Assessment of Heavy Metal Concentrations of Municipal Open-Air Dumpsite: A Case Study of Gosa Dumpsite, Abuja

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Abstract. Heavy metals are among the major components of municipal solid wastes with a high atomic weight and a minimum density five times that of water. These metals pose serious environmental and health problems. This study was conducted to determine the concentrations of selected heavy metals- Lead (Pb), Cadmium (Cd), Copper (Cu), Zinc (Zn) and Manganese (Mn)- in a solid waste site, Gosa dumpsite, Abuja. These heavy metals were studied during the 2019 dry season using Atomic Absorption Spectroscopy. Six soil samples were collected from six different points from the main dumpsite. Soil samples were digested and the physicochemical parameters such as particle size, pH, Cation exchange capacity, exchangeable cations and analysis of the soils were carried out using standard procedures. The results revealed variations in the physicochemical parameters in the different study points. Notably, there was a high level of Pb (1.382 ± 1.223 mg/l), Cd (0.257 ± 0.022 mg/l) and Mn (0.615 ± 1.347 mg/l) which exceeded the WHO (Pb: 0.010 mg/l, Cd: 0.001 mg/l and Mn: 0.050 mg/l) and SON (Pb: 0.010 mg/l, Cd: 0.003 mg/l and Mn: 0.200 mg/l) limits for agricultural and industrial soils. However, Cu and Zn were within WHO and SON permissible limits. These results were similar in the soil samples obtained from the main dumpsite and the nearby study points within the Gosa village. The high levels of Pb, Cd and Mn may be attributed to the transfer and infiltration of leachate from the dissolved materials in solid waste from the dumpsite.

Keywords: Gosa village · Municipal solid waste · Open air dumpsite · Heavy metals

1 Introduction

Uncontrolled dumpsites in open-air areas are generally observed in many parts of the world, especially in developing countries—and Nigeria is a typical example [1]. Dumpsites attract flies and insects (which are eventually pathogenic vectors) that considerably

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impact human health by causing diseases. Communities living near an open-air dumpsite, particularly individuals commonly known as scavengers who always get in contact with wastes are susceptible to developing health disorders. But a landfill is properly designed and offers a great advantage over the open one [2]. It is a more efficient system that helps minimize environmental issues thereby reducing health risks [2]. Gosa inhabitants are fond of indiscriminate disposal of both liquid and solid municipal wastes. Thus, the Gosa dumpsite is characterized by drained sandy loamy and clay loamy soils from different locations of the site, mountainous heaps of solid waste and refuse packs dumped openly besides households mainly at the backyards of the village. Besides, the villagers openly dispose of solid wastes, including faeces, and any types of wastes close to their houses.

Heavy metals are among the major components of municipal solid wastes, found naturally with a high atomic weight and a minimum density five times that of water**.** Because of their toxic and tenacious nature, these metals pose serious environmental and ecological threats as a result of the poor disposal of solid wastes. Substantial heavy metals are created from two sources-natural and man-made. The natural source is a result of filtering of metal stores and standard rocks while the man-made sources incorporate metal refining, industrial effluents, and solid waste disposal [3]. For instance, Lead (Pb), and Nickel (Ni) which are man-made are derived from coal and gas, whilst Manganese (Mn), Cadmium (Cd), and Zinc (Zn) are obtained from batteries that are improperly disposed of [4].

Most of the metals get into the ground, form leachate and runoff into our waterways [5]. They either become volatilized or are tied up in the soil due to their ability to form volatile species through natural biogenic processes [6]. The soil is inhabited by many species and families of microorganisms such as the total heterotrophic bacteria (THB) and the rhizobia. These soil microbes are very important as they perform various functions in the soil which include improving soil structure and soil aggregation, recycling of soil nutrients and water recycling [6]. In fact, the soil is constantly infected through human activities through the unintentional launch of chemical substances or the wrong method of hazardous waste disposal. In addition, plants located on and or around the waste dumpsites have the tendency to accumulate heavy metals in their cells especially in the edible parts with potential health implications when consumed. Likewise, the high fixation levels of the metals hamper the physical, synthetic, and organic functionalities of the soil altering plant growth and soil microorganisms and can be toxic to humans [7].

