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Systematic Assessment of Bottomland Resources Influenced by Waste Disposal

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Abstract

In Ile-Oluji, Nigeria, issues with waste disposal brought on by population growth have resulted in contamination of the bottomland resources that sustain humankind. Random soil samples were taken from a solid dumpsite and its adjacent closed bottomland at depths of 0–15, 15–30, and 30–75 cm and analyzed in the laboratory. Soil texture, soil moisture content (MC), porosity, bulk density, pH, electrical conductivity (EC), organic carbon (OC), potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) were measured. Also examined was the concentration of heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), nickel (Ni), chromium (Cr), and manganese (Mn) in the samples. Soil moisture content (MC), porosity, bulk density, pH, and electrical conductivity (EC) ranged from 8.52 to 16.08%, 30.14 to 51.19%, 1.16 to 1.46 g/cm^3, 6.98 to 7.58, and 299.82 to 432.61 µS/cm, respectively. The concentrations of nutrients and heavy metals (OC, K, Ca, Mg, and Na) and (Pb, Cd, As, Ni, Cr, and Mn) in the soil samples collected from the solid waste dumpsite and bottomland ranged respectively from 2.13–3.10%,, 3.98–6.57, 5.08–8.11, 5.41–7.11, and 0.98–2.61 Cmol/kg, and 6.83–29.04, 0.00–0.35, 0.41–3.92, 0.89–3.46, 0.00–0.63, and 13.74–74.38 mg/kg. The highest concentrations of nutrients and heavy metals were found in the soil sample collected from the solid waste dumpsite between 0 and 15 cm of soil depth, and it was closely followed by the sample obtained from the bottomland at the same soil depth compared to other locations. The concentration of heavy metals did not exceed the limits established by the World Health Organization (WHO) and the Food and Agricultural Organization (FAO), but persistent dumping of waste in the area may eventually increase the concentration of heavy metals beyond the acceptable limit. There is a need for the locals to be aware that the growing of crops on dumpsites and closed adjacent bottomland due to its fertility status could result in the uptake of heavy metals and eventually end up in human or animal bodies. A measure to avoid dumping waste close to the bottomland should be put in place by ensuring the immediate construction of a standard environmental sanitary dumpsite in combination with the waste recycling strategy in the study area.

Keywords: Bottomland resources, Solid waste dumpsite, Heavy metals concentration, and soil health

INTRODUCTION

Bottomland refers to low-lying areas adjacent to rivers, streams, or floodplains. These areas are characterized by their fertile soil and abundant water resources, making them crucial for agricultural productivity. The soil in the bottomlands is typically rich in organic matter, nutrients, and minerals, making it highly suitable for cultivating crops. The water resources in bottomlands play a vital role in supporting agricultural activities. The proximity to rivers

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and streams ensures a consistent water supply for irrigation, which is essential for crop growth. Additionally, the water in bottomlands helps maintain soil moisture levels, preventing drought stress and promoting healthy plant development.

The importance of bottomland for agricultural productivity cannot be overstated. These areas often have higher crop yields compared to upland regions due to their fertile soil and access to water. However, the impact of an adjacent closed waste disposal site on bottomland can be detrimental. Waste disposal sites, if not properly managed, can contaminate the soil and water resources in the surrounding area. Toxic chemicals, heavy metals, and other pollutants from the waste can leach into the soil and groundwater, posing a significant risk to agricultural productivity. Contamination of the soil can lead to reduced crop yields and poor plant health. The presence of pollutants in the water resources can also impact irrigation practices, potentially rendering the water unsuitable for agricultural use.

Environmental contamination brought on by improper disposal of waste has been a major concern worldwide, especially in Nigeria (Akintola, Adeyemi, Olokeogun, & Bodede 2021). A product or material that is no longer appropriate for its intended use is considered waste. Daily waste management is a challenge brought on by the population's rapid growth, the expansion of metropolitan areas, and the growth of companies (Karak, Bhagat, & Bhattacharyya, 2012; Essienubong, Okechukwu, & Ejuvwedia, 2019; Mouhoun-Chouaki, Derridj, Tazda, & Salah-Tazda., 2019). In addition to the issue of littering and creating a nuisance, the majority of waste decomposes and releases harmful compounds that have an adverse effect on the soil environment (Bayene & Banerjee, 2011; Kebede, Olani, & Edesa, 2016).

