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## Effects of Dump Site on Chemical Properties of the Soil

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### Abstract

The indiscriminate disposal of institutional, municipal, and industrial solid waste on open land poses serious threats to soil quality, ecosystem health, and both surface and groundwater systems. This study investigates the influence of solid-waste dumping on the chemical characteristics of soils at the Asunle dumpsite, Obafemi Awolowo University, Ile-Ife, Nigeria. Soil samples were collected from the dumpsite and from a control location situated 200 m upstream, at depths of 0.40 m, 0.80 m, and 1.20 m. The elemental and chemical compositions of the soils were determined using X-ray fluorescence (XRF) and standard laboratory procedures. The statistical significance of differences between the dumpsite and control soils was evaluated using analysis of variance (ANOVA) implemented in Microsoft Excel. The results show that the soils contain a wide range of major, minor, and trace elements, including Mg, Al, Si, P, S, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W, As, Au, Pb, Rb, Zr, Nb, Mo, Ag, Cd, Sn, and Sb. Based on their concentrations, these elements were classified into four groups: major (>90.0 mg/g), mega (25.0–90.0 mg/g), micro (2.0–25.0 mg/g), and nano (<2.0 mg/g) compositions. Statistical analysis indicates that at shallow depths ( $\leq 0.40$  m) within the centre of the dumpsite, waste disposal significantly alters soil chemical composition at the 95% confidence level ( $F\text{-value} > F\text{-critical}$ ). However, at depths greater than 0.40 m and in areas surrounding the dumpsite, the influence of waste dumping is not statistically significant ( $F\text{-value} < F\text{-critical}$ ). These findings suggest that contamination is largely confined to near-surface soils, highlighting the need for effective waste management and remediation strategies.

### Keywords

Microsoft Excel;  
Analysis of Variance;  
Heavy metals;  
Chemical Properties;  
Dump Site

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## INTRODUCTION

Rapid population growth has increased solid waste production, leading to more landfills and dumpsites around the world. Open dumping is one of the most widely used methods for managing solid waste in developing countries (Udoumoh et al., 2023). Mir et al. (2024) reported that large amounts of solid waste are treated utilizing dumping systems at several open sites hourly. These materials have severe impacts on the environment, water (surface and ground), and soil around these sites. Landfilling is normally utilised for both industrial and municipal solid waste disposal based on some economic factors (Farooq et al., 2024; Mir et al., 2024, Jasrotia and Solomon, 2021; Nanda and Berruti, 2021).

Municipal and industrial solid waste are heterogeneous mixture of both non-biodegradable and biodegradable compositions, which are subject to biological, chemical, and physical degradation processes. Figure 1 presents a typical site and various materials available with the composition. Figure 2 shows techniques used in the disposal of municipal solid waste. In addition to severe impacts on the environment, water (surface and ground), and soil around these sites, it has been documented that natural soil shows greater and higher shear strength than soil from landfilling sites or contaminated soil with solid wastes (Chihi et al., 2025).

cThese contaminated soils are often affected by leachate from the solid waste, the wet and dry seasons, and the chemical and biological processes from the solid waste that alter the natural moisture content, plasticity, compressibility, and strength of

the soil (Ale et al., 2024b; Chihi et al., 2025). These changes caused by the actions of landfill and solid waste dump sites affect and impact the engineering safety and environmental risk within and around the dumpsite. Understanding the geotechnical properties of a dumpsite is important for foundation and construction planning for future possible land re-use and to prevent infrastructure collapse (Ale et al., 2024a; Ota et al., 2024). It has been reported that in most cases with open dumping, the solid wastes are not segregated, and hence the soils have higher moisture content with lower Atterberg limits and increased compressibility and settlements (Gyabaah et al., 2024; Tovide et al., 2025; Chihi et al., 2025). Waste segregation at the point of collection limits soil degradation in dumpsites. A reduction in organic and hazardous substances reduces the toxicity of the leachate generated and reduces the negative influence on the underlying soil (Zhang et al., 2022; Wang and Qiao, 2024; Chihi et al., 2025). Previous studies on dumpsites examined the geotechnical properties of the dumpsites and reported that the key geotechnical properties of soil around dump and landfill sites, such as hydraulic conductivity, shear strength, and Atterberg limits, were significantly changed (leading to a reduction in shear strength, a decrease in the plastic and liquid limits, and an increase in permeability) in these soils. These changes in the geotechnical and chemical properties pose substantial threats to soil stability and infrastructure (Jahanfar et al., 2017; Zhan et al., 2018; Onwe et al., 2020; Gyabaah et al., 2023; Ohaeri et al., 2024; Tovide et al., 2025; Singh et al., 2025; Harun et al., 2025; Mir et al., 2024).



