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Determination of Heavy Metals and Organic Pollutants in Soil Near Dumpsites in Communities in Delta State, Nigeria: Implications for Human Health and the Environment

*[1]Osemele Wilson, [2]Ajokporise Alfred

[1]Department of Geology,

Federal University of Petroleum Resources, Effurun, Delta State, Nigeria.

[2]Environmental Management and Toxicology,

Federal University of Petroleum Resources Effurun, Delta State, Nigeria.

*Corresponding Author: Osemelewilson1986@gmail.com

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ABSTRACT

This study assessed the physico-chemical characteristics of soils from two dumpsites at Agaga and Ugborikoko communities, in Delta State, Nigeria. Soil samples were collected at depths of 0–10, 10–20, 20–30, and 30–40 cm, representing topsoil and subsoil, alongside control samples from an uncontaminated site. The samples were digested with *aqua regia* and analyzed using Atomic Absorption Spectrophotometry (AAS), while the data were subjected to one-way Analysis of Variance (ANOVA). Soil pH ranged from 3.30 to 6.10, indicating acidic conditions. Heavy metal concentrations were in mg/kg: Mn (13.1–20.5), As (4.4–12.3), Zn (6.0–18.4), Cd (0.20–3.51), Cr (0.05–1.61), Pb (10.7–19.5), Ni (2.6–16.4), and Hg (0–0.008). Concentrations of the metals were consistently higher than those of the control samples across all depths. ANOVA ($p < 0.05$) revealed significant differences in the concentrations of Mn, As, Cd, Cr, and Ni between the dumpsites and the control site. The findings indicated that indiscriminate solid waste disposal has significantly degraded soil quality, resulting in heavy metal contamination and potential environmental pollution in the study area.

Keywords: Contamination, dumpsites, soil, organic pollutants, heavy metals

INTRODUCTION

The rapid growth of the global population, urbanization, industrialization, and changing consumption patterns have significantly increased the generation of municipal solid waste worldwide. In many developing countries, particularly in sub-Saharan Africa, inadequate waste management infrastructure has resulted in the indiscriminate disposal of domestic, commercial, industrial, and healthcare wastes in open dumpsites. These poorly managed disposal sites

constitute major sources of environmental pollution because they generate leachates and gaseous emissions that contaminate surrounding soils, surface water, groundwater, and the atmosphere through infiltration, runoff, volatilization, and wind dispersion [1–3].

Soil is a fundamental natural resource that supports agricultural production, nutrient cycling, water filtration, biodiversity conservation, and numerous ecosystem functions. However, soil quality is increasingly threatened by anthropogenic activities such as industrialization, mining, petroleum exploration, transportation, agricultural practices, and indiscriminate waste disposal. Open dumpsites receive heterogeneous wastes, including household refuse, plastics, electronic waste, batteries, scrap metals, paints, pharmaceuticals, pesticides, construction debris, hospital waste, and industrial residues. As these materials undergo physical, chemical, and biological degradation, they release leachates enriched with inorganic and organic contaminants that migrate into surrounding soils and groundwater [4–7].

Heavy metals are among the most persistent environmental contaminants because they are non-biodegradable, resistant to chemical degradation, and capable of remaining in soils for prolonged periods. Metals such as lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), arsenic (As), mercury (Hg), copper (Cu), zinc (Zn), manganese (Mn), cobalt (Co), and iron (Fe) occur naturally in soils; however, their concentrations are substantially elevated by anthropogenic activities including municipal waste disposal. Continuous accumulation of these metals in soils may exceed natural background concentrations, thereby posing significant environmental and ecological risks [8–10]. The environmental behaviour of heavy metals depends largely on soil physicochemical properties, including pH, organic matter content, cation exchange capacity, soil texture, mineralogical composition, and oxidation-reduction conditions. Acidic soils generally increase the mobility and bioavailability of many metals, enhancing their uptake by plants and facilitating their transport into groundwater systems. Consequently, contaminated soils may continue to act as long-term sources of pollution long after waste disposal has ceased [11,12].