It is impossible to overstate the effects of inadequate waste management on people's health and wellbeing due to the possibility of waste contaminating food, plants, animal, people, and other bottomland resources adjacent to waste disposal site are at a high risk (Njoroge, 2017). Most waste produced by various residences, businesses, organizations, etc. ends up in waste disposal site.

Waste can be classified according to its source, ecological risks, utility, and physical characteristics. According to Ogbeibu, Chukwurah, & Oboh. (2013) research, waste production by humans is inevitable and results from human activity. More waste is being produced by humans than at any other point in recent memory, which is harming the environment. Today's surroundings are home to a large amount of waste due to a combination of factors such as population growth, industrialization, and thoughtless waste removal.

Contaminants from waste are transferred by complicated biological and physical mechanisms from waste disposal sites to nearby ecosystems (Mpofu, Nyamugafata, Maposa, & Nyoni, 2013). Open waste dumpsites may be a source of soil contamination from harmful chemicals and microorganisms. Additionally, this can contaminate manually excavated wells, putting human health at risk and causing the ecosystem's biodiversity to be destroyed (Ogunmodede, Adewole, Ajayi, & Onifade, 2014). At the dumpsites, water might seep through the debris mound. As a result, leachates that are richer in heavy metals, dissolved organics, cyanide, and other harmful chemicals are formed (Ogbeibu et al., 2013). These leachates are also higher in nutrients, such as potassium, phosphorus, and nitrogen.

The concentration of the components of the leachates that may be adsorbed onto the soil during this diffusion is influenced by the makeup of the waste (Shaikh, Bhosle, & Yannawar, 2012). As the ambient temperature rises, this process produces more health risks, pollutes the soil and water of its bottomland, and releases unpleasant scents (Abdus-Salam, Ibrahim & Fatoyinbo, 2011).

Research has shown that a variety of important effects of solid waste in soils have been studied in the past, such as increases in pH, cation exchange capacity, percentage base saturation, organic matter, and nitrogen (Anikwe and Nwobodo, 2001). However, excessive waste in soil, especially bottomlands, may increase the concentration of heavy metals in the soil and underground water, which can have negative effects on crops, soils, and human health (Smith, Hopmans, & Cook, 1996). This is because some pollutants have long half-lives in soils due to the adsorptive and buffering properties of soils, meaning that food crops grown on these polluted soils may be exposed to the pollutants for centuries or even millennia due to the difficulty and expense of cleaning up the soil (Alloway and Ayres, 1997).

Bottomlands are particularly suitable for growing crops but the presence of an adjacent closed waste disposal site can have severe consequences, potentially contaminating the soil and water and negatively impacting agricultural activities. To mitigate the impact, proper waste management practices are crucial. Regular monitoring and testing of soil and water quality should be conducted to ensure early detection of any contamination. Remediation measures, such as soil treatment and water purification, may be necessary to restore the health of the bottomland resources. The primary objectives of this research are to evaluate the degree of heavy metal pollution, its variability at various soil depths of an adjacent closed bottomland to a waste disposal site, and inform the locals of the dangers inherent in the improper waste disposal to the population as a whole and the soil environment.

MATERIALS AND METHODS

Study Area

The research was carried out at a bottomland adjacent to the main solid waste dumpsite in Ile Oluji Ondo State. Figures 1 - 5. At a height of 247 meters, Ile-Oluji is situated in Nigeria's rainforest zone at latitude {7 ° 20 N} and longitude {5 ° 13 E}. The area experiences bimodal rainfall, ranging from 1250 to 1460 mm, with an average yearly rainfall of 1367 mm and approximately 112 rainy days on average. The year-round average temperature ranges from 23 to 32 °C, with few variations from the mean annual temperature of 27 °C. The two warmest months, February and March, with mean temperatures of 28 and 27 °C, respectively. With an average yearly radiation of roughly 130 kcal cm-3 year-1, the average total sunshine hour is approximately 2000 hours. The region is located in the upper forest zone, which was formerly home to lush tropical woods. Tropical humidity characterizes the area, with distinct wet and dry seasons. With a brief dry season in August, the wet season lasts from late March to October (meteoblue.com).