On account of the environmental concerns, the fate and adverse effects of heavy metals have gained considerable interest in the past few years. Thus, this paper focuses on the determination of the concentrations of heavy metals in soil with emphasis on Gosa dumpsite, Abuja.

2 Materials and Methods

2.1 The Study Area and Samples Collection

Gosa village is among the dirtiest satellite towns in Abuja. It is located along the ever-busy Airport Road, opposite the popular Gosa market. The dumpsite at Gosa is one

of the largest open-air and uncontrolled dumpsites in Abuja and is characterized by drained sandy loamy and clay loamy soils. The dumpsite also has mountainous heaps of solid waste and refuse packs dumped openly near households and mainly at the backyards of the village. The figure below shows the geographical representation of the Federal Capital Territory and the main Gosa dumpsite. The figure also shows the sampling points- the centre of the main dumpsite (9.0246320, 7.3390300), two meters (9.0256520, 7.3388750), four meters (9.0269286, 7.3389735), and six meters away from the centre (9.0275780, 7.3394782), then two randomly selected points from the main Gosa village (9.0324889, 7.3369012) and (9.0369600, 7.3396130). Soil samples were collected during the 2019 dry season at a depth of between 15–30 cm from each point using a soil auger. Collected soil samples were transferred into sterilized plastic containers and transported to the laboratory for chemical analyses (Fig. 1).

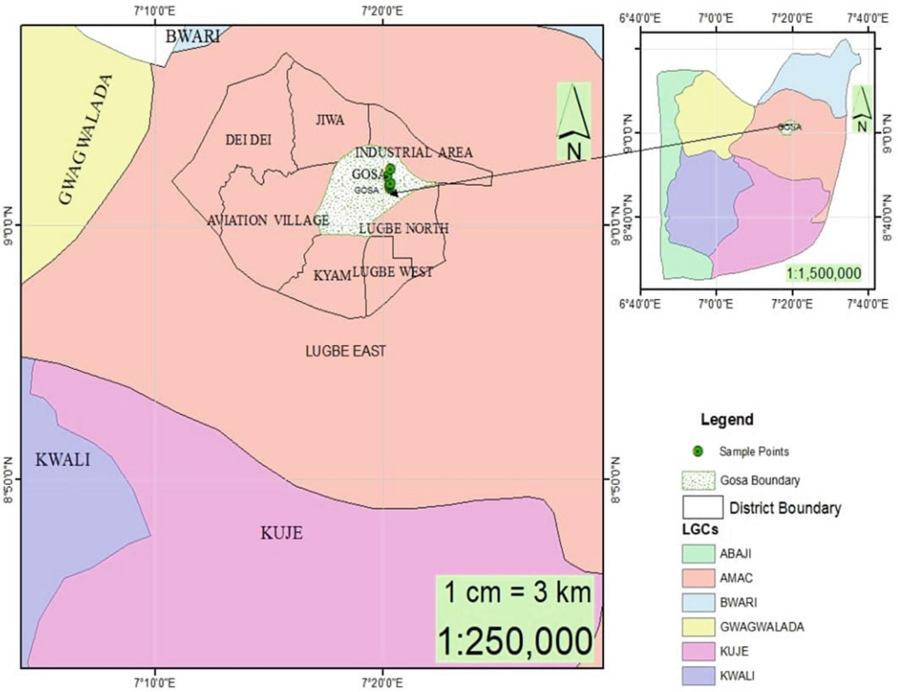

Fig. 1. Map displaying the Abuja districts and Gosa boundaries with the sampling points