In addition to heavy metals, municipal solid wastes contain numerous organic contaminants, including petroleum hydrocarbons (TPHs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, phthalates, phenolic compounds, volatile organic compounds (VOCs), and other persistent organic pollutants (POPs). These contaminants originate from discarded petroleum products, plastics, solvents, electronic waste, industrial

chemicals, and household products. Many are persistent, lipophilic, resistant to degradation, and capable of accumulating in soils and sediments, thereby posing long-term ecological and human health risks [13].

The simultaneous occurrence of heavy metals and organic pollutants in dumpsite soils creates complex contamination scenarios that adversely affect soil quality and ecosystem functioning. Heavy metals may interact with soil organic matter, influencing their mobility and bioavailability, while organic contaminants may alter microbial communities responsible for nutrient cycling and natural attenuation processes. These interactions may reduce soil fertility, inhibit plant growth, diminish microbial diversity, and compromise ecosystem productivity [8,11].

Human exposure to contaminants originating from dumpsites occurs through several pathways, including ingestion of contaminated soil particles, inhalation of contaminated dust, dermal contact, consumption of crops grown on contaminated soils, and drinking groundwater polluted by landfill leachates. Chronic exposure to elevated concentrations of heavy metals has been associated with neurological disorders, kidney and liver damage, cardiovascular diseases, reproductive disorders, developmental abnormalities, immune dysfunction, and increased cancer risk. Similarly, many persistent organic pollutants possess carcinogenic, mutagenic, teratogenic, and endocrine-disrupting properties that constitute significant public health concerns [14–16].

Several studies conducted in Nigeria have reported elevated concentrations of heavy metals in soils surrounding municipal dumpsites and industrial areas. Investigations in Lagos, Kano, Awka, southeastern Nigeria, and other urban centres have consistently demonstrated significant enrichment of lead, cadmium, chromium, nickel, copper, and zinc attributable to indiscriminate waste disposal and related anthropogenic activities [17–21].

Delta State is one of Nigeria's major industrial and commercial centres, characterized by rapid urbanization, petroleum exploration, manufacturing activities, transportation, and increasing municipal waste generation. Many communities rely on open dumpsites that lack engineered liners, leachate collection systems, and environmental monitoring programmes. Consequently, surrounding soils are susceptible to contamination by hazardous substances capable of impairing agricultural productivity, degrading groundwater quality, reducing ecosystem integrity, and threatening public health. Despite growing environmental concerns, comprehensive information

on the combined occurrence of heavy metals and organic pollutants in soils surrounding community dumpsites in Delta State remains limited.

Most previous studies have focused primarily on heavy metal contamination, with relatively few investigations evaluating both inorganic and organic contaminants simultaneously. Such information is essential for pollution assessment, ecological risk evaluation, environmental monitoring, waste management planning, and the formulation of effective remediation strategies and evidence-based environmental policies.

Therefore, this study aims to determine selected heavy metals and organic pollutants in soils collected around community dumpsites in Delta State, Nigeria.

STUDY AREA

The study area is located in the Ugborikoko, west of Warri town. It is about 10 km away from the coast and lies on latitude N5º53'30'',N5º53'30'' and longitude E5º75'80",E5º77'50" (Figure 1). The geographical position coordinates of the sampled locations were identified and mapped using global position system (GPS). Two municipal solid waste dumpsites each in Ugborikoko, Warri, Delta state were considered. The first dumpsite, the largest in Ugborikoko community is located behind the Old Warri Airport which is situated in a large pit that has encroached into the nearby stream. The second dumpsite is located in Agaga community by First Marine Gate, Warri, Delta State. Both dumpsites are surrounded by residential houses, churches, schools, clinics and offices. The area is easily accessible through a series of interconnecting minor roads, footpaths and a few major roads, with an uneven distribution of topography (fairly lowlands to highlands).