Soil Samples Collection

In order to assess the effect of waste disposal on the quality of the soil resources of the bottomland, samples of soil were taken from the dumpsite and the bottomland. The sampling points were located using the Global Positioning System (GPS). Six soil samples, ranging in depth from 0 to 15, 15 to 30, and 30 to 75 cm, were randomly taken and put in a black polythene bag. The physicochemical and heavy metal contents in these samples were analyzed during the analytical phase.

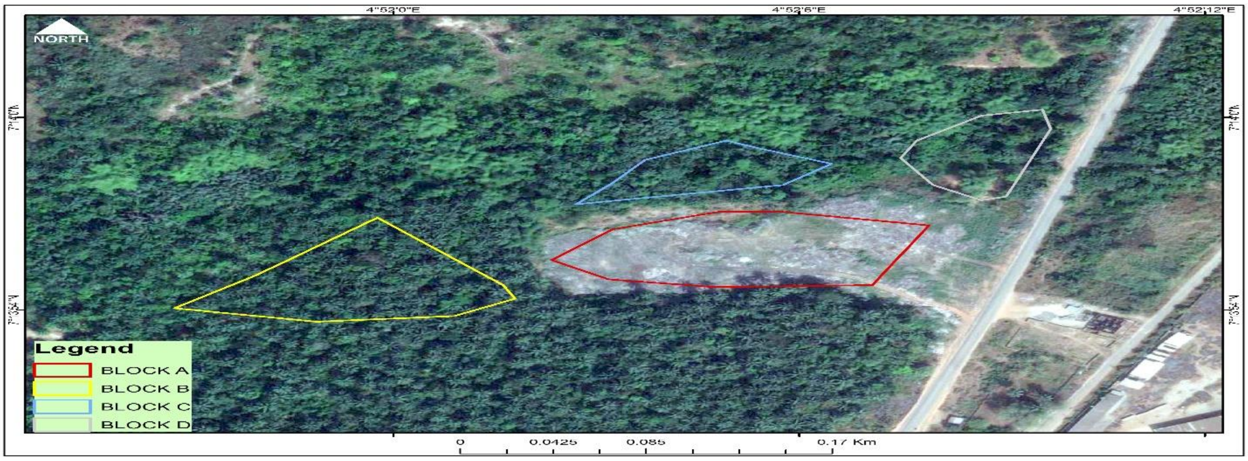

Figure 1: Location of the study area showing solid waste dumpsite and the closed adjacent bottomland