Figure 1: A typical site and various materials available with the composition (Source: Images Landfill, 2025a).



Figure 2: Techniques used in the disposal of municipal solid waste (Source: Images Landfill, 2025b)

More on effects of dump site on chemical composition of soil can be found and established in the literature such as Nyiramigisha (2021); Siddiqua et al. (2022); Ali et al. (2014); Olagunju et al. (2018); Ashraf et al. (2026); Alharth et al. . (2025); Roy et al. (2025); Langunu et al. (2025); Oued Lhaj et al. (2025); Yayu et al. (2025); Nekhoroshkov et al. (2025); Elobaid et al. (2025); Kornienko et al. (2025a and b); Sumalinog et al.. (2025); Abd-Elhalim et al. (2025); Kucherova et al. (2025); Lalrinfela et al. (2024); Chernysh et al. (2024); Gupta et al. (2024); Abedi et al. (2022); Aiguoarueghian et al. (2024). With the critical importance of chemical properties of the soil on the stability of infrastructures on land, evaluation of the chemical properties dump site is essential.

Figure 3 shows the impact of weak chemical, index properties and geotechnical properties of soil on an infrastructure. Although previous studies provided information and data on the impact of dumped solid wastes on chemical, index properties, and geotechnical properties of soil around the dump site between a depth of 0.0cm and 150 cm, but little data and information on the variation

of chemical properties of soil at a dump site beyond 200 cm. Hence this study investigated the variation of chemical properties of dumpsite soil from Asunle, Obafemi Awolowo University, Ile-Ife, Nigeria.

#### **MATERIALS AND METHODS**

Soil samples were collected at a depth of 0.4 m, 0.8 m, and 1.2 m from three (3) excavated pits at the dumpsite and at the control point, which is outside the dump site. Figure 4 presents the location of the sampling sites and the control. The chemical composition of the collected soil samples (contaminated and control) was determined using X-ray fluorescence (XRF). Effects of the depth and locations on chemical properties of the soil at the dumpsite were evaluated using analysis of variance. The analysis of variance between the chemical properties of the pits at various depths was determined using Microsoft Excel functions.

**RESULTS AND DISCUSSION** Results from this study are presented and discussed as follows:

a)Side views of the dump site:

Figure 5 shows the site and solid waste treatment facilities available at the site. These figures revealed that there are currently four treatment techniques on the ground. The treatment techniques are open dumping, open burning, incineration, reuse, and recycling. The use of open dumping and open burning can be attributed to high organic and combustible materials in the solid waste generated. The use of incineration treatment in both old and new facilities (Figure 5c) can be attributed to the presence of infectious waste, such as waste from health units.

#### b) XRF Results and Chemical Compositions

The XRF results for the soil from the dump site and the control at selected depths of 0.4 m, 0.8m and 1.2m are presented in Figure 6. These figures revealed that at all the depths the common chemical compositions are Magnesium, Aluminium; Silicon, Phosphorus, Sulphur, Potassium, Calcium,

Titanium, Vanadium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Tungsten, Arsenic, Gold, Lead, Rubidium, Zirconium, Niobium, Molybdenum, Silver, Cadmium, Tin, and Antimony. The concentrations of these chemical compositions established that the materials can be grouped into four classes of concentrations of the chemicals greater than 90.0 mg/g (major-composition), between 90.0 mg/g and 25.0 mg/g (mega-composition); between 25.0 mg/g and 2.0 mg/g (micro-composition) and concentration of less than 2.0 mg/g (nano-composition). The study shown that major-composition elements are Al, Si, Ca, Fe, Co, Zn and Zr, mega-composition elements include P, K, Rb, Nb, Mo and Sb, while micro-composition elements are Cd, Ag, Sn, Pb, As, W, Cu, Ni and Mn with nano-composition elements as Au, Cr, V, Ti S and Mg. It was established that these concentrations decrease with increasing depth of the pit and the distance of the location from the centre of the dump site.



