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Physiochemical Properties of Soil from Waste Dumpsites within Choba, Alakahia and Rumuosi Communities in Akpor, Rivers State, Nigeria

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ABSTRACT: The objective of this paper was to evaluate the physicochemical properties of soil from solid waste dumpsites within Choba, Alakahia and Rumuosi in Akpor, Rivers State, Nigeria using a standard analytical methods. Date obtained show that the values of pH; Cation Exchange Capacity (meq/100g); Phosphorus (mg/kg); Potassium (mg/kg) and Nitrogen (%) were 6.5; 2.8; 1.6; and 0.4 in Choba; 6.7; 2.4; 2.5; 9 and 0.48 in Alakahia, 8.2; 1.9; 3.4; 31.0 and 0.7 in Rumuosi respectively. Furthermore; Results showed that there was an increase in the pH, potassium, phosphorus, nitrogen content value at each dumpsite than their corresponding control. Potassium level was higher at Rumuosi dumpsites than other sites. The mean soil porosity indicated higher porosity in the control sites (0.2 ±0.001 – 0.32 ±0.0012). The soil particle size distribution indicated an average of 82% sand, 8.2% clay and 3% silt for dumpsite and 75% sand, 8.5% clay and 5% silt for control site. Indeed, based on the study findings, it can be concluded that solid waste dumps alter the soil nutrient contents with no-impact on the physical characteristics of the soil, such as its particle size distribution and texture. Therefore, continued monitoring and management of solid waste dumps are necessary to ensure the long-term health and sustainability of soils and surrounding ecosystems.

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Keywords: Dumpsites; physicochemical characterization; systematic sampling technique.

Indeed, the environment plays a critical role in the existence and well-being of all living organisms. It encompasses various factors that influence organisms in their specific time and place. As mentioned by Oreyomi (2005), the environment not only provides a habitat for organisms but also significantly contributes to their quality of life. However, addressing environmental health hazards, particularly in developing nations, has proven to be challenging. Omotosho (2005) highlights two major factors contributing to poor environmental management which include poor environmental sanitation education and awareness and disregard to the rule of law. Lack of knowledge and awareness about environmental sanitation practices can lead to improper waste disposal, pollution, and other environmental hazard. Limited education and literacy levels can hinder people's understanding of environmental issues and their ability to adopt sustainable practices and inadequate governance structures and ineffective policies may fail to address environmental concerns adequately. Corruption and mismanagement can exacerbate environmental degradation. When there's a lack of enforcement of

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environmental regulations, individuals and industries may disregard environmental protections, leading to pollution and degradation (Tchobanoglous *et al*., 1993). The transition from the prehistoric period to the modern era indeed brought significant changes in waste generation and management practices. In prehistoric times, waste disposal was not a major concern due to the relatively small population and industry. The environment could naturally absorb the waste produced without significant degradation. However, with the advent of the industrial revolution in the sixteenth century, there was a notable shift in population dynamics as people migrated from rural areas to cities in search of employment opportunities. This rural and urban resulted in various multifarious waste (Vergara and Tchobanoglous, 2012).

The environmental degradation in Port Harcourt, Nigeria, is primarily attributed to the inefficient management of solid waste. The city, being a hub for oil companies, industries, health centers, institutions, and markets, generates significant amounts of waste from various sources including municipal, domestic, and industrial activities. This waste often ends up in dump sites, contributing to pollution and posing serious environmental and health hazards. One of the key concerns associated with the solid waste in Port Harcourt is the potential presence of heavy metals (Lenntech, 2014; Amadi and Chuku 2023). These metals can leach into the soil and water, contaminating the environment and posing risks to human health and ecosystems. Heavy metals such as lead, mercury, cadmium, and arsenic are known for their toxic effects, even at low concentrations.

Efforts to address this issue require a comprehensive waste management strategy that includes proper collection, segregation, treatment, and disposal of solid waste. Additionally, there is a need for stricter regulations and enforcement to ensure that industries and other sources of waste adhere to environmental standards and practices. Furthermore, public awareness and community involvement are crucial for promoting responsible waste disposal practices and reducing waste generation. Sustainable solutions such as recycling, composting, and waste-to-energy initiatives can also help mitigate the environmental impact of solid waste in Port Harcourt and similar urban centers facing similar challenges. (Babatunde *et al*., 2014).

