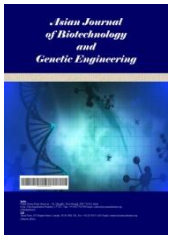

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Heavy Metal and Physicochemical Properties of Soil in Ugwuaji Solid Waste Dumpsite during the Dry Season

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Authors' contributions

This work was carried out in collaboration among all authors. Author EJO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author AGI managed the analyses of the study. Author ICE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The practice of open dumping of solid wastes is becoming very common, irrespective of the dangers it poses to the environment and to humans. The present study is aimed at assessing the heavy metal and physicochemical properties of soil in Ugwuaji solid waste dumpsite during the dry season; using standard techniques. Using circular plot method, soil samples were collected from the study area at depth 0 to 15 cm, 15 to 30 cm, and 30 to 45 cm during the months of November, December and January. The results of the findings showed reduction in most of the soil physicochemical properties such as: soil pH, CEC, clay, silt, TOC, nitrogen, phosphorus, potassium, and moisture content [5.65 pH.H_2O, 11.8 cmol/kg, 14.2 %, 17.7 %, 388.2 g/kg, 0.96 g/kg, 57.8 mg/kg, 0.88 cmol/kg and 8.12 % respectively]. High SOM was observed (234.3 g/kg) and the soil textural class was observed to be sandy-loam. The concentration of heavy metals observed reduced progressively from November to January. The metal concentration was observed in the order: Zn > Pb > Cu > Cr > Hg > Cd. The study concluded that the presence of heavy metals in soils from Ugwuaji dumpsite affects the soil physicochemical properties.

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Keywords: Heavy metals; physicochemical; open dumpsite; Ugwuaji; solid waste; dry season.

1. INTRODUCTION

The high rate of environmental pollution due to improper management of solid waste has continued to generate global attention. The activities of man such as improper disposal of municipal solid waste (MSW) often referred to as "garbage" or "trash" has continuously aggravated environmental pollution. Environmental pollution has worsened from the geometric increase in human population and rapid industrialization which results to the generation of huge quantity of solid waste [1]. Solid waste is a term that refers to waste with low liquid content or non-biodegradable wastes. Solid wastes are often generated from sources like; households' materials, heavy industrial sites, economic activities, hospital and clinical waste etc. Solid wastes are normally made up of materials that are not biodegradable or materials whose content cannot be used as manure to improve soil fertility due to its non-compostable nature [2,3].

In developing countries, open dumping of solid waste is commonly practiced possibly because of poor budgetary allocations for waste disposal and management, no skilled man power and poor attitude of people to proper refuse disposal. According to Madu [4], it was reported that solid waste is part of the major challenges in Enugu State as several tonnes of solid waste generated in the area are left uncollected, littered all over the streets or dumped in open site. It was also observed that the disposal of solid wastes in dumpsite, behind residential houses, and in gutters are common practices of the urban dwellers in Enugu [5]. Indiscriminate dumping of solid waste on open areas and improper management of waste has been reported to pose significant human and environmental problems. For example, toxic contaminants such as heavy metals from the open dump may pollute the soil and underground or surface water as leachate resulting to water pollution [6]. Also, through the process of bioaccumulation, the edible crops cultivated within the dump site environs get contaminated.

Heavy metals such as Cadmium (Cd,), Lead (Pb), Copper (Cu), Iron Fe), Nickel (Ni), Zinc (Zn) can disrupt the soil chemistry and adversely affect the organisms or plants depending on the soil [7]. Plant absorption of these metals can retard plant growth and productivity; human intake of heavy metals (through consumption of contaminated plants) can cause diseases like cancer [8]. The level of heavy metals present in solid waste can be increased from the disposal of wastes like electronic goods, electro-plating waste, painting waste, used batteries, plastics, tires etc., when dumped with municipal solid wastes. Untreated solid wastes dumped openly into the environment can cause toxic environmental effects. The leaching of these heavy metals under acidic environment during the degradation process leads to leachates with high metal concentrations which are potential sources of soil and ground water pollution.

