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INFLUENCE OF ANTHROPOGENIC POLLUTION ON SOIL AND PLANTS OF GOSA DUMPSITE, ABUJA, NIGERIA

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Abstract
Despite increased awareness of the causes of environmental pollution, it continues to pose a serious threat to both developed and developing countries worldwide. The Gosa dumpsite in Abuja serves as a receptacle for various waste materials from both high and low-income areas of the metropolis. Surprisingly, peri-urban farmers residing in the vicinity still cultivate edible crops on this polluted land. This study aims to assess the impact of waste dumping at Gosa dumpsite on selected soil properties and the uptake of heavy metals by plants.

In order to achieve this objective, soil and plant samples were collected from established 5 x 5 m2 quadrants during the early and late dry as well as rainy seasons of 2019 and 2020. The collected samples underwent analysis using standard methods to determine their physical and chemical properties. Additionally, the study identified the dominant plant species within the dumpsite through standard methods.

The findings revealed that the dumpsite soil exhibited characteristics of loamy sand, with the highest pH value of 8.85 ± 0.90 recorded during the dry season of 2020. Other significant soil results included total nitrogen at 1.09 ± 0.64 g kg-1, organic carbon at 9.88 ± 0.10 g kg-1, Cd at 11.93 ± 2.25 mg kg-1, Hg at 2.18 ± 1.08 mg kg-1, and Pb at 54.68 ± 8.68 mg kg-1, all of which were observed during the early rainy season of 2020. During the remaining seasons considered, lower values were obtained. Notably, these values exceeded the permissible levels set by the FAO for soil intended for cultivating edible crops.

Furthermore, the plant species Ageratum conyzoides demonstrated the highest uptake of heavy metals, with concentrations of 4.47 ± 1.15 mg kg-1 for Cd, 1.77 ± 1.08 mg kg-1 for Hg, and 19.56 ± 4.83 mg kg-1 for Pb, all recorded during the early dry season of 2020.

In conclusion, although the Gosa dumpsite in Abuja may appear fertile enough for cultivation, the study's results highlight that it cannot be deemed suitable for the production of edible crops. The presence of heavy metals and other pollutants in the soil poses a significant risk to crop health and, consequently, to human consumption.

KEYWORDS

Dumpsite, solid waste, heavy metal, soil fertility, crop health

INTRODUCTION

All living organisms generate waste, which eventually finds its way to dumpsites. The management of solid waste in developing countries poses a significant problem that demands urgent attention. Numerous studies have established that open dumping is among the least preferred waste management options in the waste disposal hierarchy (Babayemi and Dauda, 2014; Rajaram et al., 2016). Open dumpsites facilitate the percolation of water through solid waste heaps, resulting in the generation of leachate (Prasad et al., 2016). This leachate infiltrates the subsoil, spreading throughout the dumpsite, contaminating various media along its path, including the sub-soil, surrounding surface water, and groundwater. Consequently, these contaminants are absorbed by plants through the food chain, leading to higher concentrations of toxic metals in water and soil and heavy metal bioaccumulation in plant parts.

Obasi et al. (2012) investigated the impact of an abandoned dumpsite on plants and water in Port-Harcourt, Nigeria, and their findings revealed that the dumpsite negatively affected the physico-chemical properties of the soil, leading to reduced pH levels and increased cation concentrations. In Surakatar, Indonesia, Nyiramigisha et al. (2021) measured heavy metal concentrations in the soil and crops growing near dumpsites. The study highlighted that the types of wastes, topography, runoff, and the number of waste pickers scavenging on the dumpsite influence the levels of heavy metals in the surrounding soil. Heavy metals deposited in soil are non-biodegradable and persist in the ecosystem for extended periods, causing significant environmental damage (Odiwe et al., 2018). Parasad et al. (2016) observed that waste dumping could lead to substantial loading of cations and heavy metals in the soil beyond permissible limits in the vicinity of the dumpsites.

In many developing countries, people cultivate on dumpsite soil, believing it to be beneficial for plant growth and yield due to its nutrient content. However, Zhang et al. (2020) warn that continuous production of consumable crops in or around dumpsites poses a significant risk to human health. Furthermore, Obasi et al. (2012) found that abandoned dumpsites negatively impact species diversity in their vicinity and affect the physico-chemical properties of the soil, leading to reduced pH levels and increased cation concentrations.

A baseline investigation of the dumpsite at Gosa, Abuja, Nigeria, conducted by Popoola et al. (2011), assessed the metal concentration and physical and chemical parameters of surface water samples near the dumpsite. The results indicated that some metals, including Pb, Cd, Fe, Mn, Cr, and Ni, exceeded WHO recommended guideline limits, while Ca, Mg, and Cu were within standard permissible limits. However, this study did not provide information on the effects of the dumpsite on the soil and plants or how their interaction affects the quality of crops in the environment.

Therefore, this investigation aims to offer baseline information on these crucial components of the environment, providing insights into the effects of solid waste dumps on the quality of soil and plants at Gosa dumpsite, Idu, Abuja.

MATERIALS AND METHODS

Study Area

The study was conducted at the Gosa dumpsite, situated in the Idu Local Government Area of the Federal Capital Territory (FCT), Abuja, the capital city of Nigeria, spanning the period from 2019 to 2021 (Figure 1). Abuja, established in 1976, was carved out from portions of the states of Nasarawa, Kaduna, Niger, and Kogi, encompassing an approximate landmass of 8,000 km2. The city's geographical coordinates lie between Latitudes 080 25′N and 090 20′N and between Longitudes 0060 45′E and 0070 39′E of the Greenwich Meridian. The Gosa dumpsite, being the largest in the area, receives waste materials from various parts of Abuja.