Hence, the objective of this paper was to evaluate the physicochemical properties of soil from solid waste dumpsites within Choba, Alakahia and Rumuosi Communities in Akpor, Rivers State, Nigeria

MATERIALS AND METHODS

Study Area: The study area for this research comprises three solid waste dump sites located in Port Harcourt, within the Niger Delta area of Nigeria. The selected dumpsites are situated at specific geographic coordinates:

1. Choba Dumpsite: - Latitude: 4.89424, - Longitude: 6.91144
2. Alakahia Dumpsite: - Latitude: 4.89531, - Longitude: 6.91334
3. Rumuosi Dumpsite: - Latitude: 4.89424, - Longitude: 6.91144

For each of these dumpsites, a control site was designated. The control sites were chosen at a distance of 100 meters away from the respective dumpsites to provide comparative data. These control sites are intended to represent baseline conditions unaffected by the direct influence of waste disposal activities. The dumpsites were named after their respective locations to distinguish between them. It's important to note that the coordinates provided are crucial for accurately identifying the study sites and conducting fieldwork and data analysis. This approach allows for a systematic comparison between the conditions of the dumpsites and their respective control sites, enabling a comprehensive assessment of the environmental impacts of solid waste disposal in the area.

Sample Collection: The starting point for sampling, located 10 meters away from the road, was cleared using a cutlass and marked with a carved wooden peg. Subsequently, a footpath was created by slightly clearing the field to facilitate access. At each dumpsite and corresponding control site, a study area measuring 15 meters by 30 meters was measured out using a measuring tape. This area was then demarcated using wooden pegs and rope to define the boundaries of the study site. A systematic sampling approach was employed, consisting of three line-transects spaced at 5-meter intervals within each study site. Along each line-transect, three sample plots were established at intervals of 10 meters, resulting in a total of nine sample plots per study site. Each sample plot measured 2 meters by 2 meters (2m x 2m), providing sufficient area for soil sampling and analysis. Soil samples were collected at each designated sample plot using a soil auger. Sampling was conducted at a depth of 0 to 15 centimeters from the soil surface to capture the topsoil layer, where most biological and chemical processes occur. The soil auger was used to collect soil samples within the 0-15 cm depth range, ensuring consistency in sampling depth across all sample plots within the study sites.

Determination of Physicochemical Characteristic of Soil: The physicochemical properties was determined using standard methods as outlined in the International Institute of Tropical Agriculture (IITA) Selected Material for Soil Analysis (1991). The soil texture was determined using the hydrometric method, which involves separating soil particles based on their size by suspending them in water and allowing them to settle according to their respective particle sizes. Soil pH was measured using a pH meter model HANNA HI8314. Soil pH is a critical parameter that influences nutrient availability, microbial activity, and overall soil health. Electrical conductivity, an indicator of soil salinity, was determined using a conductivity meter model HANNA HI 98303. High levels of electrical conductivity can indicate elevated levels of dissolved salts in the soil. Total nitrogen content in the soil was determined using the Macro-kjeldahl digestion method (Black, 1965). Phosphate content in the soil was determined using the Bray no.1 method. This method involves extracting phosphate from the soil using a solution containing ammonium fluoride and hydrochloric acid, followed by colorimetric analysis. Cation exchange capacity (CEC) and available potassium content in the soil were determined using the ammonium acetate method. CEC refers to the soil's ability to retain and exchange positively charged ions, while available potassium represents the portion of potassium in the soil that is readily available for plant uptake.

Data Analysis: The Data collected were statistically analyzed using descriptive statistics (mean, and standard error) and two - way ANOVA.