Improper disposal of solid waste at Ugwuaji dumpsite in Enugu, has continuously affected the environmental quality in the area. According to studies, the accumulation of tonnes of solid waste at Ugwuaji has led to the contamination of soil, water and air with toxic pollutants such as heavy metal. Considering the dangerous nature of these chemicals, it is important to study its distribution in the solid waste dumpsite in order to fully understand and monitor the effects of these metals on ecosystem and biological system.

2. MATERIALS AND METHODS

2.1 Study Area

Ugwuaji is a town in Southern part of Enugu state, Nigeria. The state is one of the five Southeastern states of Nigeria, located between latitude 6°.00'N and 7°.00'N and longitude 7°.00'E and 7°.45'E. It falls within the humid tropical rainforest belt of the Southeastern Nigeria [9]. There are two distinct seasons experienced in the state: the dry and rainy seasons. The annual rainfall ranges between 937.2 mm to 2243.3 mm and the temperature between 20.3°C to 32.16°C [9,10]. The estimated population of Enugu inhabitants is around 722, 664 (2006 census) [10].

The geographic position system (GPS) coordinates of Ugwuaji is: Elevation 186 m; North 6°26.27'; and East: 7°32.831 as originally mapped out by Enugu State Waste Management Authority (ESWAMA) municipal solid waste (MSW). It is used by the establishment (ESWAMA) as the final disposal site of all municipal solid waste generated in Enugu metropolis. The area is approximately 7.878 ha of land space [9]. The dump site is about 1.6 kilometers off Enugu-Port Harcourt expressway

as shown in Fig. 1. The dumpsite was originally conceived as a landfill but has degenerated to a massive open dump due to poor management, inadequate manpower and lack of requisite technology. The bottom of the landfill was not lined for leachate containment, and no compaction was undertaken. There is no perimeter fencing, hence scavengers and stray animals roam the dumpsite unrestricted [9].

2.2 Experimental Design

A randomized complete block design was adopted for the study. The site was partitioned into units through the circular plot method. Soil samples was collected for dry season within the months of November, December and January.

2.3 Sample Collection

Soil sampling will be conducted using circular plot method. In this method, the open landfill was used as the central point, and a rope marked at 2 m intervals was pivoted to determine the edges of the circular plot (Fig. 1). Through this means, three circles 2 m apart were created. Within the circumferences of the circles soil samples were collected at random [11]. Soil samples was collected from the study area at depth 0 to 15 cm, 15 to 30 cm, and 30 to 45 cm using a calibrated soil auger. Each sample was immediately placed in sterilized bags and tightly sealed. After which, the samples were taken to the laboratory for preparation and analysis. Control soil samples were also be collected from uncontaminated (pollution free) area for comparison purpose.

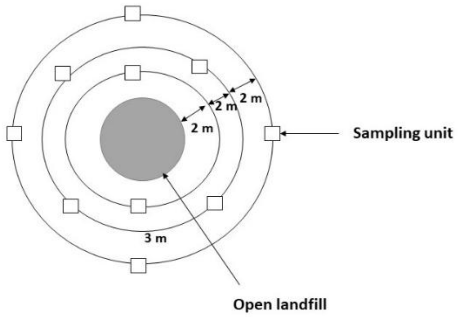

Fig. 1. Layout of soil sampling plots

2.3.1 Sample preparation and digestion

All the samples were dried at 100 – 110 ^{o}C to drive out moisture. On cooling, each sample was sieved through a nylon sieve of 0.2 mm diameter to remove stones, plant residues and obtain a uniform particle size.

Soil samples were digested using dry-ash method according to FAO [12]. One gram of the representative soil sample was weighed into a porcelain crucible and heated on heating mantle to volatilize all organic matter. Two millilitre of concentrated nitric acid was added and evaporate to dryness using a heating mantle. The sample was introduced into a muffle furnace and ashed at 450 ^{o}C for four hours. After ashing, the dish was removed from the muffle furnace and 50 ml of 50 % aqueous hydrochloric acid solution was used to wash out the sample into a 100 ml beaker. The solution was heated gently for 30 minutes for complete de-solution. The solution was allowed to cool and filtered into a 100 ml volumetric flask. The digest was made up to the mark using distilled water. Metals in the sample were determined by Atomic Absorption Spectrophotometry (AAS).