Figure 2: Solid waste dumpsite

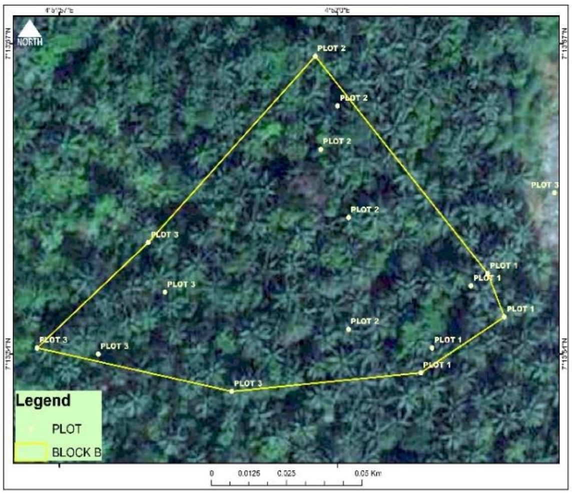

Figure 3: Plot next to solid waste dumpsite

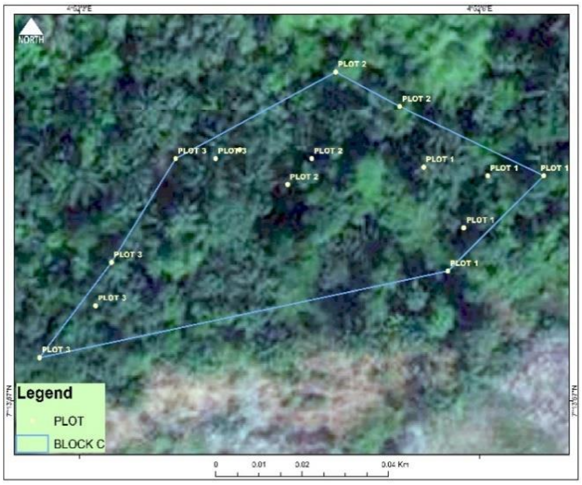

Figure 4: Adjacent closed bottomland to the solid waste dumpsite

Figure 5: Bottomland next to C plot

Soil Samples Analysis

Following air drying and crushing, soil samples were run through a 2 mm filter. The soil samples were placed in clean polythene bags and kept at room temperature. The normal procedures of the Association of Official Analytical Chemists (AOAC, 2023). were followed in determining the physicochemical characteristics of the soil samples. moisture content, bulk density, porosity, pH, electrical conductivity, potassium, magnesium, calcium, and sodium are the characteristics checked. Hydrochloric acid digestion was used for the selected heavy metals Lead (Pb), Cadmium (Cd), Arsenic (As), Nickel (Ni), Chromium (Cr) and Manganese (Mn) analysis. Metal ion concentrations were measured using an atomic absorption spectrophotometer (model Philips PU 9100) equipped with a hollow cathode lamp and a fuel-rich flame (air acetylene). After aspirating each sample, the mean signal response at the wavelength of the metal ion was noted.

Data collection and statistical analysis

To determine the significant effects of waste disposal on the bottomland moisture content, bulk density, porosity, pH, electrical conductivity, potassium, magnesium, calcium, and sodium and the selected heavy metals Lead (Pb), Cadmium (Cd), Arsenic (As), Nickel (Ni), Chromium (Cr) and Manganese (Mn) at the various soil depths, the soil data collected were subjected to analysis of variance (ANOVA) using the SPSS package (version 23) and treatment means were compared using the Duncan's multiple range test (DMRT).

RESULTS

The results of the assessment of soil resources in the bottomland influenced by solid waste disposal are presented in Tables 1–5. The soil texture and textural classes of the sampling plots are shown in Table 1. Sand, silt, and clay particles, respectively, ranged from 68.02 to 82.81, 10.16 to 18.32, and 7.03 to 15.82 g/kg. Among the four plots, A (solid waste dumpsite), B (plot next to the dumpsite on the right), C (bottomland adjacent to the solid waste dumpsite), and D (bottomland next to the plot C on the right) were examined. The sand was highest in the soil sample obtained from the 0–15 cm soil depth of plot A compared to other samples, and it was significantly different ($p < 0.05$) compared with the value recorded for the 0–15 cm soil depth obtained from plot B. Silt was found to be highest in the C plot between 15 and 30 cm of soil depth, while clay was highest in the B plot between 30 and 75 cm of soil depth. The values of soil particles sand, silt, and clay were significantly ($p < 0.05$) higher compared with one another, while the least values of 68.02, 10.16, and 7.03 g/kg were recorded for plots C (30–75 cm), A (0–15 cm), and A (0–15 cm). The dominant textural class across the soil depths examined was sandy loam, except within the 0–15 cm soil depth of plot A, which was loam sand.

Table 1: Texture and Textural Class of the study area

Sampling Plot	Soil Depth (cm)	Sand	Silt (g/kg)	Clay	Textural Class
A	0-15	82.81a	10.16k	7.03l	loam sand
	15-30	74.13c	14.62g	11.25k	sandy loam
	30-75	73.62d	14.85f	11.53j	sandy loam
B	0-15	75.05b	13.23i	11.72i	sandy loam
	15-30	71.84f	14.62g	13.54c	sandy loam
	30-75	71.03g	13.15j	15.82a	sandy loam
C	0-15	69.96h	17.28c	12.76f	sandy loam
	15-30	69.47i	18.32a	12.21h	sandy loam
	30-75	68.02j	17.83b	14.15b	sandy loam
D	0-15	73.27e	14.41h	12.32g	sandy loam
	15-30	71.84f	15.02e	13.14d	sandy loam
	30-75	71.02g	16.16d	12.82e	sandy loam