RESULTS AND DISCUSSION

Solid waste has become a ubiquitous issue globally, with its impacts extending far beyond just visual pollution. One of the critical areas affected by solid waste is soil physicochemical characterization. The composition and presence of solid waste in soil can drastically alter its physical and chemical properties, leading to detrimental effects on both the environment and human health (Amadi and Chuku 2023). Improper waste disposal methods, such as open dumping or burning, can result in soil contamination and degradation. Geological characteristics and environmental conditions of the study areas, such as soil type, topography, climate, and hydrology, can also influence soil physicochemical properties. This assertion is further corroborated in the findings of Azuka and Igué, 2020 who reported on the negative impact of solid waste on physicochemical properties may be influenced by the predominant activities within the waste collection point. This result was also similar with the findings Obianefo et al. (2017) who reported that the characteristics of soil may vary and its physical, chemical and biological properties may be influenced by the activities of the environment. Hence these properties determined the capability of the soil to promote plant growth. The result on mean soil pH revealed several significant findings: There was a significant increase in soil pH observed both between and within treatment groups, with a significance level of p=0.05. This indicates that the presence of solid waste dumpsites had a notable impact on the pH of the surrounding soil. The highest increment in mean soil pH was recorded for the Rumuosi waste dumpsite, suggesting that this particular dumpsite had the most pronounced effect on soil alkalinity. On the other hand, the least increase in soil pH was found for the Choba waste dumpsite, indicating a comparatively lower impact on soil pH compared to the other dumpsites. The control study locations, which were situated away from the dumpsites, exhibited lower pH levels compared to the soil within the dumpsites. Specifically, the control locations were characterized by acidic soil conditions, with a pH of around 5, whereas the soil within the dumpsites ranged between pH 7 to 9, indicating alkaline conditions. The observed trends in soil pH were consistent across all study locations, with the dumpsites consistently exhibiting higher pH levels compared to the control sites Figure 1.

The pH of the studied soil ranged from 8-6, the soil from Rumuosi waste dumpsite had the highest value then the Alakahia and Choba waste dumpsites respectively. This is higher than the values (4.8-7.66) obtained by Obianefo *et al.*, (2017), the significant higher pH values recorded in the dumpsite soils could be attributed to several factors related to the decomposition and interaction of waste materials with the surrounding environment. Organic waste materials such as food scraps, yard waste, and paper products undergo decomposition over time. During this process, organic acids are produced, which can initially lower the pH of the waste. However, as decomposition progresses, organic acids are consumed, leading to a gradual increase in pH. Conversely, Solid waste can contain materials that inherently have basic properties, such as certain types of construction debris (e.g., concrete, cement, lime), ashes from burnt materials, or alkaline chemicals. When these materials come into contact with water and air in the waste dumpsite, they can release alkaline substances, leading to an increase in pH. In some cases, anaerobic (low oxygen) conditions can develop within the waste dumpsite due to the compacted nature of the waste and limited air circulation. Under anaerobic conditions, certain chemical reactions may occur that result in the production of basic compounds, contributing to pH elevation. In addition, the presence of high quantity of liming material, and biological activities (soil microorganisms) on the solid waste. This findings agrees with the report of Ideriah *et al*., (2006) who reported an increase in pH level and was attributed to the waste degradation process enable by microbial activities. Generally, the pH of the soil in most of the dumpsites was high and ranged from neutral to alkaline compared to the control. Other authors (Ideriah *et al*., 2006; Obasi *et al*., 2012) also made a similar observation. According to Kanmani and Gandhimathi (2012), free volatile acids concentration decreases mainly as a result of anaerobic decomposition and partial ionization of fatty acids contribute to higher pH value. Different types of waste, such as organic, inorganic, hazardous, or inert materials, can alter soil pH, nutrient content, and physical structure. In addition, the management practices employed in waste disposal can also impact soil properties