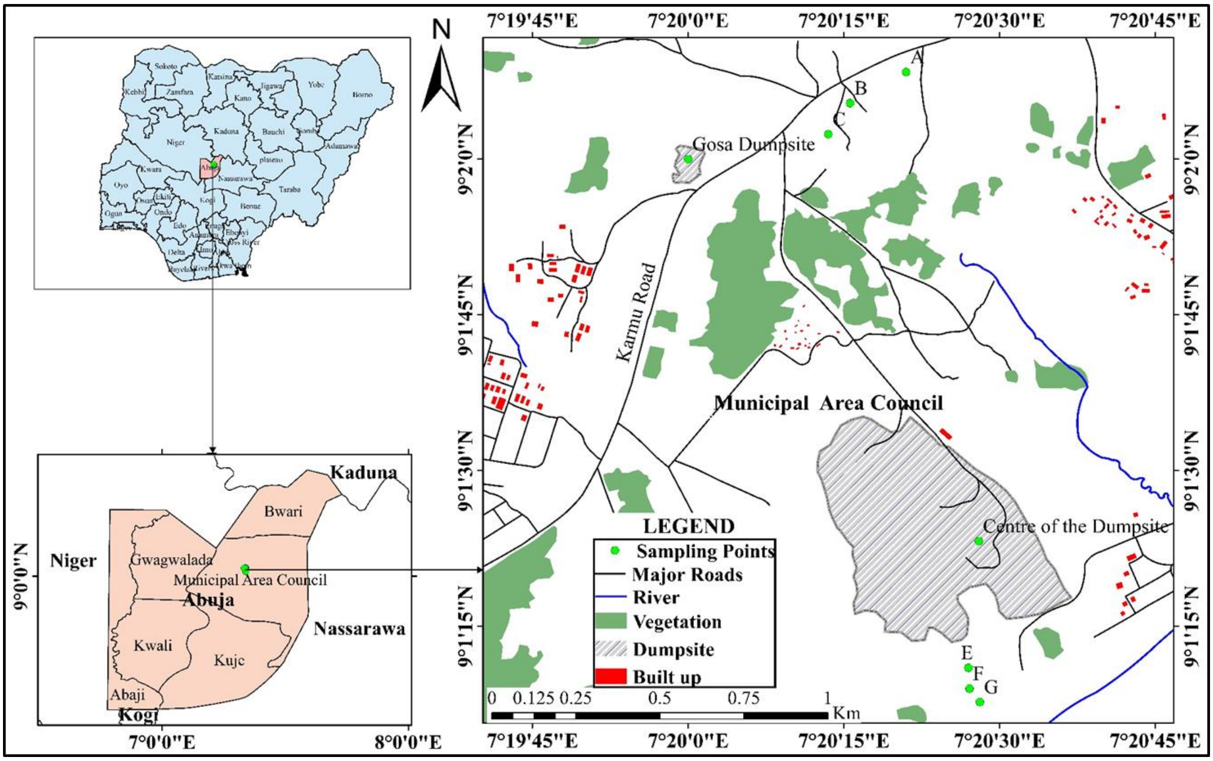

Figure 3.1: Map of Nigeria showing Abuja Municipal Area Council, and the Study Area Source: Abuja Master Plan

Soil and Plant Sample Collection and Preparation

Stratified sampling method was used for sample collection at different designated points as represented in Figure 1

Dumpsite

Figure 1: Field Experimental Layout

Legend

- SD3= Soil and plant southern direction at 100 m away from dumpsite

- SD2= Soil and plant southern direction at 50 m away from dumpsite
- SD1= Soil and plant southern direction at the boundary of the dumpsite
- CP0= Soil and plant sample at the centre of the dumpsite
- ND1= Soil and plant northern direction at the boundary of the dumpsite
- ND2= Soil and plant northern direction at 50 m away from dumpsite
- ND3= Soil and plant northern direction at 100 m away from dumpsite.

Soil samples were collected from various locations at the Gosa dumpsite and control stations. Designated distances included the centre and boundaries of the dumpsite, as well as 50, 100 m upstream and downstream of the dumpsite, and at 500 and 1000 m away from the dumpsite, which served as control stations. At each established plot (pixel), ten core samples were randomly taken within a 5 m by 5 m area to form bulk samples. These samples were then homogenized to create composite samples, which were labeled accordingly. The homogenized composite soil samples were air-dried at room temperature for five to seven days, depending on ambient conditions. The dried soil samples were hand-crushed and mixed regularly to ensure even drying, and then sieved using a 2 mm mesh. Subsequently, the samples were stored in zip-lock polyethylene bags and labeled appropriately before being transported to the laboratory for physical and chemical analyses. Soil samples were collected during the early (May) and late (September) rainy seasons and the early (November) and late (March) dry seasons of the years 2019 through 2021.

Plant Sampling: Plant samples were collected from the dumpsite in the morning at designated distances. Seven to ten stands of the same plant species were carefully uprooted using a shovel and rinsed in distilled water to eliminate any sand or dust adhering to the aerial parts. The plant samples were then divided into shoots and roots. The shoots and roots were oven-dried at 70°C until reaching a constant weight and were then taken to the laboratory for analysis. For plant identification, additional samples were carefully uprooted, including the root, shoot, and seeds (if present), and were neatly stored in brown envelopes for plant authentication at the IFE Herbarium. A total of sixty-five (65) plant species were identified, while seventeen (17) plant species were selected for laboratory analysis of their heavy metal contents.

Soil and Plant Analysis: The determination of selected heavy metals (Cd, Pb, Hg) in the sampled soil was performed using Atomic Absorption Spectrophotometry. The dried soil samples were initially sieved with a 2 mm sieve and further sieved with a 0.5 mm sieve. Approximately 0.5 g of each sample was weighed into a beaker, and an acid mixture of nitric acid and perchloric acid in a ratio of 2:1 was added. The beaker was placed on a hot plate under a fume cupboard and heated at 70°C for about 30 minutes. After a color change to colorless, the digest was allowed to cool and made up to 25 ml with distilled water. The digests were analyzed using a Buck Scientific Atomic Absorption Spectrophotometer model 210/21, VGP to determine the concentrations of Pb, Cd, and Hg.

Heavy Metal Uptake Assessment: Transfer factor, bioaccumulator factor and pollution load index were used to determine the level of heavy metals concentration in the plant and rate of pollution.

Translocation factor (TF)

Translocation Factor (TF) is described as ratio of heavy metals in plant root to that in plant shoot (Usman et al. 2012). The TF of the analysed plant species were obtained using equation below (Usman et al. 2012).

$$TF = C\_shoot/C\_root \quad (1)$$

Where Cshoot and Croot are the metals concentration in the shoot (mg/kg) and the root of plant (mg/kg), respectively.

When TF > 1- High Accumulator; TF < 0.5- Low Accumulator; TF > 0.5- Moderate Accumulator (Turekian and Wedepohi, 1961; Li et al., 2007; Oyekunle et al., 2014)

Bio-concentration factor (BCF): Bio-concentration factor was calculated as metal concentration ratio of plant to concentration in soil. When BCF is greater than 1, it means the plant is an accumulator, when BCF is less than 1, it means the plants is an excluder. (Ginocchio and Baker, 2004).

$$BCF = C\_plant/C\_soil \quad (2)$$

Where Cplant is the metals concentration in the plant and Csoil is the metal concentration in the soil.

Statistical Analysis

Analysis of Variance (ANOVA) was carried out on soil, plant physical and chemical properties. Significant means were compared using the Duncan's Multiple Range Test (at $p < 0.05$) in Statistical Package for Social Sciences (SPSS version 24 (IBM)). Graphs were plotted using Excel Spreadsheet 2013 for the concentration of heavy metals in the plant.

RESULTS AND DISCUSSION

Solid waste dumps are frequently used in Nigeria and other developing nations, leading to potential risks of soil pollution due to inadequate waste management practices. The health of plants, animals, and humans relies heavily on the well-being of the soil. Therefore, continuous monitoring of garbage dump sites is crucial, especially in high-income cities where waste generation rates are significantly higher compared to rural areas. This study aims to investigate the physicochemical characteristics and bioaccumulation factors of soil and plant samples obtained from Gosa dumpsite in the Federal Capital City, Abuja. The dumpsite receives varying amounts and qualities of municipal, agricultural, and industrial solid wastes.

Selected heavy metal concentrations in the soil during the early rainy season of 2019 and 2020 are presented in Table 1. The soil pH in water ranged from 5.40 to 7.40, with no significant difference ($p > 0.05$) observed among these values, indicating weakly acidic soils. The total nitrogen and organic carbon content ranged from 0.16 to 1.09 and 1.48 to 9.88%, respectively. Concentrations of Cd, Hg, and Pb ranged from 4.20 to 11.93, 0.31 to 1.13, and 12.14 to 54.68 mg/kg, respectively. Significant differences (P-value < 0.05) in heavy metal concentrations were observed among the soil samples from designated pixels.