Figure 3b: Collapsed building during construction (Source: istockphoto, 2025a)



Figure 3a: The impact of weak index properties and geotechnical properties of soil on an infrastructure (Source: NewsScientist, 2025)



Figure 3c: Collapsed building after earthquake (Source: istockphoto, 2025b)



Figure 3d: Crack in the wall of a collapsed building after earthquake (Source: istockphoto, 2025c)

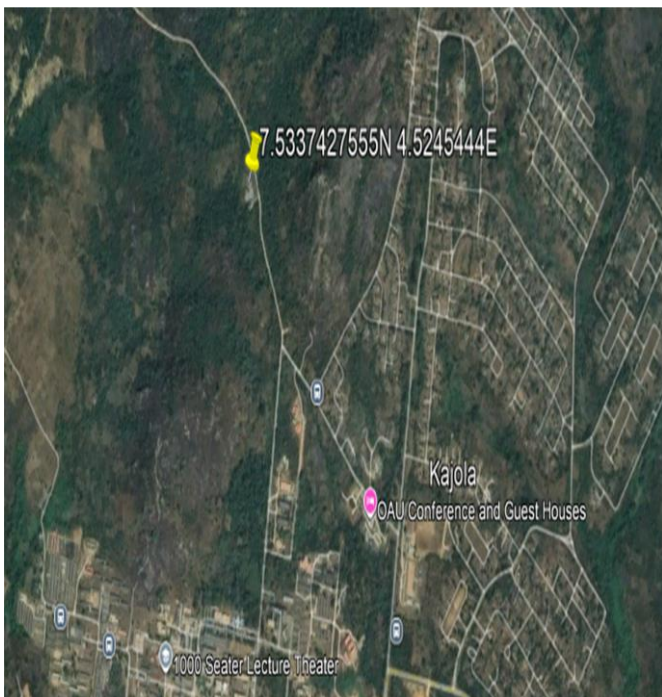


Figure 4a: The location of the Dump site



Figure 4b The location of the sampling site (Point A)

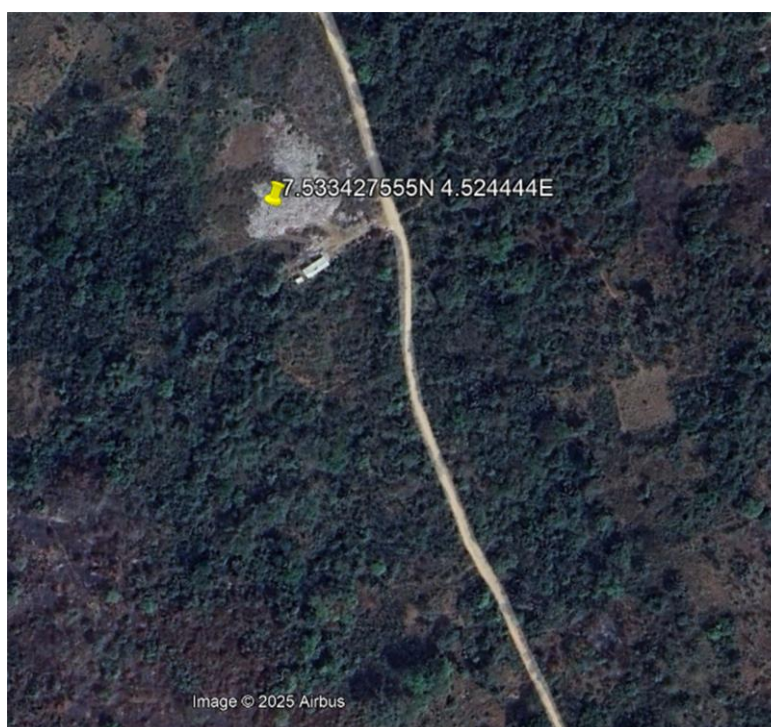


Figure 4c: The location of the sampling site (Point B)



Figure 4d The location of the sampling site (Point C)