2.3.2 Metal determination

Heavy metals (Pb, Cd, Cu, Cr, Hg, Zn) were analysed by atomic absorption spectroscopy. The concentration of heavy metal in the soil was determined using the formula

$$\text{Metal concentration (mg/kg)} = \frac{Reading\ (mg/L) \times Final\ volume\ (ml)}{Initial\ sample\ weight\ (g)}$$

3. RESULTS

3.1 Soil Physicochemical Properties

The physical and chemical properties of the soil collected within the dumpsite were investigated and presented in Table 1. The parameters tested include; soil pH, cation exchange capacity, soil organic matter, soil texture (clay, silt, and sand), nitrogen, phosphorous, potassium, total organic carbon, and soil moisture content. The result indicated that the soil pH of samples from the dumpsite were reduced compared to the control; samples collected close to the center of the dumpsite showed more lower pH levels [S1 (5.65±0.15), S2 (5.75±0.20), S3 (5.82±0.15), and S4 (5.86±0.31)]. The cation exchange capacity was lowest in S1 and S2 (11.8±0.10 and 11.9±0.15 respectively) and highest in S9, S10, and control (26.5±0.40, 26.5±0.40, and 28.9±0.44 respectively). Although, no significant difference was observed in the mean cation exchange capacity of S9, S10, and control.

The soil organic matter was highest in S1 to S4 (ranging from 388.2 to 376.1 g/kg) and varied significantly from the control soil organic matter

(138.1 g/kg). The clay and silt content of the soil samples increased progressively from S1 to S10 [ranging from 5.2 % to 23.2 % (for clay) and 14.6 % to 20.8 % (for silt)]. There was significant difference in the level of silt observed in the control compared to the silt content of the samples from the dumpsite. The percentage of sand was highest in S1 (80.2 %) and decreases progressively from S1 to S10 (which sand percentage was 56.0 %). The percentage of sand from samples from dumpsite varied significantly from the percentage of sand observed in the control. The soil textural class of all the soil samples from the dumpsite were sandy-loam, while that of the control was loamy-sand.

The soil minerals; nitrogen, phosphorous, and potassium were observed to be lesser in the soil samples from dumpsite and higher in the control. The level of these minerals increased progressively from S1 to S10 but showed significant differences from the levels observed in the control. The total organic carbon was higher in S8, S9, and S10 (20.5±0.63, 20.7±0.64 and 20.9±0.64 g/kg) compared to the other sites. The level of TOC observed in S8, S9, and S10 were not significantly different from the level of TOC observed in the control. The moisture content of the soil samples from the dumpsite were observed to be lowest in S1, S2, S3, and S4 (8.12±0.85, 8.15±0.80, 8.86±0.79, and 8.87±0.80 respectively) and higher in S7, S8, S9 and S10 (11.7±1.12, 11.8±1.10, 11.8±1.10, and 11.9±1.00 respectively); but varied significantly from the soil moisture content observed in the control (21.8±1.24).

3.2 Assessment of Metal Concentration in Soil Samples

The level of heavy metals (Pb, Cd, Cu, Cr, Hg and Zn) in the soil samples collected from locations S1 to S10 of the dumpsite were investigated for the months of November, December, and January. The findings are represented in Table 1 to 3.

3.2.1 Metal accumulation for the month of November

The result showed that the concentrations of Pb, Cd, Hg, and Zn were above WHO permissible limit (100 mg/kg, 0.35 mg/kg, 0.03 mg/kg, and 300 mg/kg respectively). The concentration of Cu was within the WHO permissible limit (100 mg/kg) for soil samples from S1; while soil samples from sites S2 to S10 showed lesser concentrations of Cu which were below WHO permissible limit (100 mg/kg). In the soil samples from sites S1, S2, S3, and S4; it was observed that the concentration of Cr was slightly above WHO permissible limit (70 mg/kg). The concentration of Cr observed in soil samples from sites S5 to S10 were below WHO permissible limit.