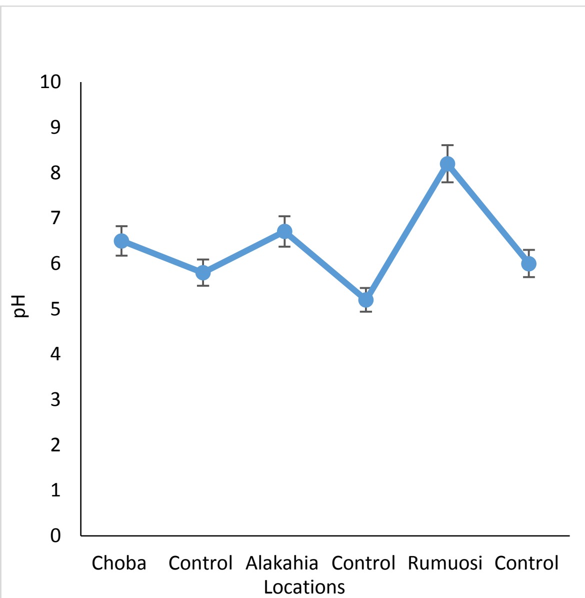

Fig 1: The mean concentration of pH in the study locations

Mean Soil Cation Exchange Capacity (CEC): There was a significant decrease in CEC observed both between and within study locations. This indicates that the presence of solid waste dumpsites had an impact on the CEC of the surrounding soil. The lowest decrease in CEC was recorded for the Rumuosi waste dumpsite, suggesting that this dumpsite had the least impact on soil CEC compared to the other dumpsites. Conversely, the highest decrease in CEC was found for the Rumuosi control site, indicating that factors other than waste dumping may have influenced the CEC at this location. The control site at Rumuosi recorded the highest CEC compared to the control sites at Choba and Alakahia dumpsites. This suggests that factors other than waste dumping may have contributed to the higher CEC observed at the Rumuosi control site. The observed trends in CEC were consistent across all study locations, with a decrease in CEC observed within the dumpsites compared to the control sites shown in Fig 2. However, the variation in CEC suggests that solid waste might have distorted the soil natural ability to retain nutrients. Another study suggested that seasons also affects the level of cation exchange capacity, the study stated that the high level of electrical conductivity in the dry season indicates the role of season in the soil as flood water from the wet season helps to dilute the solutes and mineral components of the wastes which may have accounted for the low conductivity in the wet season (Obianefo *et al*., 2016). Soils with a low CEC are more likely to develop deficiencies in potassium (K^+), magnesium ($Mg^{2}+$) and other cations while high CEC soils are less susceptible to leaching of these cations (CUCE 2007).

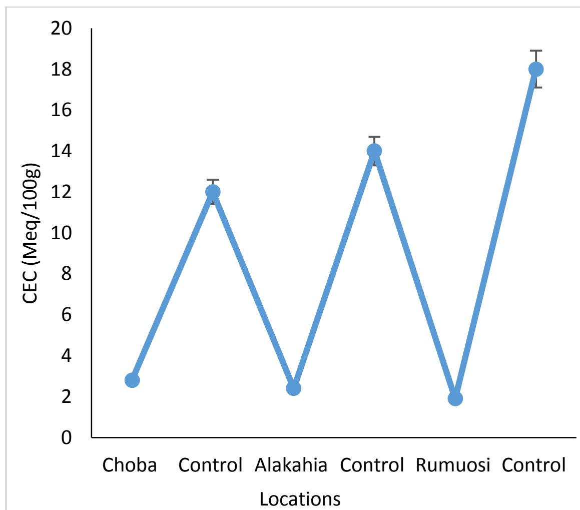

Fig 2: The mean concentration of CEC in the study locations

Mean Soil Phosphorus: Figure 3. The highest increment in mean phosphorus content was recorded for the Rumuosi waste dumpsite, suggesting that this dumpsite had the most pronounced effect on soil phosphorus levels. Conversely, the least decrease in phosphorus content was found for the Choba waste dumpsite, indicating a comparatively lower impact on soil phosphorus compared to the other dumpsites. The control sites recorded little or no concentration of phosphorus for all of the study locations. This suggests that phosphorus levels in the control sites were generally lower compared to the dumpsites, further indicating the influence of waste disposal activities on soil phosphorus content. There was a significant difference in phosphorus content observed both between and within treatment groups, with a significance level of p=0.05. The high phosphorus content recorded could be associated with the nutritive content of the waste since majority of the municipal waste are household and agricultural wastes. The organic waste materials such as food scraps, plant matter, and agricultural residues are rich sources of potassium. Leachate from the decomposing waste can carry dissolved potassium ions, increasing the concentration of potassium in the soil and groundwater in and around the dumpsite. During decomposition, organic phosphorus compounds are mineralized, releasing soluble phosphate ions into the environment. In addition to organic sources, certain types of waste, such as detergents, fertilizers, and sewage sludge, may contain inorganic phosphorus compounds that contribute to the phosphorus load in dumpsites.