2.2 Physicochemical Analysis

To evaluate the soil quality, physicochemical properties of the soil were determined. The percentages of sand, silt and clay as well as the texture of the collected soil samples were determined using the Jar test technique. Soil pH was determined at a ratio of 1 part soil to 5 parts potassium chloride solution, using a digital pH meter. Cation concentration

of the soils was determined using the pH 7 ammonium acetate (NH_4OAc) method, as described by [8], which is a modified method of [9]. The Effective Cation Exchange Capacity (ECEC) was computed by the summation of exchangeable bases. While the base saturation (BS) was computed as the sum of basic cations expressed as a percentage of ECEC. The electrical conductivity of the soil was measured following the method of [10]. The digital conductivity meter was employed to measure the soil electrical conductivity, using the same soil solution that was used during the determination of the soil pH. Soil organic matter (SOM) was determined using the wet acid dichromate digestion and ferrous ammonium sulphate titration method of Walkley-Black measurements of soil organic carbon (SOC) following a modified procedure from [11]. The total Nitrogen was determined following a modified method of [10]. Phosphorus from the testing soil sample was measured with a spectrometer using the molybdenum blue colour method.

2.3 Digestion of Soils

The soils were sieved with a 2 mm sieve. Prior to the metal analysis, the remaining portion of each collected sample was digested following [10] method. 2 g of soil was weighed into a conical flask. 10 ml of Nitric acid (HNO_3) and 2 ml of hydrochloric acid (HCl) were added and the mixture was heated at 95 °C till the volume reduced before being allowed to cool. And then the cold solution was filtered using a filter paper and distilled water was added to make it 50 ml.

2.4 Heavy Metals Analysis

Heavy metal analysis was performed using Atomic Absorption Spectroscopy (iCE™ 3300 AAS, Thermo Scientific, MA, Boston, USA) connected to a Thermo Scientific SOLAAR™ software. The Thermo Scientific SOLAAR™ software contained pre-set spectrophotometer parameters for copper, cadmium, lead, manganese and zinc, which were used to measure the samples. Each measurement was performed in triplicate and the fast resample method was adopted to speed up the analysis. Copper, cadmium, lead, manganese and zinc stock standard solutions containing 1000 mg/L of these metals were diluted with a pre-mixed solution of deionized water and analytical grade concentrated nitric acid to provide working standards of various concentrations in 2% (w/v) HNO_3. The calibration blank solution used throughout was a 2% w/v HNO3 solution. The calibration curve was obtained using the calibration standards that were manually prepared. The method of quadratic least-squares fit was used for the calibration.

3 Results and Discussion

3.1 Soil Particles Size

The results for soil particles size were expressed in percentage (Table 1). Sand had the highest percentage in terms of soil particle size, across all the soil samples, with an average of 57.51%, higher than that of the control soil obtained from the botanical garden of Nile University of Nigeria. However, from all the collected soil samples, clay had

the least percentage of particle size with 13.96%. These results are comparable to those of [8] and [12], using surface and middle slope soils respectively. The results from the physical properties of the soil samples indicate that sand is the prevalent soil particle, and the dominant soil texture is loamy-silt across all collected soil samples. According to [4] and [12], this texture limits the proliferation of microorganisms and the mineralization of natural matter.

Table 1. Percentage particle size fraction (%) of the soil samples

	Height of each layer (cm)				Percentage of particles		
	Sand	Silt	Clay	Total	% Sand	% Silt	% Clay
CT	3.50	1.30	0.80	5.60	62.50	23.21	14.29
2M	3.60	2.15	0.75	6.50	55.38	33.08	11.54
4M	4.20	1.55	1.00	6.75	62.22	22.96	14.81
6M	3.90	3.00	0.80	7.70	50.65	38.96	10.39
VP1	4.75	3.00	1.75	9.50	50.00	31.58	18.42
VP2	4.50	1.50	1.00	7.00	64.29	21.43	14.29
CON	3.3	1.8	1.5	6.6	50.00	27.30	22.70

CT = Centre, CON = Control area, 2M = 2 m, 4M = 4 m, 6M = 6 m, VP1 = first point from the village and VP2 = second point from the village
% Sand = (Height of sand)/(Total height) *100
% Silt = (Height of silt)/(Total height) *100
% Clay = (Height of clay)/(Total height) *100
Total height = height of the three particles

3.2 Soil Organic Matter (SOM)

The SOM results revealed that the soils from Gosa dumpsite have relatively low organic matter compared to the control soil (1490.00 mg/kg^{-1}) and to [13] standard (Table 2).