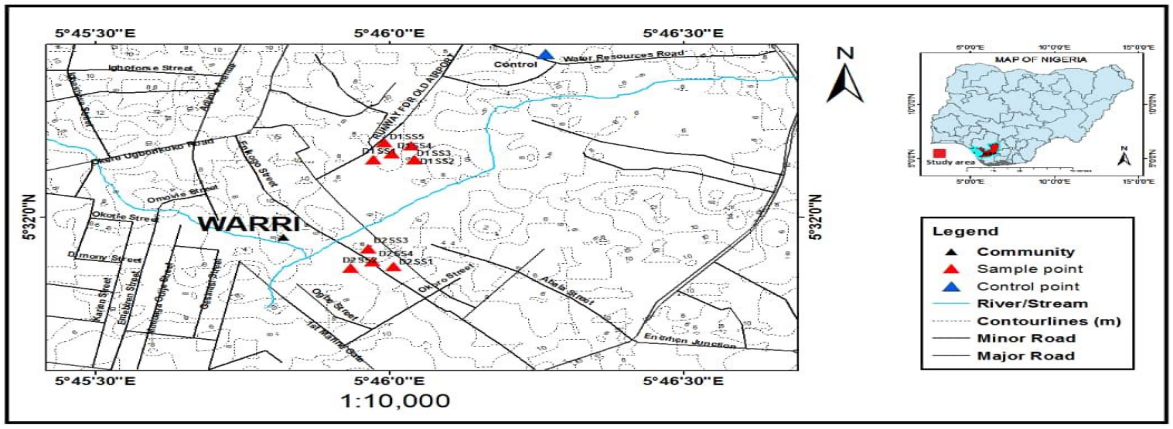

Figure 1: The study area in Ugborikoko, west of Warri town, Nigeria

Geology of the Study Area

The study area (Fig. 2) is underlain by the deposits of the quaternary coastal plain sands and alluvium deposits [17]. These formations consist of medium-coarse grained sand, clay lenses (coastal plain sands), and gravel, sand, clay and silt (Alluvium deposits). In the Alluvium deposits, a river/stream cuts across it which transports sediments to the Escravos River which is then deposited in the deposited in the Gulf of Guinea. The coastal plain sands formation generally does not exceed 120 metres in thickness and it is predominantly unconfined [18]. Lithological, it consists of sands, clays and silt. This plain has swamps that are commonly flooded during the peak of the rainy season.