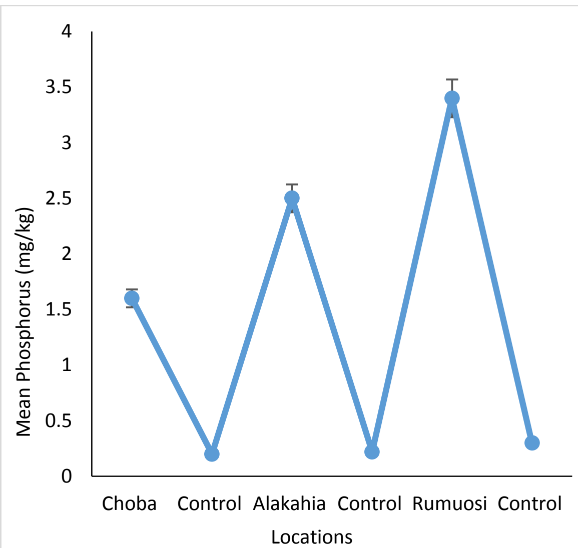

Fig 3: The mean concentration of phosphorus in the study locations

Mean Soil Potassium: The highest increment in mean soil potassium was recorded for the Rumuosi waste dumpsite, compared to their initial levels. This suggests that while there may have been some reduction in potassium content, it was relatively minor compared to other dumpsites. The control site recorded different concentrations of potassium compared to the dumpsites. Specifically, the Choba and Alakahia control sites recorded potassium concentrations of above 100. This suggests that the control sites exhibited varying levels of potassium content, which may have been influenced by factors other than waste disposal activities indicating a substantial increase in potassium levels in the soil at this location. On the contrary, both the Choba and Alakahia waste dumpsites showed the least decrease in potassium content as shown in Fig 4. Potassium level was found predominate at Rumuosi dumpsite than Choba and Alakahia. The variation in the increased potassium content at the Rumuosi solid waste dumpsite could indeed be attributed to several factors, including the nature and volume of waste discharged at this location, as well as the sources of the waste deposited there. This findings also agrees with Amadi and Chuku (2023) noted that variation in increased potassium content at the Rumuosi solid waste dumpsite likely arises from a combination of factors related to the characteristics of the waste deposited there, the volume of waste accumulated over time, the sources of waste from surrounding communities, and the management practices implemented at the dumpsite. Absolutely, the decrease in potassium levels recorded at Choba and Alakahia solid waste dumpsites could indeed be attributed to environmental conditions and waste composition. Environmental conditions such as soil pH can affect the mobility and availability of potassium in the soil. If the soil at Choba and Alakahia dumpsites is more acidic or alkaline compared to Rumuosi, it could affect the solubility and leaching of potassium, leading to lower concentrations in the soil. High rainfall and water percolation can leach potassium from waste materials, causing it to move downwards through the soil profile. This leaching process can result in the depletion of potassium from the upper layers of the soil, contributing to lower levels recorded at Choba and Alakahia dumpsites.