The concentration of metals was observed to decrease progressively form site 1 to site 10. The concentration of Pb in soil samples from S1 and S2 were the highest (131.2 mg/kg for both sites) compared to the other samples. The level of Cd was observed to fall within the range of 5.83 to 5.57 mg/kg. The soil samples from site 1 showed the highest concentration of Cd (5.83 mg/kg) while the soil samples from site 10 showed the least concentration of Cd (5.57 mg/kg). The concentration of Cu observed in the soil samples from the various sites within the dumpsite were within 100.2 mg/kg to 86.0 mg/kg. Although, these concentrations (of Cu) were with the WHO permissible limit. Zn concentration was the highest compared to the other metals investigated. Soil samples from site 1 to 10 showed Zn concentration of 368.1 to 329.2 mg/kg.

3.2.2 Metal accumulation for the month of December

The concentrations of metals observed in all the soil samples from the various locations within the dumpsite were below the concentrations observed in soil samples collected in the month of November. The level of Pb was observed to be highest in soil samples from location S1 (128.5 mg/kg), and decreases progressively from S1 to S10. The least concentration of Pb was observed in soil samples from S10 (115.8 mg/kg). The concentration of Pb in all the soil samples from the various locations within the dumpsite were above the WHO permissible limit (100 mg/kg). The level of Cd was highest in soil samples from S1 (5.59 mg/kg), while similar concentration of Cd was observed in soil samples from S9 and S10 (5.32 mg/kg) which was the least level of Cd observed in the soil samples. The concentration of Cd in all the soil samples collected from S1 to S10 were above the WHO permissible limit (0.35 mg/kg).

Table 1. Physicochemical properties of the soil samples collected from the dumpsite and the control sample during the dry season

Parameters	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Control
pH.H_2O	5.65±0.15^{d}	5.75±0.20^{d}	5.82±0.15^{d}	5.86±0.31^{d}	5.96±0.15^{c}	6.15±0.30^{c}	6.24±0.28^{c}	6.68±0.15^{b}	6.68±0.15^{b}	6.76±0.18^{b}	7.20±0.28^{a}
CEC (cmol/kg)	11.8±0.10^{d}	11.9±0.15^{d}	12.0±0.12^{d}	12.6±0.10^{d}	15.2±0.15^{c}	15.6±0.30^{c}	18.9±0.20^{b}	19.2±0.32^{b}	26.5±0.40^{a}	26.5±0.40^{a}	28.9±0.44^{a}
SOM (g/kg)	388.2±4.4^{a}	380.0±4.0^{a}	376.1±4.4^{a}	380.1±4.0^{a}	279.6±3.2^{b}	274.2±3.2^{b}	260.2±3.2^{b}	242.5±3.4^{c}	238.1±3.2^{c}	234.3±3.0^{c}	138.1±3.0^{d}
Clay (%)	5.2±0.24^{d}	6.5±0.24^{d}	18.6±0.91^{b}	11.2±0.64^{c}	11.8±0.64^{c}	15.3±0.71^{b}	16.9±0.70^{b}	20.8±0.81^{a}	20.2±0.85^{a}	23.2±0.80^{a}	21.8±0.78^{a}
Silt (%)	14.6±0.62^{d}	14.0±0.60^{d}	13.7±0.64^{d}	23.3±0.81^{b}	23.0±0.81^{b}	22.3±0.80^{b}	22.0±0.78^{b}	20.9±0.80^{c}	20.9±0.80^{c}	20.8±0.71^{c}	41.8±1.00^{a}
Sand (%)	80.2±1.02^{a}	79.5±1.00^{a}	68.7±1.00^{b}	66.5±1.04^{b}	66.2±1.02^{b}	63.0±0.90^{b}	61.1±0.91^{c}	58.3±0.84^{c}	58.9±0.74^{c}	56.0±0.70^{c}	36.4±0.40^{d}
Textural class	S-L	S-L	S-L	S-L	S-L	S-L	S-L	S-L	S-L	S-L	L-S
N (g kg^{-1})	0.76±0.02^{d}	0.76±0.02^{d}	0.77±0.02^{d}	0.79±0.04^{c}	0.86±0.04^{c}	0.87±0.04^{c}	0.90±0.04^{b}	0.93±0.05^{b}	0.95±0.05^{b}	0.96±0.05^{b}	1.32±0.08^{a}
P (mg kg^{-1})	39.7±2.80^{d}	40.1±2.90^{d}	45.3±3.00^{d}	54.2±3.70^{c}	55.8±3.70^{c}	56.4±3.80^{c}	74.0±5.00^{b}	75.6±5.30^{b}	75.9±5.40^{b}	76.0±5.40^{b}	113.5±7.8^{a}
K (cmol kg^{-1})	0.39±0.03^{d}	0.39±0.03^{d}	0.64±0.05^{c}	0.66±0.05^{c}	0.70±0.05^{c}	0.82±0.11^{b}	0.83±0.10^{b}	0.86±0.11^{b}	0.88±0.13^{b}	0.88±0.13^{b}	1.86±0.15^{a}
TOC (g kg^{-1})	16.7±0.57^{c}	16.8±0.57^{c}	17.9±0.58^{c}	18.2±0.58^{b}	18.7±0.58^{b}	18.9±0.59^{b}	19.0±0.59^{b}	20.5±0.63^{a}	20.7±0.64^{a}	20.9±0.67^{a}	21.6±0.85^{a}
Moisture content (%)	8.12±0.85^{d}	8.15±0.80^{d}	8.86±0.79^{d}	8.87±0.80^{d}	10.2±0.46^{c}	10.2±0.46^{c}	11.7±1.12^{b}	11.8±1.10^{b}	11.8±1.10^{b}	11.9±1.00^{b}	21.8±1.24^{a}