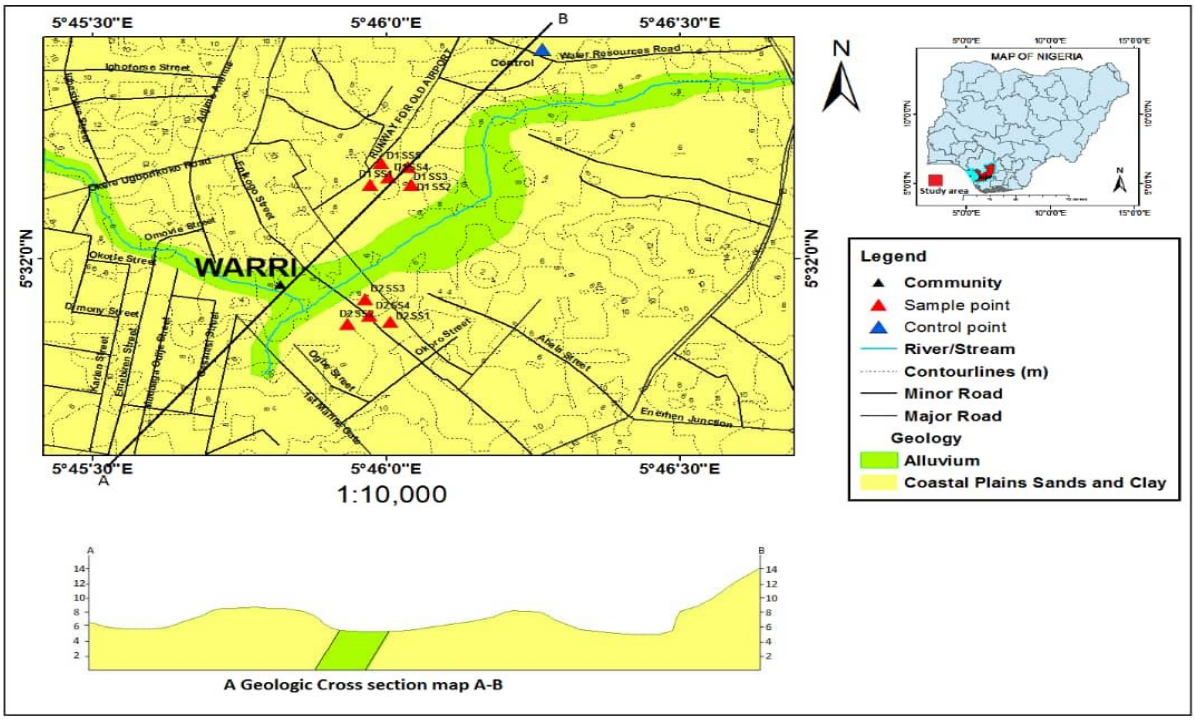

Figure 2: The geology of the study area

MATERIALS AND METHODS

Soil sampling and preparation

Composite soil samples from top soils at 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm depth were collected at nine sampling locations randomly from two different dumpsites. While a control sample (1 km away from the dumpsites; a pristine environment devoid of anthropogenic activities with similar lithology) was also collected. Each composite sample was then bulked down to one

representative sample. The soil samples from each site were kept in polyethylene soil bags labeled appropriately and transported to the laboratory, spread out on sheets of paper, and air-dried in a dust free environment at room temperature (29 °C) for a period of seven days. The soil samples were then pulverized with a porcelain mortar and pestle; and later sieved through a 2 mm mesh-sized sieve. The sieved soil samples were analyzed to determine pH, EC, organic matter, cations, anions, lead, manganese, copper, zinc, chromium, nickel, cadmium, iron and mercury using standard methods as specified by APHA (2005). The samples were air-dried for a period of two weeks in a well ventilated space [20].

Data Analysis

The data derived from various determinations was subjected to statistical analysis including mean, range, standard deviation and one-way analysis of variance (ANOVA) at $P<0.05$ (95%) test of significance. Statistical analysis is very useful in providing knowledge, and assists in interpretation of data. It is widely applied in recent times to investigate the heavy metal concentration, accumulation and distribution in soils and groundwater [1]. A statistical analysis of physico-chemical results in the soil and groundwater samples in the study area was performed using one-way analysis of variance. It determined if the means of the heavy metal content in the soils varies within the sampled locations. Finally, descriptive statistics was performed to ascertain the measures of dispersion (mean, range, standard error, and standard deviation) of the physic-chemical content. All statistical treatment mentioned above were performed using IBM-SPSS 16.0 software and Microsoft Excel (2007 version).

RESULTS AND DISCUSSION

Physicochemical and trace metal parameters analyzed from two dumpsites soil samples were hydrogen potential, electrical conductivity, organic matter, sodium, potassium, calcium, magnesium, sodium, chloride, phosphate, sulphate, manganese, arsenic, zinc, cadmium, chromium, lead, nickel and mercury. The results are presented in Table 1.

Table 1: Physicochemical parameters of soil samples in the study area.

