content, compared to coarse grained soils with low water content. Hence, aquatic environments tend to have higher metals content, which will results in high buildup of these metals by aquatic organisms in their bodies (Sobhanardakani *et al.*, 2011).

Lead (Pb) and aluminum (Al) are some of the most toxic and abundant heavy metals (elements) in the world. They occur in soils mostly as a result of the weathering of rocks; although, leachates from waste dumpsites and other anthropogenic sources also contribute greatly to their concentrations in the soil. The environment acquires its heavy metals contamination through direct atmospheric deposition, geologic weathering, anthropogenic sources, etc. (Wang and Rainbow, 2008; EPA, 2020; Ogbaran and Uguru, 2021a; Ogbaran and Uguru, 2021b). Multiple factors such as, soil pH, soil moisture content and its holding capacity, texture, organic materials content, vegetation type, etc., usually influenced the concentration and distribution of metals in the soil (Marques *et al.*, 2009; Rakesh *et al.*, 2013).

According to previous researches (Giller *et al.*, 1998; Friedlov´a, 2010; Chibuike and Obiora, 2014; Akpokodje and Uguru, 2019), heavy metals toxicity is dependent on the soil temperature, soil pH, organic materials present, chemical forms of the metal, etc. Lead and aluminum contamination of the environment had become an alarming issue, mainly due to their impact on the soil's geotechnical and physiochemical properties (Kidd and Proctor, 2001; Ohadi *et al.*, 2015). Therefore, the presence of these heavy metals in the soils did not only have adverse effects on plants and human beings, but altered the soil's mechanical/geotechnical properties (Begun *et al.*, 2009). Ohadi *et al.* (2015) worked on the impact of lead metal on the liquid limit of sand–clay soil samples, and they observed a decline in the liquid limit as the lead concentration increased. Accordingly, Negahdar *et al.* (2017) studied the influence of lead on sandy clay soils, and observed that the soil's cohesion decreased non-linearly, as the lead concentration increases; although, the soils internal friction angle was not affected by the lead concentration. Furthermore, Jafer *et al.* (2021) stated that aluminum had great effect on the unconfined compressive strength (UCS) of contaminated soils samples, as a reduction in the soil's UCS was observed as the aluminum concentration increased.

Regarding the impact of these heavy metals on plants, Nas and Ali (2018) reported that high lead concentration in the soil could result in retardation of crops' growth, inhabitation of the photosynthesis process, and several other factors. Likewise, Barceló and Poschenrieder (2002) in their study reported that a high concentration of aluminum can results in extensive plants roots injuries, resulting in poor ion and water uptake by the plants' roots. According to Sivaguru and Horst (1998), the toxicity of aluminum in plants includes callose buildup in the plants' roots cells, thus hindering cell-cell trafficking, and disrupting the structure of the plant cytoskeleton (Panda *et al*., 2009).

Although many studies (Atikpo and Ihimekpen, 2018; Hua *et al*., 2012; Burgos *et al*., 2006; Stirbescu *et al*., 2018) had investigated spatial variation patterns of heavy metals in the environment, there is no recorded literature on the spatial variability of lead and aluminum metals in the soils in the Niger Delta area with particular reference to the Ozoro community of Delta State, Nigeria. Ozoro is a center for agricultural and commercial development, and is presently undergoing construction/development activities. Therefore, this study is aimed at investigating the concentration and spatial distribution of lead and aluminum metals in the topsoil in a selected area of Ozoro community, Delta State, by using geostatistical method.

## MATERIALS AND METHODS

**Description of experimental area**

The study was done at Delta State University of Science and Technology, Ozoro, located in Delta State, Nigeria. Ozoro falls within the tropical forest zone of Nigeria, and is characterized by two major climatic seasons (rainy and dry season); with rainfall of about 1800 mm annually. The study area usually experiences tropical rain storms and flood during the rainy season (Eboibi *et al*., 2018). The geographical coordinates of the university are: 5.549° N and 5.570° N, 6.241°E and 6.249°E; and is made up of developed and undeveloped areas. The undeveloped area of the university is covered with natural vegetation, and the soil is mainly the alluvial type; while the built up area is covered by both alluvial deposits and imported laterite and sands.