Comparing the soil samples with the control stations, it was found that Cd concentrations (11.93 ± 2.25 and 8.48 ± 1.89 mg/kg) at CP0 and ND1, respectively, were generally higher than those around the dumpsite. The control station CS1 exhibited the lowest Cd concentration of 4.20 ± 0.70 mg/kg. Hg concentration at ND2 (0.79 ± 0.25 mg/kg) was not significantly different from ND1 (0.96 ± 0.28 mg/kg) but differed from CP0 (1.13 ± 0.64 mg/kg). The pattern of high Pb concentration (41.37 ± 34.7 mg/kg) at ND1 paralleled the Cd and Hg concentrations. This high concentration at ND1 was attributed to the situation during rainy seasons when trucks could no longer access the dumpsite to unload waste, leading them to drop the waste near the entrance, about 5 m northwards from ND1. SD1 pixel, on the other hand, received minimal waste materials due to its distance from the main dumping area.

In conclusion, the findings highlight the presence of heavy metal concentrations in the soil at Gosa dumpsite during the rainy season, with variations observed among different designated pixels and control stations. Continuous monitoring and appropriate waste management strategies are imperative to mitigate soil pollution and its potential impact on the environment and human health.

Table 1: Mean Concentration Value of Selected Heavy Metals (mg/kg) of the Soil obtained at Gosa Dumpsite during Early Rain Season of 2019 and 2020

Location	**pH** (H_2O)	**Total Nitrogen** (%)	**Organic Carbon** (%)	**Cd** (mg/kg)	**Hg** (mg/kg)	**Pb** (mg/kg)
CP_0	7.25 ± 0.63a	1.09±0.64a	9.88±0.10a	11.93 ± 2.25a	1.13 ±0.64a	54.68 ± 8.68a
SD_1	6.40±0.77ab	0.19±0.08b	1.71±0.95c	5.90 ± 1.00cd	0.75 ±0.16bc	21.18 ± 1.63b
SD_2	6.85 ±0.66ab	0.17±0.06b	1.48±0.71c	6.23 ± 1.70c	0.45 ±0.10cd	19.85 ± 10.72b
SD_3	6.88± 0.94ab	0.19±0.04b	1.68±0.64c	5.43 ± 1.01cd	0.36 ±0.09d	12.53 ± 5.05b
ND_1	7.40 ±0.89a	0.45±0.08ab	4.31±0.91b	8.48 ± 1.89b	0.96 ±0.28ab	41.37 ± 34.74a
ND_2	7.40 ±0.89a	0.43±0.11ab	4.35±1.49b	6.03 ± 1.06cd	0.79 ±0.25b	24.68 ± 11.66b
ND_3	7.12 ± 1.14a	0.19±0.05b	1.73±0.66c	6.40 ± 0.97cd	0.42 ± 0.14cd	20.53 ± 5.58b
CS_1	6.05 ±1.0b	0.16 ± 0.07b	1.49 ± 0.51c	4.45 ± 0.90d	0.35 ± 0.10d	12.50 ± 8.10b
CS_2	5.4 0 ±0.90c	0.18 ± 0.12b	1.66 ± 1.24c	4.20 ± 0.70d	0.31 ± 0.07d	12.14 ± 3.59b
F-value	6.68	10.39	73.40	18.07	7.47	7.94
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05$ according to Duncan's Multiple Range Test.

Legend: CP_0 = Central Point, SD_1 =Southern Direction Boundary, SD_2 =Southern Direction at 50cm, SD_3 = Southern Direction at 100cm, ND_1 = Northern Direction Boundary, ND_2 =Northern Direction at 50cm. ND_3 = Northern Direction at 100cm, CS_1 = Control Station 1, CS_2 = Control Station 2.

Selected heavy metals concentration (mg/kg) of the soil obtained at Gosa dumpsite during rainy season of 2019 and 2020:

Table 2 presents the characteristics of the soil at Gosa dumpsite during the rainy season. The soil pH in water varied from 6.66 to 8.63, with the highest pH recorded at ND1. Total nitrogen and organic carbon content ranged from 0.06 to 0.32% and 0.54 to 4.84%, respectively.

The concentration of heavy metals (Cd, Hg, Pb) in the soil of Gosa dumpsite during this season was compared with soil samples collected at 500 m and 1000 m away from the dumpsite, labeled CS1 and CS2, respectively, located towards the north of ND3. Cadmium values ranged from 0.15 to 3.59 mg/kg. The lowest values of Cd, Hg, and Pb were found at control station 2 (CS2) with 0.15, 0.10, and 1.69 mg/kg, respectively. On the other hand, the highest values of Cd, Hg, and Pb were observed at pixel ND1, with concentrations of 1.22, 0.81, and 11.48 mg/kg, respectively.

Table 2 Mean Concentration value of Selected Heavy Metals (mg/kg) of the Soil obtained at Gosa Dumpsite during Rain Season of 2019 and 2020

Location	Ph (H_2O)	Total Nitrogen (%)	Organic Carbon (%)	Cd (mg/kg)	Hg (mg/kg)	Pb (mg/kg)
CP_0	8.25±0.90a	0.32±0.06a	4.84±1.00a	3.02 ± 1.25a	1.12 ± 0.67ab	26.15 ± 1.29a
SD_1	7.92±0.90a	0.20±0.07b	1.72±0.82bc	0.40 ± 0.10bc	0.20 ± 0.07c	3.19 ± 0.89de
SD_2	6.75±0.89b	0.18±0.01b	1.39±0.73cd	0.59 ± 0.78bc	0.37 ± 0.09c	4.46 ± 1.91cd
SD_3	6.66±0.90b	0.06±0.02c	1.93±1.18bc	0.19 ± 0.07c	0.32 ± 0.30c	2.37 ± 1.03de
ND_1	8.63±0.64a	0.20±0.07b	2.56±1.22b	3.59 ± 1.30a	1.30 ± 0.29a	28.15 ± 4.05a
ND_2	6.79±0.92b	0.11±0.01c	0.96±0.63cd	0.76 ± 0.09bc	0.24 ± 0.09c	3.93 ± 0.91cde
ND_3	6.85±1.05b	0.12±0.01c	0.70±0.09d	0.88 ± 0.10bc	0.44 ±0.16c	5.92 ± 2.11c
CS_1	6.52±0.90b	0.12±0.01c	1.14±0.10cd	1.22 ± 0.18b	0.81 ±0.11b	11.48 ± 1.10b
CS_2	6.66±0.90b	0.21±0.02b	0.54±0.18d	0.15 ± 0.04c	0.10 ±0.02c	1.69 ± 0.27e
F-value	4.90	15.96	16.86	21.45	14.49	190.11
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter(s) within a column are not significantly different at p < 0.05 according to Duncan's Multiple Range Test.

Legend: CP_0 = Central Point, SD_1 =Southern Direction Boundary, SD_2 =Southern Direction at 50cm, SD_3 = Southern Direction at 100cm, ND_1 = Northern Direction Boundary, ND_2 =Northern Direction at 50cm. ND_3 = Northern Direction at 100cm, CS_1 = Control Station 1, CS_2 = Control Station 2

Selected heavy metals concentration of the soil obtained at Gosa dumpsite during early dry season of 2019 and 2020:

Table 3 presents the soil pH in water and heavy metal concentrations during the early dry season. The pH values ranged from 6.55 to 8.09, with the highest pH recorded at ND1, while the lowest pH of 6.55 was observed at CS1. Organic carbon content and total nitrogen varied from 1.90 to 5.32% and 0.21 to 0.59%, respectively. The soil sample obtained at CS2 had high values of organic carbon and total nitrogen, measuring 3.05% and 0.34%, respectively, compared to soil samples around the dumpsite, while the highest values were observed at CP0. Regarding heavy metal concentrations, the highest concentration of Cd (2.07 ± 0.90 mg/kg) was observed at SD1, whereas the lowest values of 0.29 ± 0.07 and 0.29 ± 0.12 mg/kg were observed at SD3 and SD2, respectively. The lowest Hg concentration of 0.76 ± 0.08 mg/kg was observed at CS2, while the highest value of 1.74 ± 0.07 mg/kg was observed at ND1. Hg at CP0 (1.52 ± 0.14 mg/kg) was not significantly different from Hg at SD1, SD2, ND1, ND2, ND3, and CS1, with values of 1.32 ± 0.31, 1.19 ± 0.21, 1.74 ± 0.07, 1.39 ± 0.03, 1.60 ± 0.11, and 1.29 ± 0.70 mg/kg, respectively.