Plot A = Solid waste dumpsite, Plot B = Plot next to the solid waste dumpsite, Plot C = Bottomland adjacent to solid waste dumpsite, and Plot D = Bottomland next to C plot. Values with the same letter under a column are not significantly different from each other at $p < 0.05$

The results on soil moisture content (MC), porosity, bulk density, pH, and electrical conductivity (EC) of the soil collected from the study area are presented in Table 2. Soil samples collected from 0–15, 15–30 and 30–75 cm depths across the four locations revealed after the laboratory analysis that soil moisture content (MC), porosity, bulk density, pH, and electrical conductivity (EC) ranged from 8.52–16.08%, 30.14–51.19%, 1.16–1.46 g/cm^3, 6.98–7.58, and 299.82–432.61 µS/cm, respectively. The value of moisture content obtained across the four sampling locations (A, B, C, and D) revealed that soil MC was highest between 30 and 75 cm in the D sampling plot, and it was significantly ($p < 0.05$) higher than the closely followed value recorded for the C plot between 30 and 75 cm soil depth. The values of moisture content recorded for the sampling plots showed significant differences, with the least MC of 8.25% obtained for the A plot between 0 and 15 cm of soil depth. Soil porosity of 51.19% between 0 and 15 cm of soil depth in plot A was found to be the highest, and it was significantly higher than the value of 47.28% recorded for plot B at the same soil depth. The values of soil porosity collected across the three soil depths and sampling plots were significantly different from one another, while the least porosity (30.14%) was recorded for the D sampling plot between 30 and

Table 2: Soil Moisture Content, Porosity, Bulk Density, pH, and Electrical Conductivity of the Soil Resource of Bottomland Influenced by Solid Waste Disposal

Sampling Plot	Soil Depth (cm)	MC (%)	Porosity (%)	Bulk density (g/cm^3)	pH (H_2O)	EC (µS/cm)
A	0-15	8.52l	51.19a	1.16l	7.58a	432.61a
	15-30	9.83h	46.82c	1.29h	7.34c	348.94i
	30-75	10.71g	39.72g	1.32g	7.16f	362.57h
B	0-15	8.91k	47.28b	1.24j	7.37b	299.82l
	15-30	9.07j	41.63f	1.37e	7.14g	306.42k
	30-75	9.58i	34.71j	1.43b	7.06j	308.85j
C	0-15	12.34e	45.96d	1.26i	7.22e	394.59b
	15-30	14.16c	38.74h	1.39d	7.08h	379.33d
	30-75	15.81b	31.98k	1.46a	6.98k	382.19c
D	0-15	12.13f	45.07e	1.23k	7.26d	371.08g
	15-30	13.01d	37.01i	1.35f	7.11i	373.41e
	30-75	16.08a	30.14l	1.41c	6.82l	373.07f

Plot A = Solid waste dumpsite, Plot B = Plot next to the solid waste dumpsite, Plot C = Bottomland adjacent to solid waste dumpsite, and Plot D = Bottomland next to C plot. Values with the same letter under a column are not significantly different from each other at $p < 0.05$

75 cm soil depth. The bulk density of the sampling plots revealed that the values obtained were significantly different from one another. The highest bulk density of 1.46 g/cm^3 was obtained from the C plot within 30–75 cm of soil depth, while the least bulk density was recorded for 0–15 cm of soil depth in plot A, and it respectively followed the values obtained within the same soil depths from the D, B, and C sampling plots. Soil pH and electrical conductivity were highest within the 0–15 cm soil depth of sampling plot A, and they were significantly ($p < 0.05$) higher than the closest values obtained within the same soil depth in plots B and C for pH and EC.