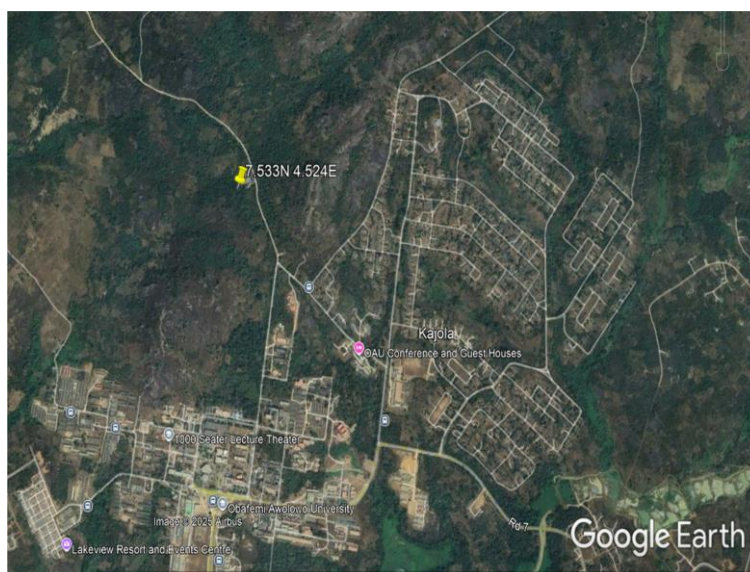


Figure 4e: The location of the Control site



Figure 4f: A typical View of dug pit for sampling



Figure 5a: Front view of the dump site



Figure 5b: Side View of the dump site



Figure 5c: Angular view of the dump site



Figure 5d: Full view of the Dump site



Figure 5e: Front view of the dump site with reusable and recycled collected materials