The control stations 1 (CS1) and 2 (CS2) showed high concentrations of Pb (26.75 ± 2.69 and 33.15 ± 5.09 mg/kg) compared to Pb (18.75 ± 2.55, 24.65 ± 3.04, 21.25 ± 2.55) at SD2, SD3, ND2, and ND3, respectively. However, the highest Pb concentration of 40.75 ± 2.55 mg/kg was recorded at CP0 during the early dry season.

Table 3: Mean Concentration Value of Selected Heavy Metals (mg/kg) of the Soil obtained at Gosa Dumpsite during Early Dry Season, 2019 and 2020.

Location	Ph (H_2O)	Total Nitrogen (%)	Organic Carbon (%)	Cd (mg/kg)	Hg (mg/kg)	Pb (mg/kg)
CP_0	8.25±0.90a	0.32±0.06a	4.84±1.00a	3.02 ± 1.25a	1.12 ± 0.67ab	26.15 ± 1.29a
SD_1	7.92±0.90a	0.20±0.07b	1.72±0.82bc	0.40 ± 0.10bc	0.20 ± 0.07c	3.19 ± 0.89de
SD_2	6.75±0.89b	0.18±0.01b	1.39±0.73cd	0.59 ± 0.78bc	0.37 ± 0.09c	4.46 ± 1.91cd
SD_3	6.66±0.90b	0.06±0.02c	1.93±1.18bc	0.19 ± 0.07c	0.32 ± 0.30c	2.37 ± 1.03de
ND_1	8.63±0.64a	0.20±0.07b	2.56±1.22b	3.59 ± 1.30a	1.30 ± 0.29a	28.15 ± 4.05a
ND_2	6.79±0.92b	0.11±0.01c	0.96±0.63cd	0.76 ± 0.09bc	0.24 ± 0.09c	3.93 ± 0.91cde
ND_3	6.85±1.05b	0.12±0.01c	0.70±0.09d	0.88 ± 0.10bc	0.44 ±0.16c	5.92 ± 2.11c
CS_1	6.52±0.90b	0.12±0.01c	1.14±0.10cd	1.22 ± 0.18b	0.81 ±0.11b	11.48 ± 1.10b
CS_2	6.66±0.90b	0.21±0.02b	0.54±0.18d	0.15 ± 0.04c	0.10 ±0.02c	1.69 ± 0.27e
F-value	4.90	15.96	16.86	21.45	14.49	190.11
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05$ according to Duncan's Multiple Range Test.

Legend: CP_0 = Central Pixel, SD_1 =Southern Direction Boundary, SD_2 =Southern Direction at 50cm, SD_3 = Southern Direction at 100cm, ND_1 = Northern Direction Boundary, ND_2 =Northern Direction at 50cm. ND_3 = Northern Direction at 100cm, CS_1 = Control Station 1, CS_2 = Control Station 2.

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CP0 (1.52 ± 0.14 mg/kg) was not significantly different from Hg at SD1, SD2, ND1, ND2, ND3, and CS1, with values of 1.32 ± 0.31, 1.19 ± 0.21, 1.74 ± 0.07, 1.39 ± 0.03, 1.60 ± 0.11, and 1.29 ± 0.70 mg/kg, respectively.

The control stations 1 (CS1) and 2 (CS2) showed high concentrations of Pb (26.75 ± 2.69 and 33.15 ± 5.09 mg/kg) compared to Pb (18.75 ± 2.55, 24.65 ± 3.04, 21.25 ± 2.55) at SD2, SD3, ND2, and ND3, respectively. However, the highest Pb concentration of 40.75 ± 2.55 mg/kg was recorded at CP0 during the early dry season.

Table 3: Mean Concentration Value of Selected Heavy Metals (mg/kg) of the Soil obtained at Gosa Dumpsite during Early Dry Season, 2019 and 2020.

Location	pH (H_2O)	Total Nitrogen (%)	Organic Carbon (%)	Cd (mg/kg)	Hg (mg/kg)	Pb (mg/kg)
CP_0	7.86±0.90ab	0.59±0.07a	5.32±0.91a	0.79 ± 0.08c	1.52 ± 0.14abc	40.75 ± 2.55a
SD_1	7.06±0.90abc	0.25±0.12bc	2.25±1.25b	2.07 ± 0.13a	1.32 ± 0.31bc	33.20 ± 2.49b
SD_2	7.79±1.45ab	0.28±0.07bc	2.51±0.93b	0.29 ± 0.12e	1.19 ± 0.21c	18.75 ± 2.55d
SD_3	6.77±0.90bc	0.25±0.07bc	2.25±0.91b	0.29 ± 0.07e	0.77 ± 0.16d	24.65 ± 3.04c
ND_1	8.09±0.63a	0.26±0.09bc	2.34±0.64b	0.58 ± 0.11d	1.74 ± 0.07a	32.25 ± 2.02b
ND_2	6.95±0.89bc	0.25±0.07bc	2.28±0.93b	0.30 ± 0.11e	1.39 ± 0.03abc	21.25 ± 2.55d
ND_3	6.74±0.90bc	0.25±0.09bc	2.22±1.04b	0.36 ± 0.08e	1.60 ± 0.1ab	14.45 ± 1.37e
CS_1	6.55±0.07c	0.21±0.07b	1.90±0.59b	0.39 ± 0.15e	1.29 ± 0.70bc	26.75 ± 2.69c
CS_2	6.57±0.63c	0.34±0.03a	3.05±0.69b	1.14 ± 0.29b	0.76 ± 0.08d	33.15 ± 5.09b
F-value	3.11	13.04	8.01	106.86	9.03	50.77
p-value	<0.008	<0.001	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05$ according to Duncan's Multiple Range Test.

Legend: CP_0 = Central Pixel, SD_1 =Southern Direction Boundary, SD_2 =Southern Direction at 50cm, SD_3 = Southern Direction at 100cm, ND_1 = Northern Direction Boundary, ND_2 =Northern Direction at 50cm. ND_3 = Northern Direction at 100cm, CS_1 = Control Station 1, CS_2 = Control Station 2.

Selected heavy metals concentration of the soil obtained at Gosa dumpsite during dry season, 2020 and 2021: The mean soil pH values were 8.61, 8.85, 7.85, 8.22, 8.85, 7.86, 8.08, 8.38 and 7.61 for CP0; SD1; SD2; SD3; ND1; ND2; ND3; CS1 and CS2 respectively all indicating alkalinity nature of the soil. The total nitrogen and organic carbon ranged from 0.16 to 0.32% and 0.90 to 9.32% respectively. The selected heavy metal concentration during dry season are represented in Table 4. The concentration of Cd, Hg and Pb ranged from 1.11 ±0.90 to 2.16 ± 0.90 mg/kg; 1.14± 0.89 to 2.18 ± 1.08 mg/kg and 15.77 ± 1.38 to 23.27 ± 7.76 mg/kg respectively. The concentration of Pb at control pixel 1 (CS1) of 23.27 mg/kg was significantly higher than the concentration of Pb in the soil at the central pixel (CP0) of 20.97 mg/kg.