Soil nutrients, such as organic carbon, potassium, calcium, magnesium, and sodium concentrations, are shown in Table 3. The concentrations of organic carbon, potassium, calcium, magnesium, and sodium in the soil samples collected from the solid waste dumpsite and bottomland ranged, respectively, from 2.13 to 3.10%, 3.98 to 6.57 Cmol/kg, 5.08 to 8.21 Cmol/kg, 5.41 to 7.91 Cmol/kg, and 0.98 to 2.61 Cmol/kg. SOC was found to be highest between 0 and 15 cm of soil depth at the solid waste dumpsite, and it was significantly higher than the concentration obtained from other sampling plots and soil depths. The lowest concentration of SOC was observed in the sample obtained for plot B between 30 and 75 cm of soil depth.

Table 3: Soil Organic Carbon, Potassium, Calcium, Magnesium, and Sodium Concentration in the Soil Resource of Bottomland Influenced by Waste Disposal

Sampling Plot	Soil Depth (cm)	OC (%)	K	Ca (Cmol/kg)	Mg	Na
A	0-15	3.10a	6.57a	8.21a	7.91a	2.61a
	15-30	3.01c	5.41b	6.83f	6.25d	2.58b
	30-75	2.36k	5.39c	6.57h	5.39j	1.97e
B	0-15	2.81d	4.28h	6.96e	6.72b	1.89f
	15-30	2.46j	4.11j	5.74k	6.29c	1.48i
	30-75	2.13l	3.98l	5.08l	5.41i	1.47j
C	0-15	2.68f	5.35f	7.44b	6.18e	2.36c
	15-30	2.63g	5.37d	7.41c	5.74g	2.28d
	30-75	2.59i	5.36e	7.29d	5.36l	2.28d
D	0-15	3.06b	4.32g	6.68g	6.07f	1.46j
	15-30	2.78e	4.18i	6.31i	5.65h	1.27k
	30-75	2.61h	4.10k	6.17j	5.63k	0.98l

Plot A = Solid waste dumpsite, Plot B = Plot next to the solid waste dumpsite, Plot C = Bottomland adjacent to solid waste dumpsite, and Plot D = Bottomland next to C plot. Values with the same letter under a column are not significantly different from each other at $p < 0.05$

The concentration values of soil K, Ca, Mg, and Na recorded between 0 and 15 cm of soil depth were the highest and significantly different compared with the values obtained from other plots and soil depths, while the least K and Ca concentrations were recorded for plot B between 30 and 75 cm of soil depth. However, the least Mg concentration was found in the sample obtained for plot C between 30 and 75 cm of soil depth, while Na was found in the soil depth between 30 and 75 cm of plot D.

The concentration of selected heavy metals in soil samples collected from solid waste dumpsites and bottomland at different soil depths is revealed in Figures 6 - 11. Heavy metal concentrations of lead (Pb), cadmium (Cd), arsenic (As), nickel (Ni), chromium (Cr), and manganese (Mn), as shown in the figures, respectively ranged from 6.83 to 29.04, 0.00 to 0.35, 0.41 to 3.92, 0.89 to 3.46, 0.00 to 0.63, and 13.74 to 74.38 mg/kg. The highest concentration of the selected heavy metals was found in the soil samples collected from plot A (solid waste dumpsite) between 0 and 15 cm of soil depth, and they were significantly different from the closed values of heavy metal concentration obtained for plot C (adjacent bottomland to the solid waste dumpsite) between 0 and 15 cm of soil depth, while the least concentration of the selected heavy metals was recorded for plot D.

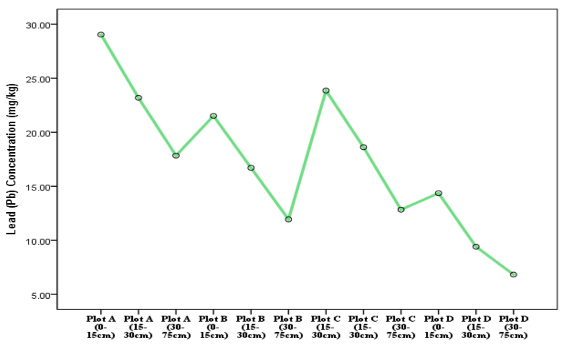

Figure 6: Lead (Pb) Concentration in the samples obtained from a solid waste dumpsite and bottomland at different soil depths