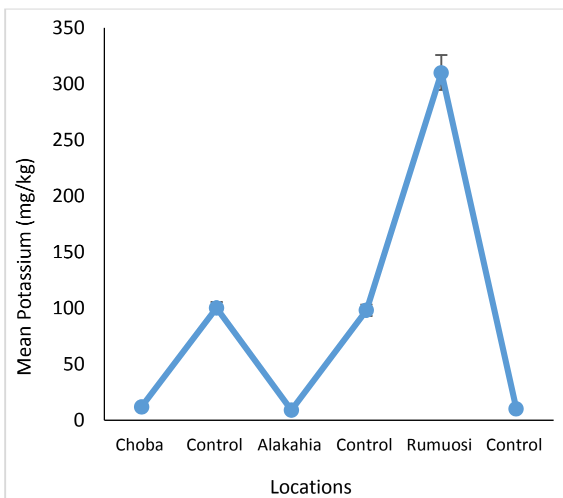

Fig 4: The mean concentration of potassium in the study locations

Mean Soil Nitrogen: Figure 5 showed that control sites and waste dumpsites exhibit variations in nitrogen content, with different trends observed in each location. Rumuosi control site: Recorded the highest nitrogen content. Choba control site: Recorded the least nitrogen content. Alakahia control site: Falls in between Rumuosi and Choba in terms of nitrogen content. Rumuosi waste dumpsite: Recorded the highest increment in nitrogen content. Choba waste dumpsite: Recorded the least decrease in nitrogen content. Rumuosi control site had no nitrogen concentration, whereas the waste dumpsite at Rumuosi recorded the highest increment. Choba control site had a higher concentration of nitrogen compared to the control site at Alakahia, and the Choba waste dumpsite recorded the least decrease in nitrogen content. There was a significant difference in soil Nitrogen between and within treatment at (p=0.05).

Nitrogen is abundant in organic waste materials, particularly in proteins and nucleic acids found in food waste, plant matter, and animal manure. Microbial activity in the waste dumpsite promotes the decomposition of organic nitrogen compounds, releasing ammonium ions (NH_4^+) and other nitrogen-containing compounds. This result corroborates the findings of other researchers (Amos-Tautua *et al*., 2014) who reported significant-high content of these nutrient elements in dumpsites relative to the control. Solid waste dumpsites have been reported to be rich in organic matter which is the source of most of the nitrogen and phosphorus which enhances soil fertility and promote plant growth (Ideriah *et al*., 2010). In addition, the activities of soil organisms in the decomposition of these wastes may have accounted for the rich nutrient contents of the soil (Amos-Tautua et al., 2014).

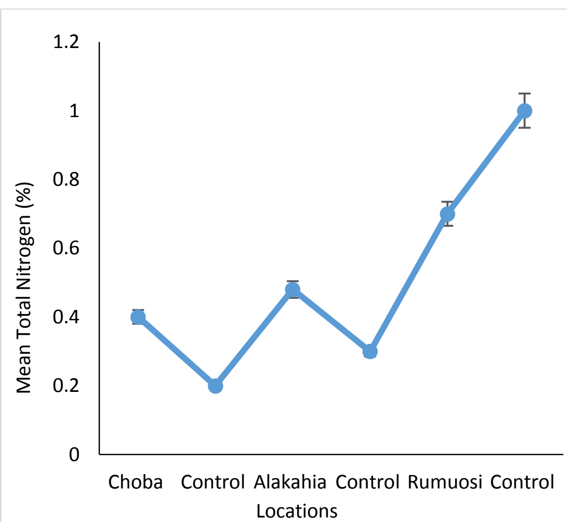

Fig 5: The mean concentration of Nitrogen in the study locations

Mean Soil Porosity; Sand; Clay and Silt: The presence of waste dumpsites has a detrimental effect on soil porosity, with lower porosity generally observed in these areas compared to control sites. The specific characteristics of each waste dumpsite may contribute to variations in soil porosity observed between different dumpsites. Control sites generally exhibited higher soil porosity compared to waste dumpsites. The highest porosity was recorded at the Rumuosi waste dumpsite, while the least porous study area was at the Alakahia waste dumpsite. There was a significant difference in soil porosity both between and within control sites and waste dumpsites. Variations in soil porosity were also observed within control sites, with some having higher porosity than others. Similarly, within waste dumpsites, the Rumuosi site had the highest porosity, and the Alakahia site had the least, as shown in Figure 6.