Table 4: Mean Concentration Value of Selected Heavy Metals (mg/kg) of the Soil obtained at Gosa Dumpsite during Dry Season, 2020 and 2021

Location	**pH (H_2O)**	**Total Nitrogen (%)**	**Organic Carbon (%)**	**Cd** (mg/kg)	**Hg** (mg/kg)	**Pb** (mg/kg)
CP_0	8.61±0.89ab	32±0.10a	9.32±0.91a	1.21 ± 0.65a	1.75 ± 0.84a	20.97 ± 6.40ab
SD_1	8.85±0.90a	24±0.10ab	2.11±0.97ab	1.31 ± 0.29a	1.40 ± 0.17a	17.78 ± 1.06bc
SD_2	7.85±0.90ab	16±0.08d	1.45±0.13d	1.75 ± 1.14a	1.52 ± 0.26a	20.05 ± 0.95abc
SD_3	8.22±0.90ab	17±0.01cd	0.90±0.11cd	2.06 ± 0.65a	1.40 ± 0.17a	17.89 ± 0.98bc
ND_1	8.85±0.90a	21±0.09cd	1.90±1.11cd	1.88 ± 0.93a	1.90 ± 1.18a	17.54 ± 2.10bc
ND_2	7.86±0.90ab	18±0.14bc	1.60±1.32bc	1.47 ± 0.90a	1.92 ± 0.94a	15.77 ± 1.38c
ND_3	8.08±0.90ab	23±0.06bcd	1.08±0.84bcd	1.50 ± 0.93a	2.18 ± 1.08a	21.65 ± 2.73ab
CS_1	8.38±0.90ab	16±0.08bcd	1.44±0.40bcd	2.16 ± 0.90a	1.32 ± 0.62a	23.27 ± 7.76a
CS_2	7.61±0.90b	16±0.02bcd	1.39±0.93bcd	1.11 ± 0.90a	1.14 ± 0.89a	19.59 ± 1.94abc
F-value	1.70	5.93	4.68	1.19	1.08	2.47
p-value	<0.125	).001	<0.001	<0.326	<0.398	<0.027

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05$ according to Duncan's Multiple Range Test.

Legend: CP_0 = Central Point, SD_1 =Southern Direction Boundary, SD_2 =Southern Direction at 50cm, SD_3 = Southern Direction at 100cm, ND_1 = Northern Direction Boundary, ND_2 =Northern Direction at 50cm. ND_3 = Northern Direction at 100cm, CS_1 = Control Station 1, CS_2 = Control Station 2.

The soil pH of Gosa dumpsite exhibited a range from weakly acidic to neutral during the early rainy season, while it showed a range from neutral to slightly alkaline during the dry seasons. The pH values obtained in all seasons ranged from 6.5 to 8.6, whereas the control stations 1 and 2 had pH values of 6.05 and 5.00, respectively, during the early rainy season. The presence of organic matter on the topsoil contributed to the uncontaminated and slightly alkaline nature of soils within the dumpsite. Soil samples analyzed in all seasons indicated significantly higher pH, total nitrogen, and organic carbon in the dumpsite soils compared to the control soil samples, which aligns with the findings of Oyedele et al. (2008). This higher pH level at the dumpsite could be attributed to the liming effect and the activities of certain microorganisms present (Billah et al., 2019). Moreover, pH serves as a straightforward measure of the overall chemical condition of the soil, and a pH of 6.5 generally ensures high nutrient availability to plants (Obianefo et al., 2017). The solubility of nutrients in the soil is known to be inversely correlated with pH (Obianefo et al., 2017). The higher total nitrogen values obtained at the dumpsite may be attributed to the composition of the solid wastes, primarily perishable organic waste, which is a source of nitrogen and available phosphorus, promoting soil fertility and enhancing plant growth on the dumpsite (Olayinka et al., 2017).

During the dry season, the concentrations of Cd and Hg in all pixels were significantly higher compared to the wet season, possibly due to cation leaching during rainfall (Ebisintei, 2015; Obehi, 2020). Additionally, the Pb contents at CP0 and ND1 were significantly higher during the wet season than the dry season. In this study, the heavy metal concentrations in Gosa dumpsite soils were generally higher for Pb and lowest for Hg. Lead is a harmful and non-essential element for plants and animals, acting as a cumulative poison when consumed (MacFarlane & Burchett, 2002; Sharma & Pervez, 2003). Lead finds usage in lead-acid batteries, solder, alloys, cable sheathing, pigments, ammunition, glass, and plastic stabilizers, among other applications (Amadi and Nwankwoala, 2013).

SOIL DEPTH

The mean concentrations of Cd, Hg and Pb in the soil at different depth (0-15 and 15-30 cm) are represented in Figures 1. The results showed that surface soil (0-15 cm) accumulated more metals than the sub soil except for ND2 and SD3 location where the concentrations (2.24 and 2.52 mg/kg) of Cd of subsoil were higher than the concentration (2.03 and 2.35 kg) of the surface soil.