CT = Centre, CON = Control area, 2M = 2 m, 4M = 4 m, 6M = 6 m, VP1 = first point from the village and VP2 = second point from the village. The soils from this study area have a slightly high clay content (mainly from the central portion of the main dumpsite). This is due to the build-up of non-biodegradable substances over the last 35 years since the dumpsite became operational [14]. The non-biodegradable substances include clothes, papers, plastic bags, buckets, tin cans, sacks, glass bottles, water sachets and strong waste.

Also, the inordinate parts of natural matter in the soil from the Gosa dumpsite may also be due to different kinds of metropolitan solid wastes released inside the dumpsite, like paper, utilized batteries, electronic merchandise, wood, plastic paper, straws, containers, metal jars, snacks, garments, glass bottles, cotton fleece, food squander, leaves, organic product waste, medication bottles, froths, cinders, water sachets, cardboard, and human excreta [14]. Previous researchers attribute this high level of organic matter in

Table 2. Mean values of carbon, available Phosphorus (Av. P), azote, organic matter and C/N ratio of soil samples

Mg/kg^{-1}					AV. P
	SOC	SOM	TN	C\N	
CT	703.80	1210.50	83.00	8.50	89.50
2M	623.26	1072.00	79.00	7.90	71.12
4M	633.72	1090.00	88.00	7.20	43.12
6M	581.40	1000.00	108.00	5.40	40.00
VP1	546.50	940.00	62.00	8.80	65.00
VP2	610.47	1050.00	980.00	0.62	63.00
CON	866.28	1490.00	41.29	21.00	24.80

soils from a dumping site to the ubiquitous availability of non-fermentable materials present in the wastes, which are barely decomposed and therefore break down very slowly [12]. Also, the slow decay of soil natural matter is likely because of a reduced flow of oxygen in the dumpsite supported by [15].

3.3 Soil pH

The results from the concentration of the hydrogen ion analysis revealed that the soil pattern from the centre of the dumpsite is acidic. And as for the two randomly selected points from the Gosa village, the first point had a water pH of 6.90 while the second point revealed acidic pH. However, the pH variation (ΔpH = pHwater - pH KCl) of soil samples from the dumpsite soil was ΔpH <1, displaying excess acidity. Thus, the soil from the centre and soil collected at points located far away from the centre were strongly acidic, with the water pH ranging from 5.98 to 5.56.

According to [16], soils with an acidic pH (less than 6) have little amounts of Ca^{2+}, Na^{+}, Mg^{2+} and K^{+} cations. Whereas, the soils possessing pH less than 5 have significant amounts of manganese concentrations.

The slight acidic content of the dumpsite soil could be due to the age of the waste, which is similar to the findings of [12]. According to their assertion, the pH - value of soil from a dumpsite diminishes consistently upon waste disposal. They likewise referenced that the impartial causticity (water pH = 6.90 and pHKCl = 6.20) of the open dumpsite soil can diminish the soil micronutrient accessibility for flora and favour the improvement of metallic accumulation.

3.4 Soil Cation Exchange Capacity

Cation exchange capacity (CEC) is defined as the fundamental soil property that helps predict plant nutrient availability. In this study, Calcium (Ca^{2+}) had the dominant basic cation within the complex, with a range of 1.0–4.5 cmol.kg^{-1}, followed by potassium (K^{+}) with a range of 0.25–3.34 cmol.kg^{-1}, Mg^{2+} (ranging from 0.15–2.15 cmol.kg^{-1}),

and Na^+ (ranging from 0.04–0.73 $cmol.kg^{-1}$), across all collection points of the study site (Table 4). The value of the cation exchange capacity (CEC) of the soil diminishes with regards to proximity to the dumpsites. Our result is consistent with the findings of [12]. However, the first point selected from the village had the highest exchange value of 11.74 $cmol.kg^{-1}$. The difference in the Base Saturate (V) ranged from 57.39 to 87.22% between the study points. Also, the results showed that these soils were strongly desaturated ($58\% < V\% < 89\%$) with a high exchange acidity, regardless of the point of collection from the study site (Table 3).