CEC-cation exchange capacity, SOM-soil organic matter, TOC-total organic carbon, S-L-sandy loam, L-S-Loamy sand. Results are in mean±SE. same alphabet in a row are not significantly different (p>0.05) by Duncan New Multiple Range Test (DNMRT)

Table 2. Metal accumulation in soil samples within study area for the month of November

Sites	Pb (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Hg (mg/kg)	Zn (mg/kg)
S1	131.2±3.00^{a}	5.83±1.03^{a}	100.2±4.02^{a}	73.5±3.24^{a}	8.48±2.15^{a}	368.1±5.30^{a}
S2	131.2±2.63^{a}	5.80±1.00^{a}	98.0±3.32^{a}	71.9±3.17^{b}	8.32±2.22^{a}	367.4±6.62^{a}
S3	128.5±2.03^{b}	5.73±1.02^{b}	95.3±4.00^{b}	70.2±3.00^{b}	8.10±1.82^{a}	351.2±5.03^{b}
S4	126.2±3.13^{b}	5.71±0.78^{b}	95.3±4.00^{b}	70.2±3.00^{b}	7.92±2.26^{b}	351.5±6.13^{b}
S5	125.5±3.10^{b}	5.69±1.00^{b}	95.0±3.80^{b}	67.5±3.05^{c}	7.78±2.18^{b}	342.8±6.04^{c}
S6	122.4±3.00^{c}	5.69±1.00^{b}	93.8±3.21^{c}	67.0±3.25^{c}	7.60±1.25^{b}	340.2±5.61^{c}
S7	122.3±3.00^{c}	5.63±1.02^{c}	91.7±4.50^{c}	65.5±3.34^{c}	7.45±1.00^{c}	336.1±5.24^{c}
S8	121.5±2.80^{c}	5.61±0.84^{c}	88.2±3.21^{d}	62.9±3.05^{d}	7.45±1.00^{c}	334.5±6.33^{d}
S9	120.0±2.46^{d}	5.59±1.12^{c}	86.3±3.03^{d}	62.3±3.00^{d}	7.20±1.10^{c}	331.8±5.36^{d}
S10	120.0±2.46^{d}	5.57±1.00^{c}	86.0±4.00^{d}	62.3±3.00^{d}	7.20±1.10^{c}	329.2±5.72^{d}
Control	4.3±0.30	0.00±0.00	6.2±0.42	0.0±0.00	0.00±0.00	82.0±3.72
WHO MAC (2007)	100	0.35	100	70	0.03	300