S/N	Parameters	Units	Depth (cm)	DI-SS1	DI-SS2	DI-SS3	DI-SS4	DI-SS5	DII-SS1	DII-SS2	DII-SS3	DII-SS4	Control mean
1	pH		0-10	5.1	3.8	6.1	4.6	4.1	4.6	5.1	5.1	4.3	5.2
			10-20	4.8	3.7	5.8	4.6	4.0	4.2	4.8	4.7	4.1	4.7
			20-30	4.4	3.9	3.7	5.2	4.3	4.6	4.8	5.1	4.2	4.9
			30-40	3.7	3.7	3.3	4.3	4.1	4.4	4.4	4.2	3.9	4.3
2	EC	µS/cm	0-10	1260	100	1560	1660	490	2370	150	5590	900	1250
			10-20	1760	300	1640	1350	390	670	450	5780	160	2710
			20-30	1800	760	770	310	690	760	760	6650	860	240
			30-40	1760	500	650	270	550	760	650	6560	780	190
3	Total Organic Matter	%	0-10	1.44	1.87	1.80	0.82	3.24	1.22	2.45	2.16	2.57	3.89
			10-20	1.10	1.15	1.25	0.17	2.54	0.62	2.16	1.73	1.80	3.47
			20-30	3.60	3.53	4.89	3.60	1.97	4.30	3.54	5.24	4.06	3.43
			30-40	3.48	3.40	3.38	2.76	1.83	3.74	3.05	4.13	4.03	3.15
4	Potassium	mg/kg	0-10	6.10	1.90	6.30	7.54	8.13	5.16	8.03	3.80	7.77	6.07
			10-20	4.01	2.20	5.75	6.10	7.72	3.62	5.90	1.83	7.64	4.14
			20-30	2.59	2.39	1.16	3.71	2.99	4.05	5.14	1.11	2.18	2.36
			30-40	2.61	2.37	1.13	3.67	2.87	4.03	5.08	1.08	2.11	2.32
5	Magnesium	mg/kg	0-10	8.93	4.10	9.73	11.81	9.75	7.59	10.80	6.04	10.78	6.94
			10-20	7.10	4.03	9.01	9.58	9.50	7.12	9.56	5.80	10.01	6.30
			20-30	5.12	7.80	5.46	5.14	5.18	4.54	6.60	4.14	4.89	4.30
			30-40	5.60	7.89	5.34	5.98	5.10	4.46	6.13	4.03	4.47	4.11
6	Sodium	mg/kg	0-10	7.40	6.36	9.51	10.57	7.94	8.32	10.29	5.51	8.88	7.90
			10-20	5.23	6.04	8.80	9.38	7.82	6.70	6.78	4.90	8.69	5.80
			20-30	4.62	9.19	6.08	6.55	1.53	0.88	7.86	5.13	3.55	6.27
			30-40	4.59	9.11	6.06	6.51	1.51	0.83	7.27	4.48	3.45	6.08
7	Calcium	mg/kg	0-10	10.80	8.32	10.26	12.01	12.56	10.54	13.10	7.77	7.77	11.30
			10-20	9.58	8.10	11.66	10.73	12.35	8.08	10.01	6.83	7.64	8.55

			20-30	6.32	12.4	7.50	8.40	9.79	6.58	15.6	6.13	5.32	8.3
			30-40	7.54	12.1	7.46	8.12	9.50	6.50	14.4	5.64	5.25	8.2
8	Chloride	mg/kg	0-10	179	209	1695	1110	380	1150	189	119	150	1340
			10-20	140	123	1990	915	297	720	151	92	104	700
			20-30	630	170	730	71	185	741	250	192	302	86
			30-40	620	230	151	83	141	752	214	196	293	68
9	Sulphate	mg/kg	0-10	304	712	1811	990	428	845	314	310	137	1204
			10-20	280	306	1312	810	314	706	219	174	223	1310
			20-30	256	316	1004	134	324	784	128	161	716	104
			30-40	224	296	1028	134	314	602	116	809	714	80
10	Phosphate	mg/kg	0-10	21.5	14.5	35.4	34.5	24.2	24.8	34.8	24.8	33.6	24.9
			10-20	18.8	13.1	34.4	32.4	13.2	24.5	33.7	24.5	22.6	23.4
			20-30	85.2	44.4	45.2	70.0	39.6	32.0	30.8	26.0	50.8	33.2
			30-40	78.4	40.4	42.8	64.8	29.6	27.6	22.8	21.6	41.6	32.4

TWO-WAY ANOVA

Tables 2 and 3 show the means of soil samples from the dumpsites of ANOVA used to compare control samples.

Table 2: Summary of physico-chemical parameters of soil samples and control in the study area.