There was little to no difference in the proportion of sand observed between and within study locations. Control sites exhibited differences in sand content, whereas solid waste dumpsites recorded the same proportion of sand. Despite differences in sand content observed between control sites, the proportion of sand remained consistent within solid waste dumpsites. The presence of waste dumpsites did not appear to have a significant effect on the mean sand content compared to control sites. Variations in sand content were primarily observed between control sites rather than within waste dumpsites. The studied dumpsites did not show a notable impact on the mean sand content, with similar proportions of sand observed within waste dumpsites and little variation between study locations. Control sites exhibited differences in sand content compared to waste dumpsites, as shown in Figure 7.
Figure 8 shows that the dumpsites at Choba and Rumuosi had the highest increase in mean soil clay content compared to the control sites, indicating that these dumpsites have contributed to an increase in clay content in the soil. Conversely, the Alakahia waste dumpsite resulted in the least decrease in mean soil clay content compared to its control site, suggesting a less pronounced impact on clay content. The range of the impact of the dumpsites on clay content varies, with Choba and Rumuosi showing a more significant impact compared to Alakahia, specified as a range of (8-5). The control site at Alakahia recorded the lowest proportion of clay for both solid waste dumpsites and the control. This suggests that natural variations in clay content between study locations need to be considered when assessing the impact of the dumpsites.

There is a significant increase in the mean proportion of silt in the soil both between and within the study locations, indicating that the dumpsites have influenced the silt content of the soil. The Rumuosi waste dumpsite has shown the highest increase in mean silt proportion compared to the other sites, suggesting that this dumpsite has contributed most to the increase in silt content in the soil. Conversely, the Choba waste dumpsite has shown the least decrease in mean silt proportion, implying that while there may have been some impact on silt content, it is less pronounced at the Choba site compared to others. The control sites also show differences in silt proportion, with the Choba control site recording the highest proportion of silt and the Alakahia control site recording the least proportion. This indicates that there are natural variations in silt content between the control sites, which need to be considered when assessing the impact of the dumpsites (Figure 9).

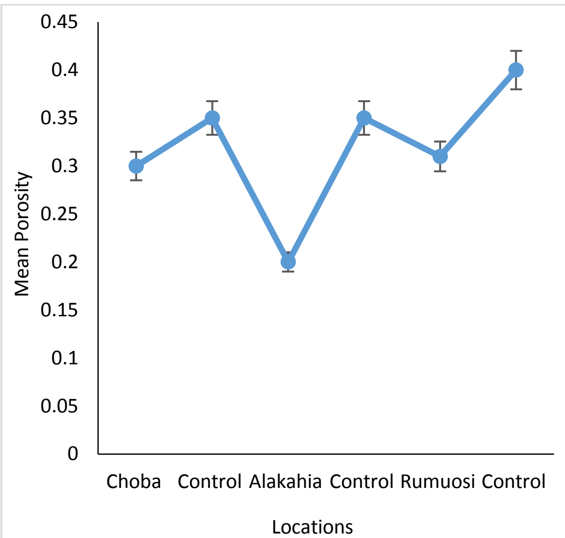

Fig 6: The mean soil porosity in the study locations

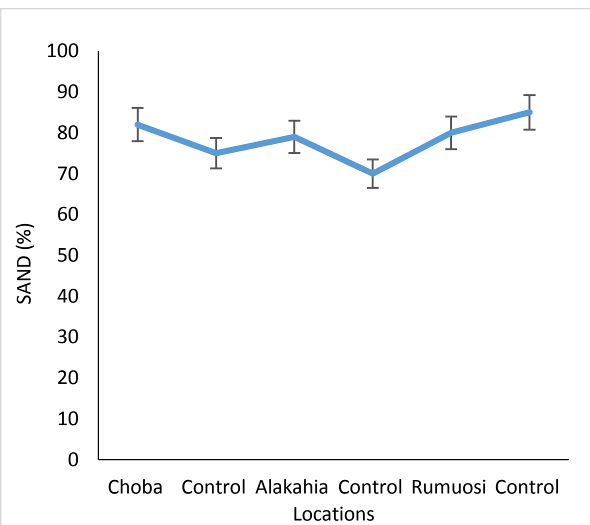

Fig 7: Mean concentration of sand present at the study locations

The relatively high sand but predominantly silt and clay contents of the soils in the study location was also reported by Akamigbo and Asadu (1985), which attributed the variation to topography and parent material of the soil found at any location, this can also be the case but as the location is a dumpsite; this sand content might be as a result of improper waste segregation, in which construction and demolition wastes may have contributed to the high sand content. Generally, soils with high sand and lower clay contents are highly permeable to water and leachates, and thus have high pollutant leaching potentials (Nyles and Ray, 1999). Changes in permeability of clay sample were observed by Sevgi *et al.*, (2015) and was said to be due to pollution and consolidation application, it was also observed that suspended materials and microorganisms in the leachate cause a decrease in permeability due to the filling of the gaps in clay soil particles.