Results are in mean±SE. Same alphabet in a column are not significantly different ($p<0.05$) by Duncan New Multiple Range Test (DNMRT)

Table 3. Metal accumulation in soil samples within study area for the month of December

Sites	Pb (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Hg (mg/kg)	Zn (mg/kg)
S1	128.5±5.40^{a}	5.59±1.10^{a}	97.3±2.20^{a}	70.5±2.00^{a}	7.98±1.15^{a}	352.3±7.81^{a}
S2	127.0±4.28^{a}	5.56±1.18^{a}	97.0±2.80^{a}	69.8±2.10^{a}	7.80±1.00^{a}	350.1±6.20^{a}
S3	125.5±4.20^{a}	5.50±1.20^{b}	94.8±2.15^{b}	67.8±2.15^{a}	7.65±1.12^{a}	347.1±7.00^{b}
S4	122.5±4.24^{b}	5.47±1.00^{b}	94.3±2.00^{b}	67.2±2.21^{a}	7.43±0.80^{b}	344.2±6.15^{b}
S5	121.3±3.90^{b}	5.43±0.88^{c}	93.0±2.28^{b}	65.7±2.00^{b}	7.32±0.75^{b}	337.5±6.00^{c}
S6	120.0±4.20^{b}	5.40±1.15^{c}	93.0±2.10^{b}	65.0±2.18^{b}	7.30±1.00^{b}	330.0±5.98^{c}
S7	117.5±3.10^{c}	5.39±1.21^{c}	90.2±1.98^{c}	63.1±2.38^{b}	7.19±1.28^{c}	328.5±7.15^{c}
S8	117.5±4.28^{c}	5.37±0.75^{d}	87.8±2.00^{c}	60.8±2.00^{c}	7.10±1.10^{c}	322.1±6.10^{d}
S9	116.2±3.10^{c}	5.32±1.00^{d}	85.5±2.15^{d}	60.3±2.28^{c}	7.08±1.15^{c}	320.5±6.00^{d}
S10	115.8±3.32^{c}	5.32±1.12^{d}	84.6±2.20^{d}	59.6±2.10^{c}	7.01±0.80^{d}	320.5±7.00^{d}
Control	3.8±0.21	0.00±0.00	5.3±0.48	0.0±0.00	0.00±0.00	79.0±3.00
WHO MAC (2007)	100	0.35	100	70	0.03	300

Results are in mean±SE. Same alphabet in a column are not significantly different ($p<0.05$) by Duncan New Multiple Range Test (DNMRT)

Table 4. Metal accumulation in soil samples within study area for the month of January

Sites	Pb (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Hg (mg/kg)	Zn (mg/kg)
S1	119.5±5.40^{a}	5.00±1.10^{a}	90.3±2.20^{a}	63.5±2.00^{a}	5.88±1.15^{a}	310.3±7.81^{a}
S2	117.0±4.28^{a}	4.85±1.18^{a}	87.0±2.80^{a}	62.8±2.10^{a}	5.80±1.00^{a}	308.1±6.20^{a}
S3	116.5±4.20^{a}	4.80±1.20^{b}	84.8±2.15^{b}	62.8±2.15^{a}	5.65±1.12^{a}	304.1±7.00^{b}
S4	114.5±4.24^{b}	4.77±1.00^{b}	84.3±2.00^{b}	62.2±2.21^{a}	4.43±0.80^{b}	304.2±6.15^{b}
S5	112.3±3.90^{b}	4.42±0.88^{c}	83.0±2.28^{b}	55.7±2.00^{b}	4.32±0.75^{b}	287.5±6.00^{c}
S6	112.0±4.20^{b}	4.40±1.15^{c}	83.0±2.10^{b}	55.0±2.18^{b}	4.30±1.00^{b}	286.0±5.98^{c}
S7	108.5±3.10^{c}	4.39±1.21^{c}	71.2±1.98^{c}	53.1±2.38^{b}	3.19±1.28^{c}	285.5±7.15^{c}
S8	107.5±4.28^{c}	3.37±0.75^{d}	70.8±2.00^{c}	42.8±2.00^{c}	3.10±1.10^{c}	262.1±6.10^{d}
S9	106.2±3.10^{c}	3.35±1.00^{d}	65.5±2.15^{d}	42.3±2.28^{c}	3.08±1.15^{c}	260.5±6.00^{d}
S10	105.8±3.32^{c}	3.34±1.12^{d}	64.6±2.20^{d}	41.6±2.10^{c}	3.01±0.80^{d}	260.5±7.00^{d}
Control	3.6±0.21	0.00±0.00	4.8±0.48	0.0±0.00	0.00±0.00	59.0±3.00
WHO MAC (2007)	100	0.35	100	70	0.03	300