Parameters	Mean	Std.E	Std.D	Min	Max	Control Mean
$pH_{(0\text{-}10cm)}$	4.76	0.23	0.69	3.80	6.10	5.2
$pH_{(10\text{-}20cm)}$	4.52	0.21	0.62	3.70	5.80	4.7
$pH_{(20\text{-}30cm)}$	4.47	0.17	0.51	3.70	5.20	4.9
$pH_{(30\text{-}40cm)}$	4.0	0.1	0.4	3.3	4.4	4.3
$EC_{(0\text{-}10cm)}$	1564.4	561.5	1684.4	100.0	5590.0	1250
$EC_{(10\text{-}20cm)}$	1388.9	584.2	1752.7	160.0	5780.0	2710
$EC_{(20\text{-}30cm)}$	1484.4	659.0	1977.0	310.0	6650.0	240
$EC_{(30\text{-}40cm)}$	1386.7	661.2	1983.7	270.0	6560.0	190
$OM_{(0\text{-}10cm)}$	2.0	0.2	0.7	0.8	3.2	3.89
$OM_{(10\text{-}20cm)}$	1.4	0.2	0.7	0.2	2.5	3.47

$OM_{(20-30cm)}$	3.9	0.3	0.9	2.0	5.2	3.43
$OM_{(30-40cm)}$	3.3	0.2	0.7	1.8	4.1	3.15
$K_{(0-10cm)}$	6.1	0.7	2.1	1.9	8.1	6.07
$K_{(10-20cm)}$	4.97	0.72	2.17	1.83	7.72	4.14
$K_{(20-30cm)}$	2.81	0.44	1.32	1.11	5.14	2.36
$K_{(30-40cm)}$	2.77	0.44	1.32	1.08	5.08	2.32
$Mg_{(0-10cm)}$	8.84	0.83	2.50	4.10	11.81	6.94
$Mg_{(10-20cm)}$	7.97	0.69	2.07	4.03	10.01	6.3
$Mg_{(20-30cm)}$	5.43	0.37	1.12	4.14	7.80	4.3
$Mg_{(30-40cm)}$	5.44	0.39	1.16	4.03	7.89	4.11
$Na_{(0-10cm)}$	8.31	0.57	1.71	5.51	10.57	7.9
$Na_{(10-20cm)}$	7.15	0.54	1.61	4.90	9.38	5.8
$Na_{(20-30cm)}$	5.04	0.92	2.75	0.88	9.19	6.27
$Na_{(30-40cm)}$	4.87	0.90	2.69	0.83	9.11	6.08
$Ca_{(0-10cm)}$	10.35	0.68	2.03	7.77	13.10	11.3
$Ca_{(10-20cm)}$	9.44	0.64	1.91	6.83	12.35	8.55
$Ca_{(20-30cm)}$	8.67	1.13	3.39	5.32	15.60	8.3
$Ca_{(30-40cm)}$	8.50	1.01	3.03	5.25	14.40	8.2
$Cl_{(0-10cm)}$	575.67	194.99	584.98	119.00	1695.00	1340
$Cl_{(10-20cm)}$	503.56	210.77	632.32	92.00	1990.00	700
$Cl_{(20-30cm)}$	363.44	87.30	261.91	71.00	741.00	86
$Cl_{(30-40cm)}$	297.78	76.77	230.32	83.00	752.00	68
$SO_{4(0-10cm)}$	650.11	173.45	520.34	137.00	1811.00	1204
$SO_{4(10-20cm)}$	482.67	127.90	383.69	174.00	1312.00	1310
$SO_{4(20-30cm)}$	424.78	108.14	324.43	128.00	1004.00	104
$SO_{4(30-40cm)}$	470.78	109.07	327.22	116.00	1028.00	80
$PO_{4(0-10cm)}$	27.57	2.45	7.35	14.50	35.40	24.9
$PO_{4(10-20cm)}$	24.13	2.73	8.20	13.10	34.40	23.4
$PO_{4(20-30cm)}$	47.11	6.45	19.35	26	85.2	33.2
$PO_{4(30-40cm)}$	41.07	6.44	19.32	21.6	78.4	32.4

Table 3: Summary of trace parameters of soil samples and control in the study area.