Figure 5f: Front view of the reusable and recycled collected materials

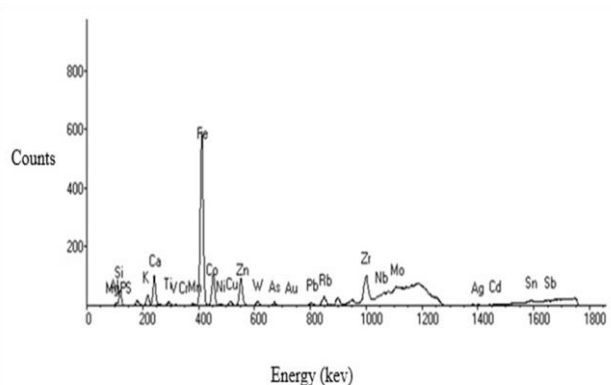


Figure 6ai: XRF for point A of the dumpsite at a 0.4 m depth

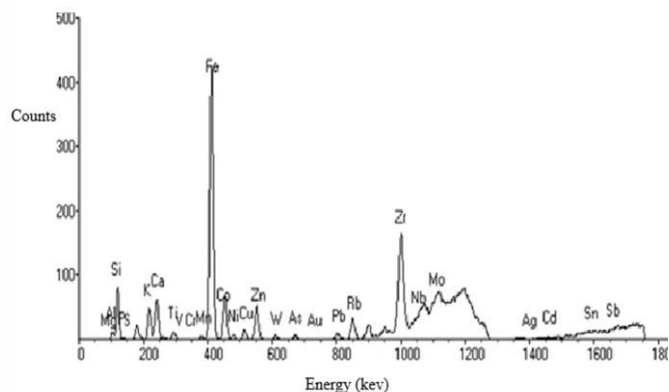


Figure 6aii: XRF for point A of the dumpsite at a 0.8 m depth

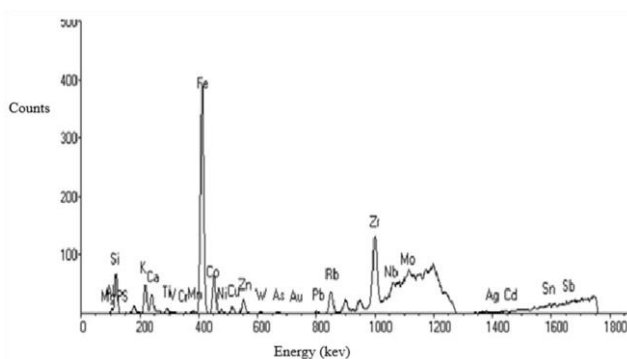


Figure 6aiii: XRF for point A of the dumpsite at 1.2 m depth

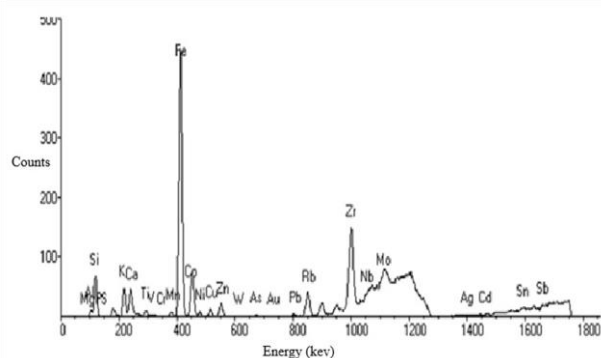


Figure 6bi: XRF for the point B of the dumpsite at a 0.4 m depth

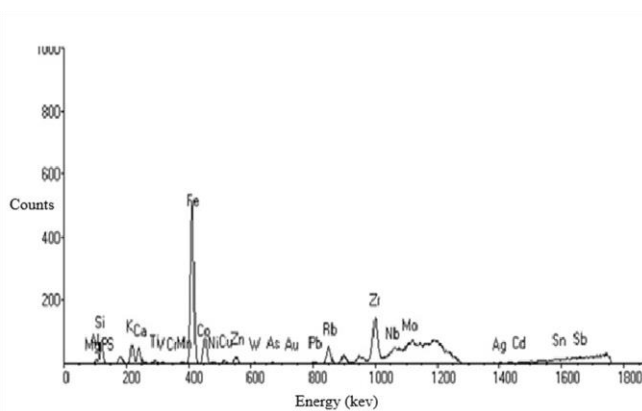


Figure 6bii: XRF for point B of the dumpsite at a 0.8 m depth

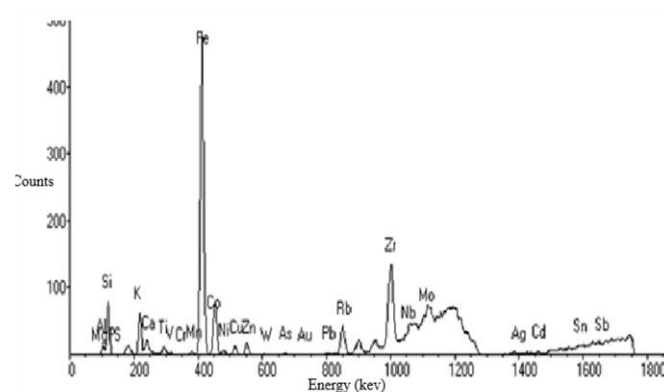


Figure 6biii: XRF for point B of the dumpsite at a 1.2 m depth

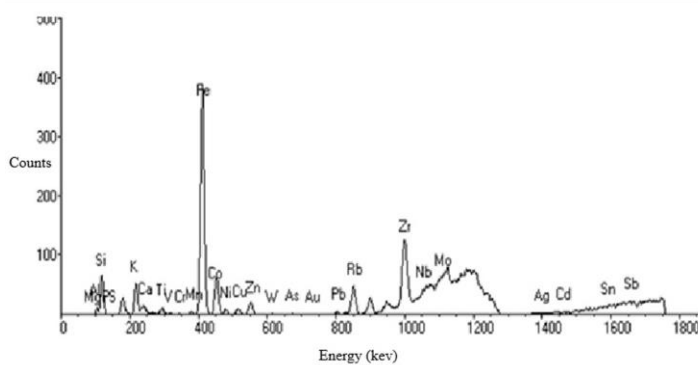


Figure 6ci: XRF for point C of the dumpsite at 0.4 m depth

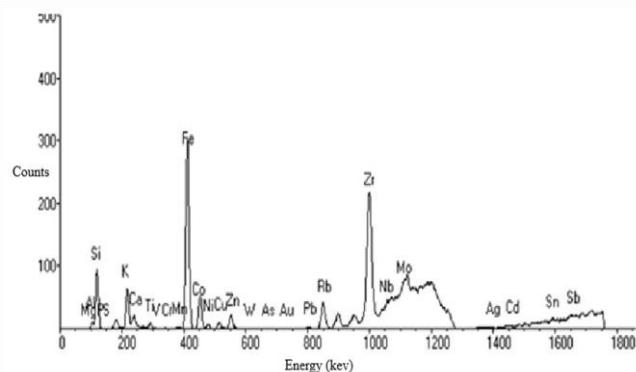


Figure 6cii: XRF for the point C of the dumpsite at a 0.8 m depth

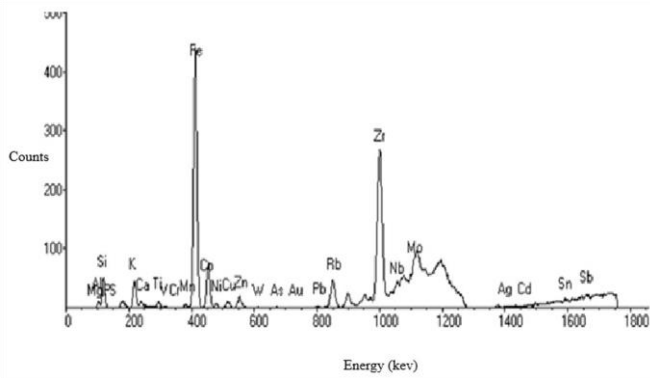


Figure 6ciii: XRF for point C of the dumpsite at 1.2 m depth

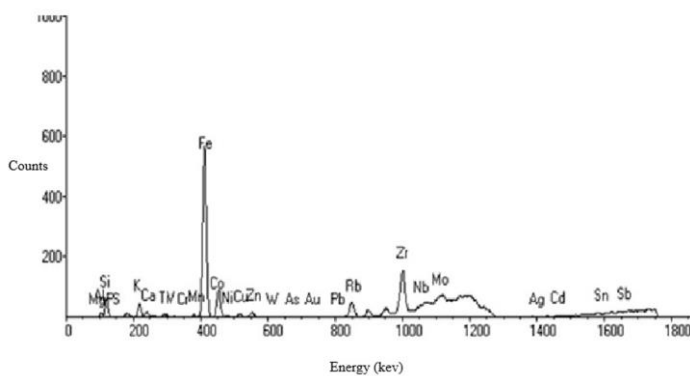


Figure 6dii: XRF for the control point at 0.8 m depth

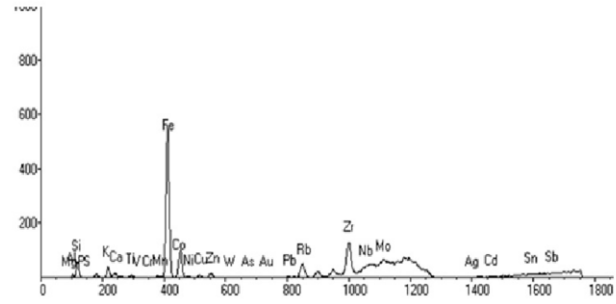


Figure 6di: XRF for the control point at 0.4 m depth

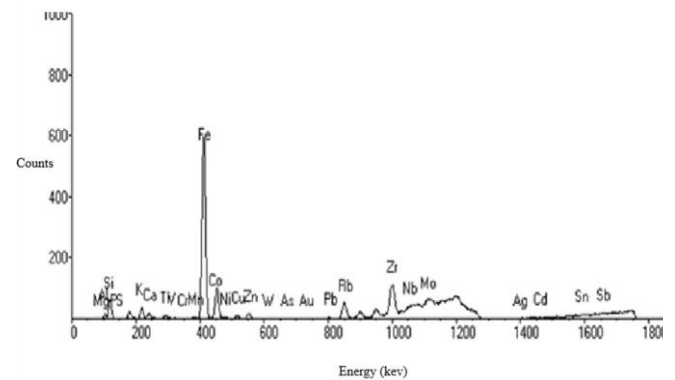


Figure 6diii: XRF for the control point at 1.2 m depth