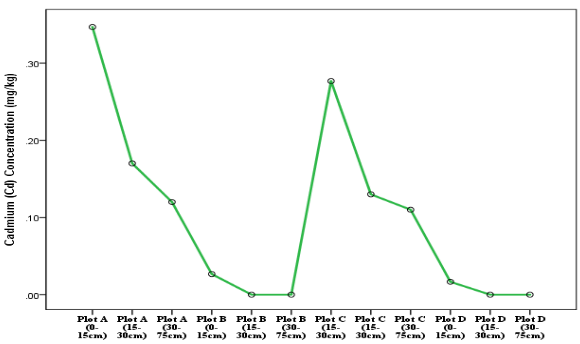

Figure 7: Cadmium (Cd) Concentration in the samples obtained from a solid waste dumpsite and bottomland at different soil depths

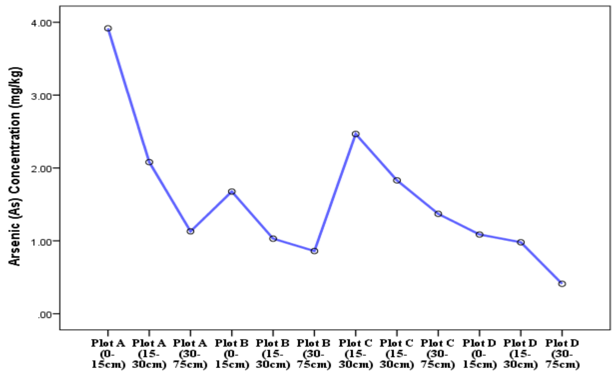

Figure 8: Arsenic (As) Concentration in the samples obtained from a solid waste dumpsite and bottomland at different soil depths

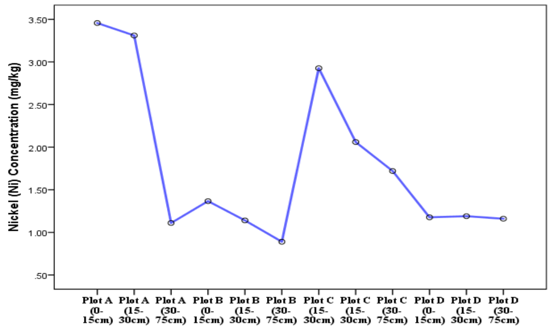

Figure 9: Nickel (Ni) Concentration in the samples obtained from a solid waste dumpsite and bottomland at different soil depths

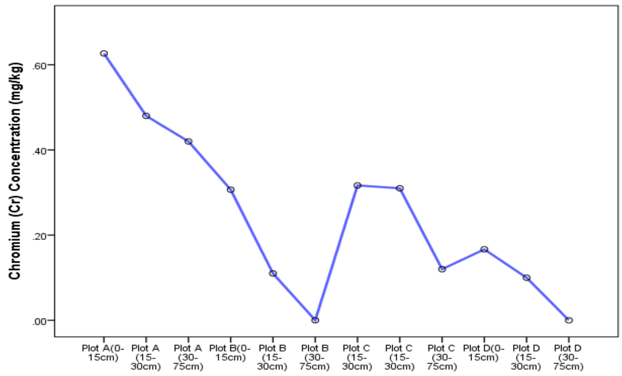

Figure 10: Chromium (Cr) Concentration in the samples obtained from a solid waste dumpsite and bottomland at different soil depths

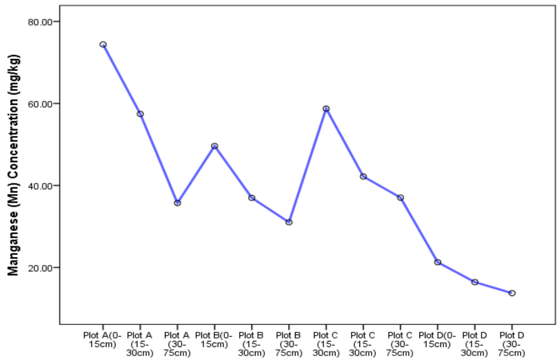

Figure 11: Manganese (Mn) Concentration in the samples obtained from a solid waste dumpsite and bottomland at different soil depths