The total experimental area used for this study was 1 km by 1 km (as shown in Figure 1) and was gridded at 200 m intervals (Figure 2). The central portion of the study area is occupied by administrative buildings and students' lecture halls; while the north and eastern regions are covered with dense natural vegetation.

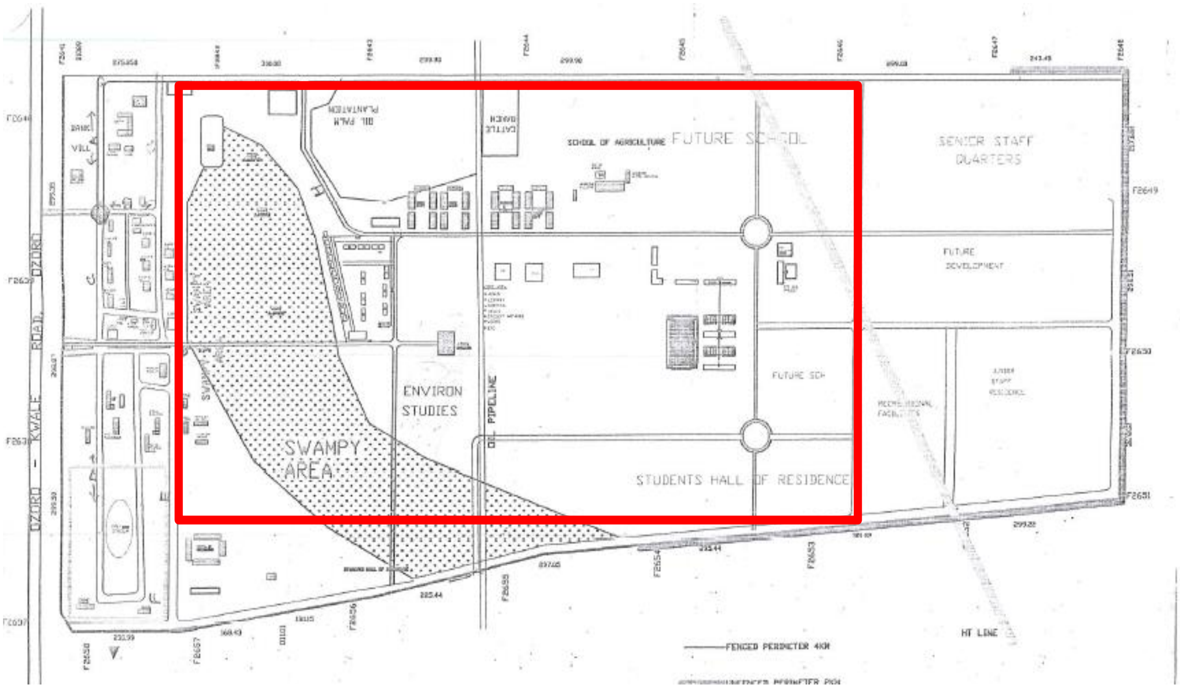


**Figure 1**. The layout map of the study area.

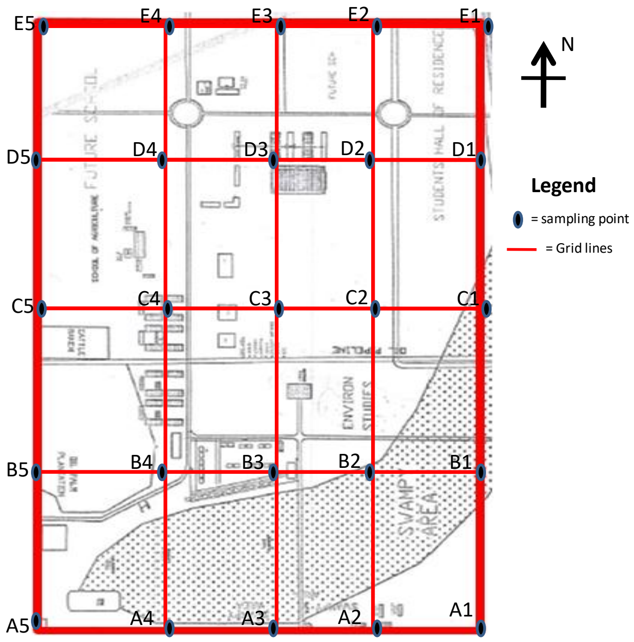


**Figure 2.** Grid Lines revealing the sampling locations at 200 m grids superimposed on layout map.

## Soil sampling

At each grid point, the topsoil (0-30cm) was collected by using a soil auger. The co-ordinates of the spatial location were measured by using a global positioning system (GPS) device.