The observations are similar to observations made on chemical properties of soil from different dump site as stated in literature such as Alao et al. (2023a and b; 2024a and 2024b), Aralu et al. (2024), Aziz & Hussain (2023), Meftah et al. (2023), Ogbuene et al. (2025), Steffy et al. (2025), Venkatesh et al. (2023), Venkatesh et al. (2024), Ale et al. (2024), Gopal et al. (2024), Kolawole et al. (2023), Sanga and Pius (2024) and Jawjit et al. (2024).

**Effects of location on the chemical composition.** Tables 1 to 3 present the effects of location on the concentration of the elements and chemical compositions at selected depths. Table 1 presents the effects of location on the concentration of the elements and chemical compositions at a

depth of 0.4 m in the pits. The Table revealed the F-value and P-value for the source of variation within the elements in the soil were 57.085 and  $4.94 \times 10^{-42}$  ( $F_{27, 81} = 57.085$  and p of  $4.94 \times 10^{-42}$ ) and the F-value and P-value for the source of variation within the elements in the soil were 2.479451 and 0.066976 ( $F_{3, 81} = 2.479451$  and p of 0.066976).

Table 2 presents the effects of location on the concentration of the elements and chemical compositions at a depth of 0.8 m in the pits. The Table revealed the F-value and P-value for the source of variation within the elements in the soil were 82.85921 and  $3.15 \times 10^{-48}$  ( $F_{27, 81} = 82.85921$  and p of  $3.15 \times 10^{-48}$ ) and the F-value and P-value for the source of variation within the elements in the soil