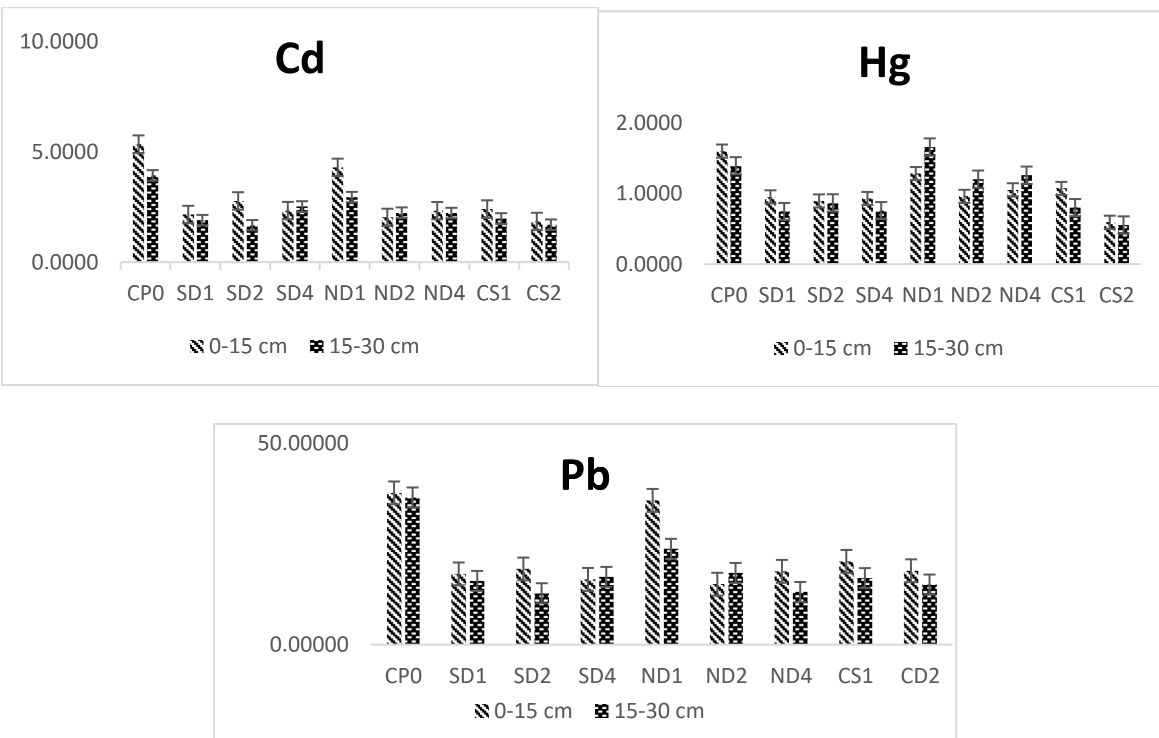

Figure 1: Concentration of Cd in the Soil at Different Depth

Legend: CP_0 = Central Point, SD_1 =Southern Direction Boundary, SD_2 =Southern Direction at 50cm, SD_3 = Southern Direction at 100cm, ND_1 = Northern Direction Boundary, ND_2 =Northern Direction at 50cm. ND_3 = Northern Direction at 100cm, CS_1 = Control Station 1, CS_2 = Control Station 2**.**

Bars indicate standard error.

The concentrations of all heavy metals at a depth of 0-15 cm (top soils) were found to be higher than those at a depth of 15-30 cm (sub soils). Additionally, the concentrations of heavy metals showed a decreasing trend as the distance from the dumpsite increased. These findings are consistent with previous studies, such as Odiwe (2018) and Obehi (2020). The concentration pattern of Pb at ND1 followed a similar trend as that of Cd and Hg. Notably, the northern part of the dumpsite exhibited higher concentrations of the selected heavy metals (Cd, Hg, and Pb) during the early rainy season compared to the southern part of Gosa dumpsite, as depicted in Figure 2. The higher concentration observed at ND1 was attributed to the practice of trucks dropping waste near the entrance of the dumpsite during rainy seasons when they couldn't access the interior area, resulting in accumulation about 20 meters north of the boundary, while the SD1 pixel received minimal waste material.

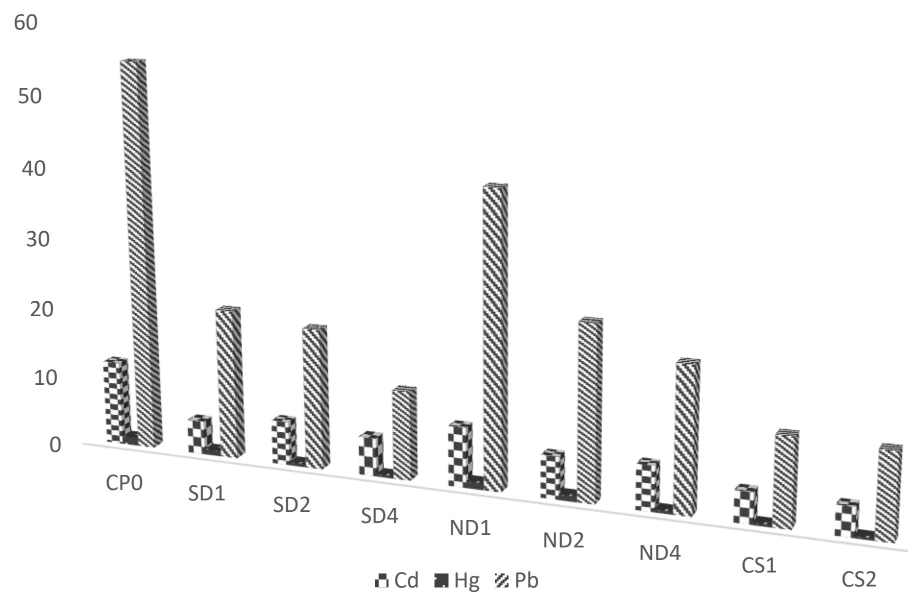

Figure 2: Northern Part High Concentration of Selected Heavy Metals of the Soil obtained at Gosa Dumpsite during Early Rain Season of the study.

Legend: CP_0 = Central Point, SD_1 =Southern Direction Boundary, SD_2 =Southern Direction at 50cm, SD_3 = Southern Direction at 100cm, ND_1 = Northern Direction Boundary, ND_2 =Northern Direction at 50cm. ND_3 = Northern Direction at 100cm, CS_1 = Control Station 1, CS_2 = Control Station 2.

The low concentration of Cd observed may be related to the low quantities of these toxic metals in waste compositions that disposed in the dumpsite. Olayinka et al. (2017) opined that the quantity of toxic metals in waste composition on landfills determines the concentration of Cu and Cd.

Heavy Metal Uptake and Pollution load in the Soil and Annual Plants.

The uptake of selected metals and pollution levels are presented in Table 4. The concentrations of Pb, Hg, and Cd in the soil ranged from 14.54 to 35.64 mg/kg, 0.75 to 1.94 mg/kg, and 1.77 to 4.23 mg/kg, respectively. Comparing the heavy metal contents in the plants, the shoot concentrations of Hg and Cd at CP0 were significantly lower than the concentrations found in the plant roots. However, the opposite trend was observed for Pb, where the shoot concentration (19.49 mg/kg) at CP0 was significantly higher than the root concentration (7.70 mg/kg). Additionally, at SD1 and CP0, the Hg concentrations in both shoot and roots were higher than the concentrations in the soil. The concentrations of Pb, Hg, and Cd in both plant shoots and roots were significantly different ($p < 0.001$).

Table 5: Metal concentration (mg/kg) in shoots and roots of annual plants obtained at each pixels and the total concentration of heavy metal in the soil (May 2019 through March 2021)

Pixel		Heavy Metal Concentration (mg/kg)		
Shoots, Roots and Soils		Cd	Hg	Pb
	Shoots	4.21±0.94	1.72±0.88	19.49±4.71
CP_0	Roots	5.88±2.06	2.30±0.99	7.70±1.80
	Soils	4.23±1.78	1.38±0.65	35.64±14.12
	Shoots	1.33±0.71	0.74±0.17	2.50±0.79
SD_1	Roots	1.80±0.83	0.78±0.14	4.09±0.63
	Soils	1.85±0.20	0.73±0.61	14.54±8.48
	Shoots	0.68±0.10	0.40±0.22	2.51±0.80
	Roots	2.22±0.99	0.70±0.15	3.71±1.08
SD_2	Soils	2.53±0.63	0.88±0.53	15.78±7.97
	Shoots	1.01±0.54	0.39±0.17	2.55±1.09
SD_3	Roots	1.90±0.55	0.78±0.72	3.90±1.81
	Soils	2.51±0.65	0.94±0.50	18.66±11.33
	Shoots	2.27±0.92	0.57±0.32	3.36±1.43
ND_1	Roots	1.61±0.57	0.66±0.17	4.24±1.14
	Soils	3.63±1.27	1.47±0.69	29.83±18.32
	Shoots	0.47±0.25	0.21±0.11	2.66±1.20
ND_2	Roots	2.14±1.47	0.73±0.21	4.26±1.22
	Soils	2.41±1.42	1.08±0.79	16.41±9.35
	Shoots	1.07±0.88	0.91±0.26	2.64±1.51
ND_3	Roots	1.22±0.61	1.04±0.70	3.35±1.99
	Soils	2.29±1.54	1.16±0.63	15.64±7.09
	Shoots	1.57±0.61	0.89±0.27	3.11±1.14
CS_1	Roots	1.99±0.87	0.90±0.36	4.35±3.20
	Soils	2.08±0.66	0.94±0.61	18.50±7.81
	Shoots	0.59±0.30	0.35±0.16	2.41±0.55
CS_2	Roots	0.97±0.57	0.48±0.21	4.23±1.31
	Soils	1.77±0.83	0.58±0.51	16.64±11.99
	F-value	18.289	13.946	81.770
Shoots	P- value	0.000	0.000	0.000
	F-value	3.733	5.368	4.655
Roots	P- value	0.001	0.000	0.000
	F-value	2.238	4.432	10.311
Soils	P- value	0.026	0.000	0.000