DISCUSSION

Solid waste dumpsites have benefits originating from the mineralization of organic materials that increases the concentration of valuable plant nutrients, optimum soil pH essential for uptake of the nutrients, and physical properties like moisture content, bulk density, and porosity that enhance plant vigorous growth and promote sustainable crop yield (Doran and Zeiss, 2000; Akintola *et al.*, 2021; Indoria, Sharma, Reddy, & Rao, 2017; Guber, Pachepsky, Shein, & Rawls, 2014; Hatten and Lilles, 2019). As found in the results of the physicochemical properties of the soil samples collected and analyzed from the solid waste dumpsite and the bottomland adjacent to the dump site, it was observed that the improvement of soil physical quality through the enhancement of soil structure, bulk density, porosity, and soil moisture content (Brevik, 2014; Njoku, 2015; Agbeshie, Adjei, Anokye, & Banunle, 2020). However, observation revealed that waste disposal did not affect the soil texture (Akinola *et al.*, 2021) due to little or no variation in the textural class of the soils used for the experiment. The presence of heavy metals in the soil samples collected from the solid waste dumpsite and the bottomland could be attributed to the fact that some solid wastes, such as batteries, lead, pipe, paint, PVC, insecticides, etc. (Akinola *et al*., 2021), are carriers of heavy metals and, as such, affect the soil resources when imposed.

The hazards associated with the presence of heavy metals as a result of indiscriminate waste disposal should receive proper attention, particularly in the bottomland adjacent to a solid waste dumpsite, to avoid the dangers inherent in the pollution of soil resources with heavy metals and their uptake by plants as well as their eventual ingestion by humans and animals. Despite the low concentrations of heavy metals observed from different soil depths in this research compared with the set limits of 20, 0.9–3, and 30–50 mg/kg, respectively, for arsenic (As), cadmium (Cd), and lead (Pb) by FAO. Sisay. (2019) reported that cadmium, lead, and mercury can be harmful to animals and humans at relatively low concentrations and should receive scrutiny. Cadmium is attributed to be carcinogenic and poses a threat to public health (Raman and Narayanan, 2008), and it contributes to kidney disease, lung damage, and fragile bones (Adeolu, 2016).

Heavy metals affect seed germination and have a detrimental effect on plant growth compared to other environmental stresses (Nyiramigisha, Komariah, & Sajidan, 2021; Bakshi, Banik, & He, 2018). Reduced nutrient uptake, plant metabolism disturbance, chlorosis, poor plant growth, and plant depression are some of the negative impacts of heavy metals through waste disposal (Nyiramigisha *et al*., 2021). Excessive levels of heavy metals are reported to be harmful to the growth of plants through oxidative stress and cell structure damage. Heavy metals were also reported to be inhibiting photosynthetic reactions in plant cells (Bakshi *et al*., 2018).

CONCLUSION AND RECOMMENDATION

Physicochemical characteristics and heavy metal concentrations in the soil resource of the waste dumpsite and its adjacent bottomland at different soil depths were examined. The studied soils had a high concentration of valuable plant nutrients, an optimum soil pH essential for uptake of the nutrients, and physical properties that could enhance plant vigorous growth and sustainable crop yield promotion. Concentrations of heavy metals in the soils of solid waste dumpsites and bottomland were not beyond the limit set by FAO, but crops growing on the dumpsite and bottomland due to their fertility status could take up heavy metals. Persistent use of the area as a solid waste dumpsite will eventually increase the concentration of heavy metals in both the waste dumpsite and the bottomland beyond the acceptable limit, and it may pose a serious threat to lives (humans, animals, and plants) if not quickly checked. Therefore, a measure to avoid dumping waste close to the bottomland should be put in place by ensuring the immediate construction of a standard environmental sanitary dumpsite in combination with the waste recycling strategy in the study area.

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Competing Interests
The authors declared that no competing interests exist.

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