Results are in mean±SE. Same alphabet in a column are not significantly different ($p<0.05$) by Duncan New Multiple Range Test (DNMRT)

The concentration of Cu observed in all the soil samples from all the locations within the dumpsite (S1 to S10) were below the WHO permissible limit (100 mg/kg). S1 showed the highest concentration of Cu (97.3 mg/kg) while soil samples from S10 had the least concentration of Cu (84.6 mg/kg). The concentration of Cr observed in the soil samples were below WHO permissible limit (70 mg/kg), except for soil samples collected from S1 (70.5 mg/kg) which was slightly higher than the WHO permissible limit. The concentration of Hg observed in soil samples from the various locations within the dumpsites were above the WHO permissible limit (0.03 mg/kg). The highest Hg concentration was observed in soil samples from S1 (7.98 mg/kg), while the least Hg concentration was observed in soil samples from S10 (7.01 mg/kg). Zn concentrations observed in all the soil samples were above WHO permissible limit (300 mg/kg). The concentration of Zn in the control soil sample (79.0 mg/kg) was below WHO permissible limit.

3.2.3 Metal accumulation for the month of January

The result revealed that the concentrations of Pb in all the sites were slightly above WHO permissible limit (110 mg/kg); the concentration of Pb ranged from 119.5 mg/kg to 105.8 mg/kg in soil samples from site 1 to site 10 respectively. The concentration of Cd observed was above the WHO permissible limit (0.32 mg/kg). the highest concentration of Cd was observed in soil samples from S1 (5.00 mg/kg) whereas the least concentration of Cd was observed in soil samples from S10 (3.34 mg/kg). The concentration of Cu was observed to be below the permissible limit (100 mg/kg) in all the soil samples from the dumpsite. Likewise, Cr concentrations were observed to be below WHO permissible limit (70 mg/kg).

The level of Hg observed in all the soil samples from the dumpsite were above the WHO permissible limit (0.03 mg/kg). The highest Hg level was observed in soil sample from S1 (5.88 mg/kg), while the lowest concentration of Hg was observed in soil samples from S10 (3.01 mg/kg). The concentration of Zn observed in soil samples from S1 to S4 were above WHO permissible limit (300 mg/kg); ranging from 310.3 mg/kg (S1) to 304.2 mg/kg (S4). Whereas, the concentration of Zn in soil samples from S5 to S10 (287.5 mg/kg to 260.5 mg/kg respectively) were below WHO permissible limit. The concentrations of the metals investigated in the control were all below WHO permissible limit. Cadmium, chromium, and mercury were not observed in the control.

3.2.4 Comparative study of the three months

The mean concentrations of heavy metal observed in the three months (November, December, January) of soil collection from the dumpsite were represented inn Fig. 2. Based on the result, it can be seen that the levels of heavy metal decreased progressively from November to January. The highest concentration of heavy metals was observed in soil samples collected in the month of November while the least concentration of heavy metals were observed in soil samples collected in the month of January (Fig. 2).