Cadmium is commonly used as an anticorrosive and is applied as an electroplating material on steel. It is also used in pigments like cadmium sulfide and selenide, which are extensively employed in plastics, batteries, and electronic components. Additionally, cadmium is present in inorganic fertilizers made from phosphate ores, and when these products are discarded, they end up on dumpsites. Over time, the decomposition of these discarded products leads to the leaching of cadmium into the surrounding soil, resulting in its accumulation. Cadmium is known to be highly toxic, and the use of soil with high cadmium content as manure for cultivating edible crops can have adverse effects on consumers, such as kidney illness and cancer (Wolnik et al., 1983; Yahaya et al., 2009).

In this study, it was observed that the concentrations of cadmium (Cd) and mercury

(Hg) in all pixels were significantly higher during the dry season compared to the wet season. This difference in concentration can be attributed to the leaching of these heavy metal cations during rainfall (Ebisintei, 2015; Obehi, 2020). Similarly, the concentration of lead (Pb) at CP0 and ND1 was significantly higher during the wet season compared to the dry season. Overall, lead concentrations were generally higher in the Gosa dumpsite soils, while mercury concentrations were lower, as evident in this study. Lead is a harmful non-essential element for plants and animals, acting as a cumulative poison when consumed (MacFarlane & Burchett, 2002; Sharma & Pervez, 2003). It is commonly used in lead-acid batteries, solder, alloys, cable sheathing, pigments, ammunition, glass, and plastic stabilizers (Amadi and Nwankwoala, 2013).

Moreover, the concentrations of heavy metals in the top soils (0-15 cm depth) were higher than those found in the sub soils (15-30 cm depth). Additionally, heavy metal concentrations decreased with increasing distance from the dumpsite. These trends were consistent with findings from other studies such as Odiwe (2018) and Obehi (2020). The northern part of the dumpsite generally had higher concentrations of selected heavy metals (Cd, Hg, and Pb) during the early rainy season compared to the southern part of Gosa dumpsite, as depicted in Figure 2. This difference in concentration can be attributed to the disposal patterns of waste materials during rainy seasons, where trucks could not access the dumpsite, leading to the dumping of wastes near the entrance in the northern direction, particularly at ND1 pixel. On the other hand, SD1 pixel received hardly any waste material.

Regarding the plant species present, different plant species were observed in all sampled pixels during the rainy season. However, no plant species were recorded at the central pixel (SD1), SD2, ND1, and CS1 during the dry season, likely due to unfavorable weather conditions and bush burning activities in the dumpsite and surrounding environment. Some plant species were consistently present at certain established pixels, such as Mimosa pudica at SD1, Chromolaena odorata at CS1, Ageratum conyzoides at ND3, and Eleutheranthera ruderalis and Calopogonium mucunoides at CS1 and CS2. The concentration of heavy metals (Pb, Hg, and Cd) in the shoots of some plants around the dumpsite and control stations were significantly lower than the concentrations obtained in their roots and the surrounding soil. However, the reverse was observed for the concentration of heavy metals at CP0, where the Pb concentration in the shoots was higher than in the roots. This difference in heavy metal uptake and distribution in roots and shoots can vary among different plant species.

Furthermore, the transfer factors (TF) of heavy metals from roots to shoots of sampled annual plants in both rainy and dry seasons were determined. In the rainy season, CS2 had the lowest transfer factor for Hg and Cd. The transfer factors of Pb, Hg, and Cd in the rainy season ranged from 0.374 to 1.921, 0.232 to 1.026, and 0.140 to 1.958, respectively. In the dry season, some pixels did not have recorded plant samples due to harsh weather conditions and routine bush burning activities. However, among the plants sampled, some exhibited high transfer factors. The transfer factors of Pb, Hg, and Cd in the dry season ranged from 0.628 to 1.825, 0.420 to 3.190, and 0.335 to 1.792, respectively.

Table 6. Transfer Factor from Roots to Shoots of Identified Dominant Annual Plants around the Dumpsite at Rain Season (2019 - 2020)

Pixel	Pb	Hg	Cd
CP_0	1.921	0.979	0.833
SD_1	0.476	0.400	0.799
SD_2	0.480	0.474	0.204
SD_3	0.660	0.422	0.140
ND_1	0.596	1.026	1.958
ND_2	0.580	0.310	0.161
ND_3	0.453	0.389	0.124
CS_1	0.374	0.470	0.475
CS_2	0.515	0.232	0.032

Table 7. Transfer Factor from the Roots to Shoots of Identified Dominant Annual Plants around the Dumpsite at Dry Season (2020 - 2021)

Pixel	Pb	Hg	Cd
CP_0	NA	NA	NA
SD_1	NA	NA	NA
SD_2	NA	NA	NA
SD_3	1.159	3.190	1.792
ND_1	NA	NA	NA
ND_2	0.628	0.420	0.335
ND_3	1.825	1.165	1.364
CS_1	0.831	0.932	0.790
CS_2	NA	NA	NA

Legend: CP_0 = Central Pixel, SD_1 =Southern Direction Boundary, SD_2 =Southern Direction at 50cm, SD_3 = Southern Direction at 100cm, ND_1 = Northern Direction Boundary, ND_2 =Northern Direction at 50cm. ND_3 = Northern Direction at 100cm, CS_1 = Control Station 1, CS_2 = Control Station 2.

The transfer factor (TF) exhibited significant variation among the pixels and different species of heavy metals. During the rainy season, the lowest TF values for Pb, Hg, and Cd were all recorded at the control stations, while the highest TF values were observed at the points where wastes were dumped. In the dry season, the highest TF values for Pb and Hg were recorded at the control stations. This study demonstrated that individual plant types display substantial differences in their uptake of heavy metals. The extent of heavy metal accumulation in both shoots and roots varied with the type of heavy metal and plant species (Mganga et al., 2011; Nkansah and Belford, 2017; Kahangwa et al., 2021).

It is worth noting that heavy metal

accumulation in plants is influenced by climatic conditions and soil characteristics (Ogundiran and Osibanjo, 2008; Mganga, 2014). Some plants have a propensity to accumulate heavy metals, while others exclude them. The TF values recorded in this study are consistent with the findings of Oyedele et al. (2008). Dada et al. (2012) also observed variations in the uptake of heavy metals by plants across different plant types. During the rainy season, soil nutrients, including heavy metals, may leach beyond the root zones, resulting in higher TF values during the dry season.

Relationship between Metal Concentration in Soil and Annual Plants on Gosa Dumpsite

Table 8 presents the bio-concentration factor (BCF) of soil to the annual plants. BCF was calculated as the ratio of the selected heavy metal concentration in the annual plant to the concentration in the soil. An annual plant with BCF > 1 is considered an accumulator, while BCF < 1 indicates an excluder. For Pb, low bioaccumulation was observed as the sampled plants in all locations did not exceed 1, indicating that the annual plants surrounding Gosa dumpsite were excluders of Pb. In other words, they were not accumulators of Pb. On the other hand, CP0 showed the highest BCF for Hg, while ND1 exhibited the lowest BCF for Pb..