Table 3. Mean values of pH, Cations (Ca^{2+}; Mg^{2+}; Na^+; K^+), cation exchangeable capacity (CEC) and saturation base (V%) of soil samples

	pH of soil samples			Cation concentration of soil ($cmol/kg^{-2}$)				Total CEC ($cmol/kg^{-2}$)	Base Saturate BS (v%)	
	pH (water)	pH (KCl)	Delta pH	K+	Ca++	Na+	Mg++	Meq /100 g	Total Base	V%
CT	6.90	6.20	0.70	0.56	2.00	0.06	0.24	4.36	2.86	65.39
2M	6.79	5.59	1.20	0.50	1.31	0.04	0.17	3.52	2.02	57.39
4M	5.98	5.00	0.98	0.75	1.75	0.73	0.25	4.98	3.48	69.90
6M	5.56	4.50	1.06	0.25	2.25	0.15	0.21	4.36	2.86	65.60
VP1	6.90	6.20	0.70	3.34	4.50	0.25	2.15	11.74	10.24	87.22
VP2	4.10	4.00	0.10	0.75	1.00	0.13	0.15	3.53	2.03	57.51
CON	6.73	6.00	0.73	4.50	3.97	0.30	2.00	12.15	10.26	87.56

CT = Centre, CON = Control area, 2M = 2 m, 4M = 4 m, 6M = 6 m, VP1 = first point from the village and VP2 = second point from the village.

3.5 Heavy Metals Analysis

Metal concentration levels in the soil varied from one point of the main dumpsite to another and to the points from the nearby vicinity (Gosa village). Lead had the highest concentration in all the samples collected from the main dumpsite with 0.473 mg/L, 1.382 mg/L and 3.249 mg/L as minimum, average and maximum concentrations respectively. The mean values of all heavy metals decreased with the distance away from the centre of the main dumpsite and this could be due to high amount of wastes at the center of the dumpsite. Only Zinc and the Manganese had widely distributed concentrations with strong standard deviations, higher than the mean value (Table 4).

Lead, Cadmium, and Manganese concentrations in all the soil samples (both from the main dumpsite site and Gosa village were above the permissible limits of WHO ($Pb = 0.010$ mg/kg^{-1}; $Cd = 0.001$ mg/kg^{-1} and $Mn = 0.050$ mg/kg^{-1}) and SON ($Pb = 0.010$ mg/kg^{-1}; $Cd = 0.003$ mg/kg^{-1} and $Mn = 0.200$ mg/kg^{-1}), except the concentrations of Copper and Zinc which were lower than the threshold limit across all the soil samples (Table 4). From four meters (4M) and six meters (6M) away to the

centre of the main dumpsite, Zinc and Copper concentrations were below the detection limit of WHO and SON. However, our results showed that metal concentrations from soils in the main landfill were generally in much greater quantities than those of soils from the nearby vicinity (the Gosa village). Increasing from the centre then two meters away from the centre (Table 4).

This degree of natural matter presumably favours the sorption of metal as a result of SOM's assimilation characteristics [4]. Additionally, the excessive lead, cadmium and manganese content observed in the soil samples from the main dumpsite compared to those soils collected from the nearby Gosa village could be due to different sorts of municipal solid squanders from the dumpsite [17]. Consistent aggregation of various sources of metropolitan solid wastes, like electronic products, electroplating waste, painting waste, and utilized batteries could be the beginning of the metalloids observed in the soil from the dumpsite [14]. These outcomes are consistent with findings from other studies, which demonstrate that uncontrolled, free-access dumpsites address a critical source of heavy metal defilement in the ecosystem [18].