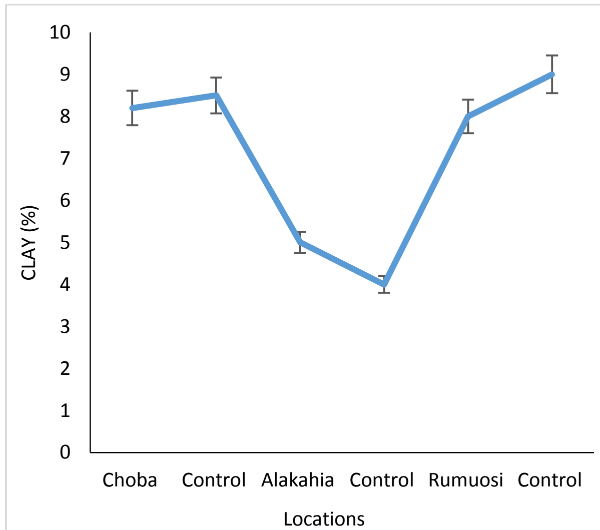

Fig 8: Mean concentration of clay present at the study locations

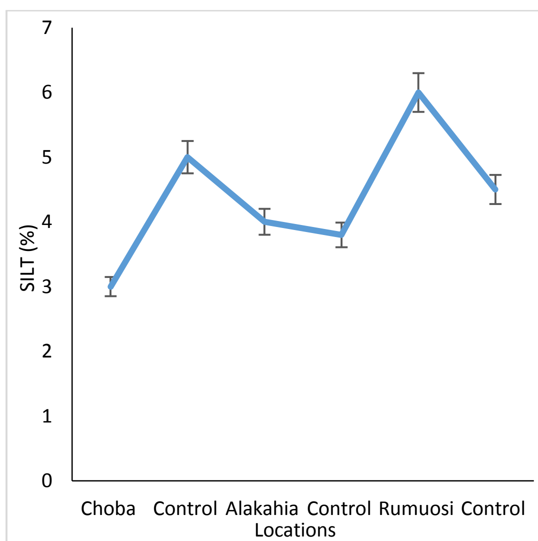

Fig 9: Mean concentration of clay present at the study locations

The low clay percentage can be suggested for the low cation exchange capacity since clay in the soil determines its water retention capacity and also the volume of water is directly related to the pore spaces in any given soil. This has also been reported in similar study that decomposition of agricultural wastes influence the texture of the soil (Ideriah *et al*., 2006). If these soils are highly permeable as seen from their values they may pose a serious environmental risk to groundwater pollution. The porosity of the soil at the different locations differed and this could be as a result of the type of waste found at the dumpsite, this corroborates with the findings of Bibhuti and Pradhan, (2021) who recorded that the increase in porosity of dumping site might be due to the presence of of non-decomposable waste materials to the dumping site soil whose presence might have been increased the pore space. But the control site at Rumuosi recorded the highest porous site both amongst the dumpsite and control, with this finding it can might be as a result of the soil found there.

Conclusion: The variations in soil physicochemical properties across study sites, such as Choba, Alakahia, and Rumuosi waste dumpsites, can indeed be influenced by several factors, including the type and nature of predominant activities in those areas. The type of waste disposed of in each dumpsite can greatly influence soil properties due to various pollutants, including heavy metals, industrial chemicals, and other hazardous substances, which can leach into the soil and groundwater over time. These contaminants pose risks to environmental and their presence requires careful monitoring and management to prevent adverse impacts. Continuous monitoring and evaluation of dumpsites for metal contamination and toxicity which is the most dangerous among all are essential to assess the long-term environmental impacts of waste deposition and to implement appropriate remediation measures where necessary.

Declaration of Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data from which this manuscript was extracted are available upon request from the corresponding author.

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