After collection, the soil samples were poured into a black plastic bag (Figure 3), and coded according to the sample location. The samples were collected during the peak of the dry season (March 2021); when the water table in the study area was very low. A total of 25 soil samples were collected for this study.

**Figure 3.** The collected soil samples.

**Heavy metals concentrations and analysis**

Each soil sample was air-dried, ground in a porcelain mortar, and then filtered with a 2 mm gauge nylon filter, as described by Agbi *et al.* (2021). The powdered soil sample (10 g) was measured with a digital balance and emptied into a heat resistance beaker. To this was then added a 15 mL mixture of concentrated inorganic acids ($HNO_3$, HCl, and $H_2SO_4$) in the ratio of 5:1:1, and heated in a water bath at a temperature of 100$^0$C until a transparent solution was obtained (Akpomrere and Uguru, 2020). The digested soil sample was cooled to room temperature under ambient environmental conditions, and filtered into a measuring cylinder using filter paper. Then distilled water was added to the filtrate to dilute it the 100 mL mark of the measuring cylinder. Lead and aluminum concentrations of the diluted digested solution were measured with the aid of the Atomic Absorption Spectrophotometer (AOAC, 2019; Turek *et al.*, 2019; Akpomrere and Uguru, 2020).

**Data Analysis**

The variability of lead and aluminum concentrations in the soil was carried out by using the ArcGIS geostatistical tool, and adopting the Kriging model.

## RESULTS AND DISCUSSION

The mean concentrations of lead and aluminum in the soils collected from all the sampled locations are presented in Table 1. As shown in Table 1, the Pb and Al concentrations varied extensively across the area investigated in this study. Although the Pb concentration across the study area was fairly high, it was below the 85 mg/kg maximum allowable limit approved by the World Health Organization (WHO, 1996). Therefore, there is no clear Pb pollution risk on agricultural practices; although, it may have significant effects on the soil geotechnical properties.

**Table 1.** Metal concentration in soil samples.

| Location | GPS co-ordinates | Metal concentration (mg kg$^{-1}$) | | Location | GPS co-ordinates | Metal concentration (mg kg$^{-1}$) | |
|---|---|---|---|---|---|---|---|
| | | Pb | Al | | | Pb | Al |
| **A1** | 5.563 N, 6.249 E | 16.3±0.4 | 998.44±23 | **B1** | 5.564 N, 6.249 E | 16.1±0.9 | 844.49±8 |
| **A2** | 5.562 N, 6.248 E | 12.8±0.3 | 641.22±14 | **B2** | 5.563 N, 6.248 E | 12.8±1.1 | 3041.28±9 |
| **A3** | 5.562 N, 6.246 E | 21.7±0.5 | 1120±32 | **B3** | 5.564 N, 6.246 E | 18.9±0.8 | 1301.9±11 |
| **A4** | 5.560 N, 6.243 E | 18.9±0.9 | 948.9±18 | **B4** | 5.562N, 6.243 E | 15.2±0.5 | 1235.2±9 |
| **A5** | 5.560 N, 6.241 E | 18.1±0.8 | 1018.1±13 | **B5** | 5.562N, 6.241 E | 14.5±0.3 | 1514.5±15 |
| **C1** | 5.566 N, 6.248 E | 26.2 | 1219±11 | **D1** | 5.568 N, 6.246 E | 13.7±0.8 | 849.25±9 |
| **C2** | 5.566 N, 6.246 E | 25.4 | 779.5±12 | **D2** | 5.568 N, 6.248 E | 12.1±0.5 | 1266±14 |
| **C3** | 5.566 N, 6.244 E | 17.3 | 499±8 | **D3** | 5.568 N, 6.245 E | 13.3±0.4 | 1840±18 |
| **C4** | 5.566 N, 6.243 E | 10.8 | 549±11 | **D4** | 5.568 N, 6.242 E | 14.8±0.9 | 1393±11 |
| **C5** | 5.566 N, 6.240 E | 15.8±0.5 | 515.8±8 | **D5** | 5.568 N, 6.241 E | 16.5±2.2 | 1538±18 |
| **E1** | 5.570 N, 6.249 E | 5.9±0.3 | 1840±10 | | | | |
| **E2** | 5.570 N, 6.246 E | 8.1±0.5 | 1245±13 | | | | |
| **E3** | 5.568 N, 6.245 E | 6.8±0.8 | 577.48±15 | | | | |
| **E4** | 5.570 N, 6.243 E | 10.6±0.4 | 1410±9 | | | | |
| **E5** | 5.570 N, 6.241 E | 12.5±1.2 | 1212±14 | | | | |