The abnormal concentrations of lead (1.382 mg/l), cadmium (0.257 mg/l), and manganese (0.615 mg/l) contents in soils from the dumpsite are above the limits recommended by the Standard Organization of Nigeria (SON) and the World Health Organization (WHO) [10], and are higher in the main dumpsite relative to the other points. Lower metal or metalloids in control soil relative to the study points suggests that the contaminated soils were human-induced. [8] reported that such human-induced contamination might be from wastes.

The contamination of the Gosa dumpsite soil with harmful metals or metalloids may present dangers and perils to the people and the biological system [12]. Also, Gosa dumpsite soil may experience an ecological danger if these metals relocate into the groundwater and plants.

Table 4. Heavy metal concentration from the soil from the Gosa dumpsite compared to WHO and SON standards

	Pb (mg/L)	Cd (mg/L)	Cu (mg/L)	Zn (mg/L)	Mn (mg/L)
CT	3.249 ± 0.000	0.287 ± 0.000	0.542 ± 0.000	0.164 ± 0.000	0.337 ± 0.000
2M	2.622 ± 0.000	0.282 ± 0.000	0.26 ± 0.000	BDL	BDL
4M	0.746 ± 0.000	0.250 ± 0.000	0.580 ± 0.000	BDL	BDL
6M	0.628 ± 0.023	0.246 ± 0.000	0.042 ± 0.000	BDL	BDL
VP1	0.473 ± 0.000	0.243 ± 0.000	1.178 ± 0.000	1.290 ± 0.000	BDL
VP2	0.571 ± 0.000	0.236 ± 0.000	0.718 ± 0.000	1.042 ± 0.000	3.351 ± 0.000
WHO	0.010	0.001	1.500	15.00	0.050
SON	0.010	0.003	2.000	3.000	0.200

In comparison to other locations in Nigeria and neighbouring African countries, the lead (1.382 mg/l) content in the soils from the Gosa dumpsite is less than that of

Oke-ogi dumpsite soil (91.67 mg/l) from Iree, Osun, Nigeria [19], Effiakuma-sekondi (5.11 mg/l) from Takoradi, Ghana [20]. The average amount of cadmium concentration (0.257 mg/l) detected in the soils from Gosa dumpsite was higher than that of soils from the Effiakuma-sekondi (0.050 mg/l) from Takoradi, Ghana [20]. But it was lower than that of the Lumberstewart dumpsite (0.400 mg/l) from Bulawayo, South Africa [21].

Additionally, the observed soils from the Gosa dumpsite have a manganese concentration of 0.615 mg/l, which is relatively higher than the permissible limits recommended by WHO (0.050 mg/l) and SON (0.200 mg/l) for agricultural soils; however, it is lower than the manganese content from Oke-ogi dumpsite soil (3.200 mg/l) from Ire, Osun, Nigeria [19].

The presence of heavy metals in the Gosa dumpsite and its close-by area (Gosa village) soils could be a significant ecological threat from the point of view of soil contamination [22]. If not, the interaction between metals and natural soil matter could prompt complex outcomes on the solvency, portability, and bioavailability of metals in the event that they are filtered into the encompassing zones [12]. This could cause soil weakening issues for agribusiness and nearby inhabitants in the closest area.

4 Conclusion and Recommendations

The results of this study indicate that soils from the main Gosa dumpsite are sandy-loam and that the loamy aspect of the soils decreases from the centre of the main dumpsite towards the nearby Gosa village. The centre of the dumpsite has soil with acidic pH and high organic matter content. However, the base saturation of these soils is relatively high across all soil samples collected from all points of collection. The heavy metal content investigation revealed that lead, cadmium and manganese concentrations were significantly higher than the permissible concentrations. This study was conducted during the 2019 dry season, thus, further studies during the rainy season are recommended, with the assumption that rain could increase the metal concentrations of the soils.

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