were 1.137108 and 0.33912 ( $F_{3, 81} = 1.137108$  and  $p$  of 0.33912). Table 3 presents the effects of location on the concentration of the elements and chemical compositions at a depth of 1.2 m in the pits. The Table revealed the  $F$ -value and  $P$ -value for the source of variation within the elements in the soil were 60.19299 and  $6.61 \times 10^{-43}$  ( $F_{27, 81} = 60.19299$  and  $p$  of  $6.61 \times 10^{-43}$ ) and the  $F$ -value and  $P$ -value for the source of variation within the elements in the soil were 1.02016 and 0.388174 ( $F_{3, 81} = 0.388174$  and  $p$  of 0.388174). These results established that at a depth of less than 0.4m depth of the soil at the dump site has a significant impact on the chemical composition of the soil at 95 % confidence level ( $F$ -values  $>$   $F$ -crit) and at a

depth of greater than 0.4m depth of the soil at the dump site has no significant impact on the chemical composition of the soil at a 95 % confidence level ( $F$ -values  $<$   $F$ -crit). In addition, these results established that at all the depths of the soil at the dump site, location has a significant impact on the elemental composition of the soil at 95 % confidence level ( $F$ -values  $>$   $F$ -crit). The observations are similar to observations made on chemical properties of soil from different dump site as stated in literature, such as Alao et al. (2023a and b; 2024a and 2024b), Aralu et al. (2024), Aziz & Hussain (2023), Meftah et al. (2023), Ogbuene et al. (2025), Steffy et al. (2025), and Venkatesh et al. (2023).

Table 1: Results of analysis of variance of chemical composition at 0.4m of the pit

Source of Variation	Sum of Squares	Degree of freedom	Mean Square	F-value	P-value	F crit
Within the elements	967139.7	27	35819.99	57.085	$4.94 \times 10^{-42}$	1.623786
Between the locations	4667.455	3	1555.818	2.479451	0.066976	2.717343
Error	50826.29	81	627.4851			
Total	1022633	111				

Table 2: Results of analysis of variance of chemical composition at 0.8m of the pit

Source of Variation	Sum of Squares	Degree of freedom	Mean Square	F-value	P-value	F crit
Within the elements	926947.9	27	34331.4	82.85921	$3.15 \times 10^{-48}$	1.623786
Between the locations	1413.429	3	471.1429	1.137108	0.33912	2.717343
Error	33561.07	81	414.3342			
Total	961922.4	111				

Table 3: Results of analysis of variance of chemical composition at 1.2m of the pit

Source of Variation	Sum of Squares	Degree of freedom	Mean Square	F-value	P-value	F crit
Within the elements	944515.4	27	34982.05	60.19299	$6.61 \times 10^{-43}$	1.623786
Between the locations	1778.643	3	592.881	1.02016	0.388174	2.717343
Error	47074.36	81	581.1649			
Total	993368.4	111				

### Effects of Depth on the Chemical Composition.

Tables 4 to 7 present the effects of location and fixed depth on the concentration of the elements and chemical compositions at selected locations. Table 4 presents the effects of location on the concentration of the elements and chemical compositions at depths of 0.4 m, 0.8m, and 1.2 m in the pit at a selected location (point A). The Table revealed the F-value and P-value for the source of variation within the elements in the depth of the soil were 36.42627 and  $7.99 \times 10^{-26}$  ( $F_{27, 54} = 36.42627$  and  $p = 7.99 \times 10^{-26}$ ) and the F-value and P-value for the source of variation within the depth in the soil were 4.078956 and 0.022399 ( $F_{2, 54} = 4.078956$  and  $p = 0.022399$ ).

Table 5 presents the effects of location on the concentration of the elements and chemical compositions at depths of 0.4 m, 0.8m, and 1.2 m in the pit at a selected location (point B). The Table revealed the F-value and P-value for the source of variation within the elements in the soil were 203.352 and  $3.01 \times 10^{-45}$  ( $F_{27, 54} = 203.352$  and  $p = 3.01 \times 10^{-45}$ ) and the F-value and P-value for the source of variation within the elements in the depths of the soil were 3.276319 and 0.045398 ( $F_{2, 54} = 3.276319$  and  $p = 0.045398$ ). Table 6 presents the effects of location on the concentration of the elements and chemical compositions at depths of 0.4 m, 0.8m, and 1.2 m in the pit at a selected location (point C). The Table revealed the F-value and P-value for the source of variation within the elements in the soil were 50.42194 and  $2.17 \times 10^{-29}$  ( $F_{27, 54} = 50.42194$  and  $p = 2.17 \times 10^{-29}$ ) and the F-value and P-value for the source of variation within the elements in the depths of the soil were 0.241302 and 0.786447 ( $F_{2, 54} = 0.241302$  and  $p = 0.786447$ ).