Mean± standard deviation; n: 3

The results obtained in this study were plotted in variation maps shown in Figure 4 and Figure 5. The variation maps revealed that the lead concentration in the topsoil was lower when compared to the aluminum concentration in the topsoil. Based on the results outcome, the lead concentration in the topsoil within the study area ranged between 5.92 mg kg$^{-1}$ and 26.2 mg kg$^{-1}$; while the aluminum concentration in the topsoil area ranged between 499 mg kg$^{-1}$ and 1840 mg kg$^{-1}$. It can be observed from the soil predication maps that, the lead and aluminum concentrations were non-uniformly distributed across the study area.

As revealed in Figure 4, high lead concentration was recorded at the North-central part of the area studied; while low lead concentration was recorded at the North-eastern and Southern parts of the area studied. As depicted by the soil map, the lead concentration generally increased from the Eastern region to the Western region, with the peak lead concentration (26.2 mg kg$^{-1}$) recorded at the north-central region of the study area. In terms of the spatial distribution of aluminum in the topsoil, Figure 5 revealed that the highest aluminum concentration was recorded in the north-eastern and southern-eastern regions of the study area. However, the lowest aluminum concentration was recorded at the North-western region of the study area. Generally, the North-central part of the area studied had a fairly low aluminum concentration. As we moved from the north central part region to the Southern region of the study area, it was observed that aluminum concentration generally decreased, before it started to increase again, reaching a peak at the distant south-eastern region. These observations are similar to the previous report of Stirbescu *et al.* (2018), where the soil lead concentration was at the peak at the central region of the study area (Targoviste city). A similar trend of non- uniformity distribution of soil lead concentration was also observed by Atikpo and Ihimekpen (2018), in Amaonye forest of Ebonyi State, Nigeria. According to Naveen *et al.* (2018) the heavy metals concentrations often declined non-uniformly, as the spatial locations moved away from the main polluting source(s).

The high heavy metals concentration generally recorded in the north-central region may be attributed mainly to anthropogenic sources. According to Agbi *et al.* (2021) and Atikpo and Ihimekpen (2018), anthropogenic activities can cause a surge in heavy metals pollution in the soil. Similarly, the low soil lead concentration recorded at the far North-Eastern region of the study area could be attributed to the presence of dense natural vegetation; which acts as a phytoremediation agent. According to Akpokodje and Uguru (2019) and Palmroth *et al.* (2006), green plant helps to reduce the heavy metals and other toxic materials concentrations in the soil, by removing, containing and detoxifying the contaminants in the soil.

The findings of this research work will be helpful in planning frameworks for agricultural and constructional activities. Hani *et al.* (2014) reported that spatial locations and source capturing of soil heavy metals are essential for the identification of pollution hot-spot zones, and the assessment of potential pollutants generators in geotechnical related soil attributes.