Table 8: Bioconcentration Factor of Selected Metals at Gosa Dumpsite (May, 2019 – March, 2021)

Pixel	Pb	Hg	Cd
CP_0	1.65	2.08	1.69
SD_1	0.31	1.55	1.21
SD_2	0.28	0.85	0.71
SD_3	0.24	0.83	0.78
ND_1	0.18	0.61	0.85
ND_2	0.29	0.53	0.64
ND_3	0.28	1.32	0.73
CS_1	0.29	1.43	1.23
CS_2	0.27	1.02	0.61

Legend: CP_0 = Central Pixel, SD_1 =Southern Direction Boundary, SD_2 =Southern Direction at 50cm, SD_3 = Southern Direction at 100cm, ND_1 = Northern Direction Boundary, ND_2 =Northern Direction at 50cm. ND_3 = Northern Direction at 100cm, CS_1 = Control Station 1, CS_2 = Control Station 2.

The findings of this study revealed that the Bioconcentration Factor (BF) of Pb, Hg, and Cd at the dumpsite were observed to be greater than 1, indicating that the plants at the location were accumulators of these heavy metals. This suggests that the plant roots were capable of solubilizing and taking up the metals from very low levels in the soil, even from nearly insoluble precipitates. Moreover, it was observed that Hg and Cd were more readily absorbed by plants than Pb at the same location, which is consistent with the findings of Ye et al. (2015) who reported maximal BCF values for Cd compared to Pb, Cr, Cu, and Zn.

The transfer factor (TF) and bioconcentration factor (BCF) of each annual plant species sampled are presented in Table 9. Ageratum conyzoides exhibited the highest TF of Pb and Hg, while Tithonia diversifolia had the highest TF of Cd. Furthermore, Zea mays, Euphorbia hirta, and Tithonia diversifolia had the highest BCF values for Pb, Hg, and Cd, respectively. These results highlight the variations in heavy metal uptake among different plant species and their potential to accumulate specific heavy metals at the dumpsite.

Table 9 Metal Concentrations in Plant Species

Plant Species	Heavy Metal	TF	BCF
Ageratum conyzoides	Lead	**2.31**	0.94
	Mercury	**1.97**	**1.06**
	Cadmium	**1.28**	0.83
Zea mays	Lead	**2.14**	**1.15**
	Mercury	**1.10**	0.93
	Cadmium	0.95	0.42
Trianthema portulacastrum	Lead	0.60	0.82
	Mercury	0.41	0.52
	Cadmium	0.66	0.93
Calopogonium muconoides	Lead	**1.14**	0.93
	Mercury	0.54	0.49
	Cadmium	0.85	0.77
Euphobia hirta	Lead	0.09	0.02
	Mercury	0.27	**1.12**
	Cadmium	0.22	0.81
Digitaria horizontalis	Lead	0.38	0.06
	Mercury	0.14	0.09
	Cadmium	0.26	0.13
Ipomoea triloba	Lead	0.08	0.49
	Mercury	0.22	0.38
	Cadmium	0.27	0.37
Synedrella nodiflora	Lead	0.34	0.19
	Mercury	0.19	0.64
	Cadmium	0.25	0.59
Spigelia anthelmia	Lead	0.11	0.18
	Mercury	0.06	0.27
	Cadmium	0.41	0.16
Gomphrena celosioides	Lead	0.33	0.47
	Mercury	0.12	0.42
	Cadmium	0.58	0.40
Tridax procumbens	Lead	0.25	0.53
	Mercury	0.14	0.19
	Cadmium	0.11	0.26
Dactyloctenium aegyptium	Lead	0.36	0.07
	Mercury	0.27	0.15
	Cadmium	0.28	0.24
Amaranthus spinosus	Lead	0.91	0.98
	Mercury	0.49	0.88
	Cadmium	**1.21**	0.84
Sclerocarpus africanus	Lead	0.39	0.57

	Mercury	0.23	0.29
	Cadmium	0.24	0.61
	Lead	0.42	0.28
Aspillia bussei	Mercury	0.18	0.27
	Cadmium	0.26	0.30
Tithonia diversifolia	Lead	**1.37**	**1.09**
	Mercury	0.93	0.84
	Cadmium	**1.55**	0.94
Eleutheranthera ruderalis	Lead	0.23	0.37
	Mercury	0.14	0.29
	Cadmium	0.36	0.43

Values greater or equal to 1 are in bold font.

his study classified Ageratum conyzoides, Zea mays, Calopogonium mucunoides, and Tithonia diversifolia as hyperaccumulators for Pb, Hg, and Cd. Previous research by Kahangwa et al. (2021) also reported Ageratum conyzoides as a species with high metal tolerance to Pb and Ni. Likewise, Obehi (2020) found that Chromolaena odorata and Ageratum conyzoides exhibited better thriving abilities in heavy metal-contaminated soils compared to other plants. Additionally, Salido et al. (2003) and Aiyesanmi et al. (2015) suggested that Ageratum conyzoides could be employed for phytoremediation in soils polluted with Pb metals. Similarly, Zhang et al. (2020) identified Ageratum conyzoides as having the highest transfer factor (TF) for Cd, making it a suitable plant for phytoremediation of Cd-contaminated soils.

It is important to note that humans consume Zea mays, while ruminant animals consume Ageratum conyzoides. As a result, heavy metals from the dumpsite can be transferred into the food chain through the consumption of these plants by animals and humans. This aspect of the study underscores the potential risks posed by heavy metals in the dumpsite, as they can enter the human body through the food chain. Adewole and Uchegbu (2010) explained that when plant nutrients, including heavy metals, are taken up by plants through their roots, they are transported to various parts of the plants. This supports the concerns raised by Watanabe (1997) and Adewole et al. (2019), who discouraged planting edible crops like maize in polluted soils due to the adverse effects it can have on human health if ingested.

CONCLUSION AND RECOMMENDATION

The soil samples analyzed in this study exhibited higher concentrations of selected heavy metals compared to control sites, indicating varying degrees of contamination. Among the heavy metals studied, Pb, Cd, and Hg were the most prevalent in the dumpsite. The concentration of heavy metals gradually decreased as the distance from the center of the dumpsite increased. Notably, heavy metal concentrations were higher at a depth of 0-15 cm than at 15-30 cm, which is the zone containing nutrients essential for annual plant growth.

Continuous monitoring and evaluation of dumpsites are crucial to identify potential increases in heavy metal concentrations and assess their toxicity. The indiscriminate dumping of solid wastes in the environment has significantly harmed our ecosystem by releasing pollutants such as heavy metals. High concentrations of heavy metals in the soil can be harmful to humans if directly or indirectly ingested, as well as to plants that depend on soil nutrients for their growth and development.

It is essential for farmers and residents around dumpsites to avoid using dumpsite soil for agricultural purposes and consuming plants from these areas. Monitoring programs and proper waste disposal methods should be formulated and implemented at both national and state levels. The establishment of landfill sites should be reconsidered, especially as development continues to encroach upon these areas.

Among the plant species studied, Ageratum conyzoides demonstrated the greatest potential for phytoremediation of lead and mercury-polluted soils under similar experimental conditions. This finding suggests that Ageratum conyzoides could be a suitable candidate for addressing heavy metal contamination in affected soils.

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