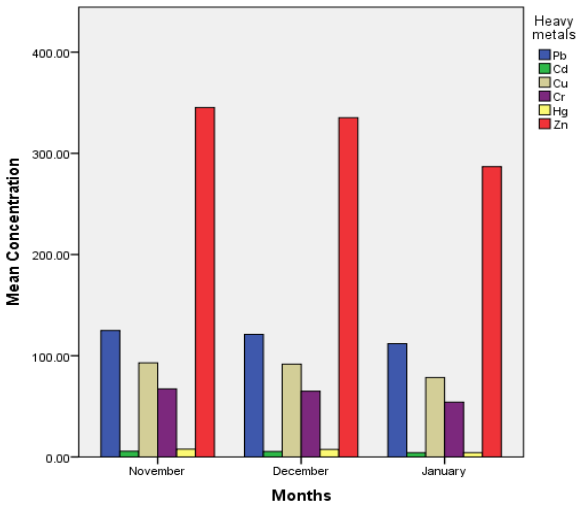

Fig. 2. Chart showing the comparison in heavy metal concentration of soil samples collected within the three months

4. DISCUSSION

In this present study, the physicochemical properties and concentrations of Pb, Cd, Cu, Cr, Hg, and Zn were assessed in different sites within the dumpsite. The study revealed the presence of all the test metals in the soil samples during the dry season. The metals were more concentrated in soil samples from sites closer to the center of the dumpsite (S1, S2, and S3); but decreased gradually from S4 to S10 as the distance from the center increased. That is to say, the concentration of the metals investigated was observed in the following order S1 > S2 > S3 > S4 > S5 > S6 > S7 > S8 > S9 > S10. Most of the metals investigated during the dry season (Pb, Cd, Hg, and Zn) were observed to be above WHO permissible limit (100, 0.35, 0.03, and 300 mg/kg respectively). Whereas the metals Cu and Cr were below WHO permissible limit (100 and 70 mg/kg respectively). The concentrations of these metals were observed to decrease during the dry season (from November to January). Furthermore, the concentration of the heavy metals was observed in the following order Zn > Pb > Cu > Cr > Hg > Cd. This is in line with Bongoua-Devisme et al. [13] findings, which identified the level of heavy metals in soil collected from dumpsite in the following order; Zn > Pb > Cr > Ni > Cd > As > Cu > Se. This study has indicated that the soil from the dumpsite are contaminated with heavy metals which have adversely affected the soil quality. According to Bongoua-Devisme et al. [13], the soil is continuously contaminated by human activities, which often involves the accidental release of chemicals or the improper disposal of hazardous wastes.

These heavy metals when present in the soil affect the soil physicochemical properties, in severe cases, making the soil unsuitable for agriculture. According to Cardoso [14], soil contaminants such as heavy metals affects the soil quality, which influences the soil basic functions (such as: retaining water, promoting biodiversity, supporting agriculture, and resisting flooding, erosion, and landslides). The result from the physicochemical investigation showed that the pH of the soil samples from the dumpsite were slightly acidic (5.65 – 6.76). There was also reduction in the soil cation exchange capacity (11.8 cmol/kg) compared to the control sample (28.9 cmol/kg). The soil organic matter (SOM) was observed to be very high (ranging from 388.2 g/kg to 234.3 g/kg) compared to the control. The high level of SOM may be attributed to the reduction of the pH of the soil. This is in line with Kekane et al. [15], that the presence of higher content of organic matter in the soil can be a possible reason for lowering of the pH of that soil. The textural class of the soil was observed to be sandy-loam which is not usually suitable for agricultural crop production. The mineral content (nitrogen, phosphorous, and potassium) of the soil samples were also reduced, so as the moisture content (Table 1). According to Chen et al. [16], Maintenance of soil quality is critical for ensuring the sustainability of the environment and the biosphere.

The findings from this research will enlighten the general public on the presence of heavy metals in polluted soil from open dumpsite and the consequent adverse effect on human health and the environment. The government and other agencies (involved in environmental protection and ecosystem preservation) can use the information from this research to create effect strategies for curbing open dumpsite practices within the State. Also, proper waste management system and waste recycling can be established to mitigate the hazardous effect of waste pollution in the environment.

5. CONCLUSION

The results from the research indicated the presence of heavy metals in the soils from the dumpsite which also affects the soil physicochemical properties negatively. This leads to the reduction of the soil quality; making the soil incapable of its natural functions. Considering the hazard these metals poses to human health and the environment at large proper waste management strategies is advised. Based on the findings from this study, it is recommended that further research study is carried out on this dumping site to determine the exact boundaries of the contaminated area and the risk faced by the people living there.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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