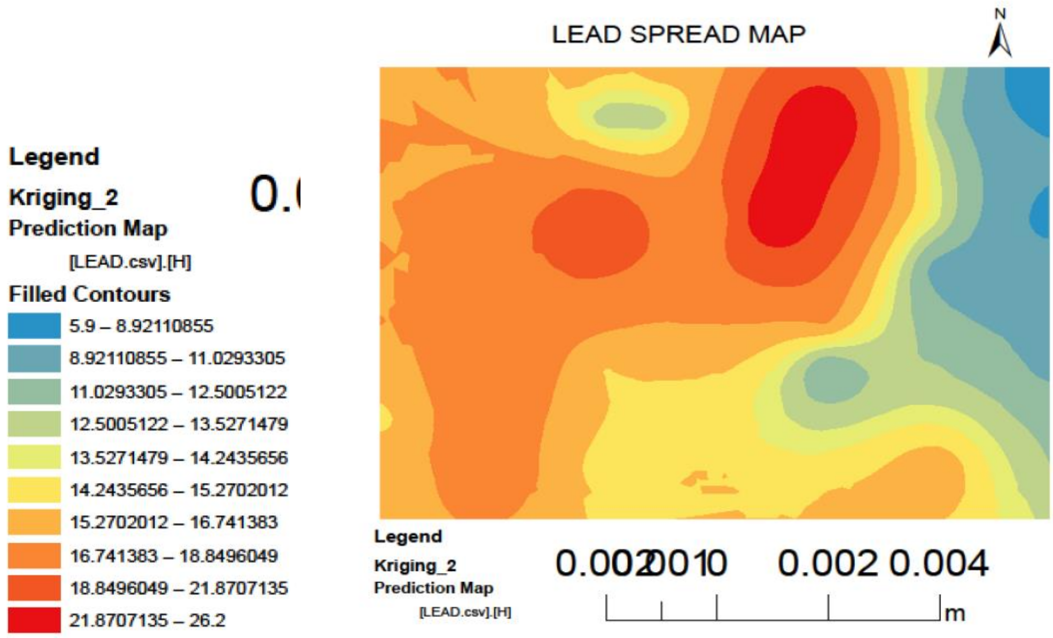


**Figure 4.** Prediction map of spatial variability of lead in the top soil.

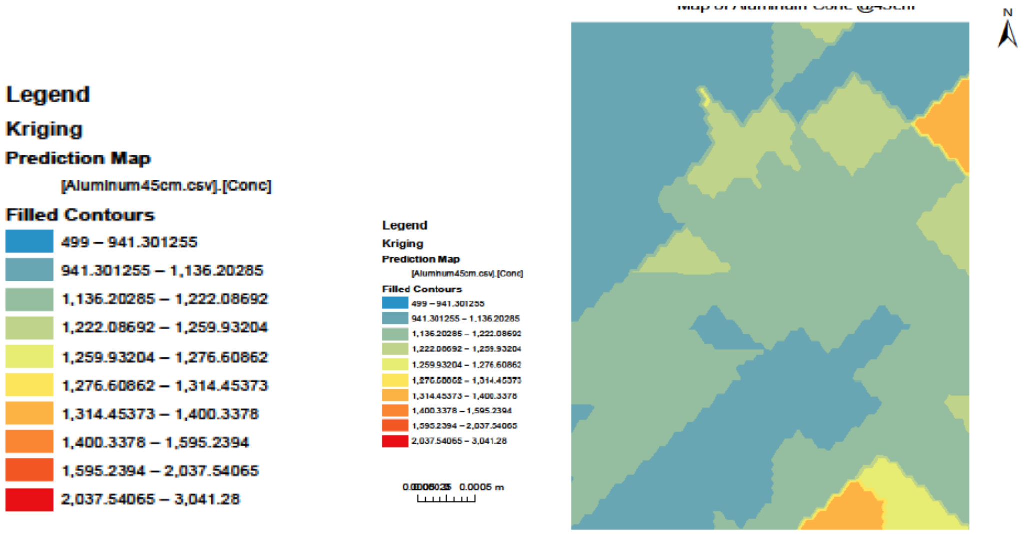


**Figure 5.** Prediction map of spatial variability of Aluminum in the top soil.

## CONCLUSION

This study investigated the lead and aluminum concentrations in the topsoil, across a section of Ozoro community of Delta State, Nigeria. Twenty-five topsoil samples (0-30 cm depth) were collected at specified grid points. The lead and aluminum concentrations of the soil samples were determined in accordance to approved procedures. Generally, the study findings depicted that the lead concentration was lower than the aluminum concentration in the soil. Also, the findings of the study revealed that the lead and aluminum concentrations varied non-uniformly across the study area. Lead concentrations ranged from 5.92 mg $kg^{-1}$ to 26.2 mg $kg^{-1}$; while the aluminum concentration ranged from 499 mg $kg^{-1}$ to 1840 mg $kg^{-1}$. The study further revealed that the north-central region had the highest lead concentration; while the north-eastern and south-eastern parts were hot-spots of aluminum accumulation. Findings obtained from this study will be useful for agricultural and geotechnical purposes.

## DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

## CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.
**Hilary Uguru**: Designed the research
**Ovie Isaac Akpokodje**: Edited the manuscript.
**Goodnews Goodman Agbi**: Write the original draft.

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