Table 7 presents the effects of location on the concentration of the elements and chemical compositions at depths of 0.4 m, 0.8m, and 1.2 m in the pit at a selected location (Control). The Table revealed the F-value and P-value for the

source of variation within the elements in the soil were 357.3896 and  $8.66 \times 10^{-52}$  ( $F_{27, 54} = 357.3896$  and  $p = 8.66 \times 10^{-52}$ ) and the F-value and P-value for the source of variation within the elements in the depths of the soil were 0.203726 and 0.81631 ( $F_{2, 54} = 0.203726$  and  $p = 0.81631$ ). These results recognised that at a depth of less than 0.4m depth of the soil at the centre of the dump site, the dump site has a significant impact on the chemical composition of the soil at 95 % confidence level (F-values > F-crit) and at a depth of greater than 0.4m depth of the soil around the dump site, the dump site has no significant impact on the chemical composition of the soil at a 95 % confidence level (F-values < F-crit). In addition, these results established that at all the depths of the soil at the dump site, location has a significant impact on the elemental composition of the soil at 95 % confidence level (F-values > F-crit). The observations are similar to observations made on chemical properties of soil from different dump site as stated in literature, such as Alao et al. (2023a and b; 2024a and 2024b), Aralu et al. (2024), Aziz & Hussain (2023), Meftah et al. (2023), Ogbuene et al. (2025), Steffy et al. (2025), and Venkatesh et al. (2023).

In addition, Siddiqua et al. ((2021) revealed that sanitary land-fillings are associated with numerous environmental pollution issues, challenges and problems, such as groundwater contamination and pollution originating from the leachates (inorganic, organic, and other toxic substances contained in the solid wastes, air pollution issues originating from particulates and other air pollutants, surface water pollution originating from potential surface run-offs. Olagunju et al. (2018) highlighted a concern about the water sources (surface and groundwater) because the communities in this dump site area depend on food from agricultural activities in the communities and groundwater supply from the hand-dug wells as well as boreholes for domestic utilization and purposes.

Table 4: Results of analysis of variance of chemical composition of Sample 1 at various depths

Source of Variation	Sum of Squares	Degree of freedom	Mean Square	F-value	P-value	F crit
Within the elements	682466.9	27	25276.55	36.42627	$7.99 \times 10^{-26}$	1.693046
Between the depth	5660.857	2	2830.429	4.078956	0.022399	3.168246
Error	37471.14	54	693.9101			
Total	725598.9	83				

Table 5: Results of analysis of variance of chemical composition of Sample 2 at various depths

Source of Variation	Sum of Squares	Degree of freedom	Mean Square	F-value	P-value	F crit
Within the elements	695403.2	27	25755.68	203.352	$3.01 \times 10^{-45}$	1.693046
Between the depth	829.9286	2	414.9643	3.276319	0.045398	3.168246
Error	6839.405	54	126.6556			
Total	703072.6	83				

Table 6: Results of analysis of variance of chemical composition of Sample 3 at various depth

Source of Variation	Sum of Squares	Degree of freedom	Mean Square	F-value	P-value	F crit
Within the elements	532753.4	27	19731.61	50.42194	$2.17 \times 10^{-29}$	1.693046
Between the depth	188.8571	2	94.42857	0.241302	0.786447	3.168246
Error	21131.81	54	391.3298			
Total	554074	83				

Table 7: Results of analysis of variance of chemical composition of the control Sample at various depths

Source of Variation	Sum of Squares	Degree of freedom	Mean Square	F-value	P-value	F crit
Within the elements	988467.4	27	36609.9	357.3896	$8.66 \times 10^{-52}$	1.693046
Between the depth	41.7381	2	20.86905	0.203726	0.81631	3.168246
Error	5531.595	54	102.4369			
Total	994040.7	83				

In another study, Ali et al. (2018) established that soils at the dump sites showed high pH, Total Dissolved Solids and Electrical Conductivity regimes in comparison to control sites. The soils at the dump sites contained several heavy metal concentrations, like Lead, Cadmium, Copper, Nickel, Chromium, and Zinc were also found to be higher at the dump sites. A similar trend and pattern were observed in plant diversity.

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## Conclusion

It can be concluded that that at a depth of less than 0.4m depth of the soil at the centre of the dump site, the dump site has a significant impact on the chemical composition of the soil at 95 % confidence level (F-values > F-crit) and at a depth of greater than 0.4m depth of the soil around the dump site, the dump site has no significant impact on the chemical composition of the soil at a 95 % confidence level (F-values < F-crit).

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