Parameters	Mean	Std.E	Std.D	Min	Max	Control Mean
$Mn_{(0-10cm)}$	16.96	0.58	1.75	14.3	20.5	10.1
$Mn_{(10-20cm)}$	17.02	1.04	3.13	14.1	25.1	11.2
$Mn_{(20-30cm)}$	14.76	0.73	2.20	13.1	18.7	11.6
$Mn_{(30-40cm)}$	14.38	0.55	1.65	13.3	18.4	12.2
$As_{(0-10cm)}$	8.73	0.75	2.25	5.4	12.3	5.3
$As_{(10-20cm)}$	8.76	0.70	2.09	5.3	11.8	5.5
$As_{(20-30cm)}$	6.27	0.56	1.67	4.4	8.9	5.9
$As_{(30-40cm)}$	6.70	0.65	1.95	4.7	9.4	4.9
$Zn_{(0-10cm)}$	13.11	1.21	3.63	8	18.1	11
$Zn_{(10-20cm)}$	13.93	1.01	3.04	8.4	18.4	10.8
$Zn_{(20-30cm)}$	10.35	0.94	2.81	6.04	13.9	9.9
$Zn_{(30-40cm)}$	10.31	0.93	2.80	6	13.6	9.6
$Cd_{(0-10cm)}$	0.86	0.31	0.94	0.2	2.6	0.33
$Cd_{(10-20cm)}$	0.81	0.29	0.86	0.17	2.4	0.3
$Cd_{(20-30cm)}$	1.12	0.46	1.37	0.2	3.51	0.14
$Cd_{(30-40cm)}$	1.13	0.45	1.34	0.18	3.43	0.18
$Cr_{(0-10cm)}$	1.28	0.16	0.47	0.05	1.56	0.1
$Cr_{(10-20cm)}$	1.14	0.16	0.49	0.05	1.48	0.12
$Cr_{(20-30cm)}$	1.56	0.01	0.04	1.5	1.61	1.54
$Cr_{(30-40cm)}$	1.53	0.01	0.04	1.47	1.58	1.52
$Pb_{(0-10cm)}$	15.23	1.02	3.05	11.2	19.5	17.7
$Pb_{(10-20cm)}$	14.37	0.92	2.76	11.5	19.4	17.2
$Pb_{(20-30cm)}$	12.83	0.48	1.43	10.7	15.4	12.9
$Pb_{(30-40cm)}$	12.72	0.43	1.30	10.9	15.3	12.6
$Ni_{(0-10cm)}$	10.08	1.37	4.10	5	16.4	8.6
$Ni_{(10-20cm)}$	9.46	1.17	3.50	5.2	15.8	7.9
$Ni_{(20-30cm)}$	5.07	0.81	2.43	2.6	8.8	5.4

$Ni_{(30-40cm)}$	5.03	0.82	2.45	2.7	9.3	5.6
$Hg_{(0-10cm)}$	0.01	0.00	0.00	0.003	0.008	0.005
$Hg_{(10-20cm)}$	0.00	0.00	0.00	0.001	0.005	0.004
$Hg_{(20-30cm)}$	0.00	0.00	0.00	0.001	0.008	0.002
$Hg_{(30-40cm)}$	0.00	0.00	0.00	0.001	0.005	0.001

Hydrogen potential

There was no significant difference between dumpsites I, II and control both at topsoil and subsoil depths. The concentrations of hydrogen potential ranged between 3.30 and 6.10 in the dumpsites and at depths of topsoil and subsoil respectively {Table 2} The maximum value for pH was observed at topsoil (0-10 cm) at dumpsite-1. Most of the topsoil and subsoil concentration values were below control values except the topsoil depths (0-10 and 10-20 cm) in dumpsite-1 the exceeded that of control value. Hence, the soils could be said to be acidic owing to their low pH concentration values which could be attributed to anthropogenic activities (leaching of trace metals into the soil from waste materials) deposited in the studied locations. The distribution of hydrogen potential in soil across the study area is presented in Figure 3

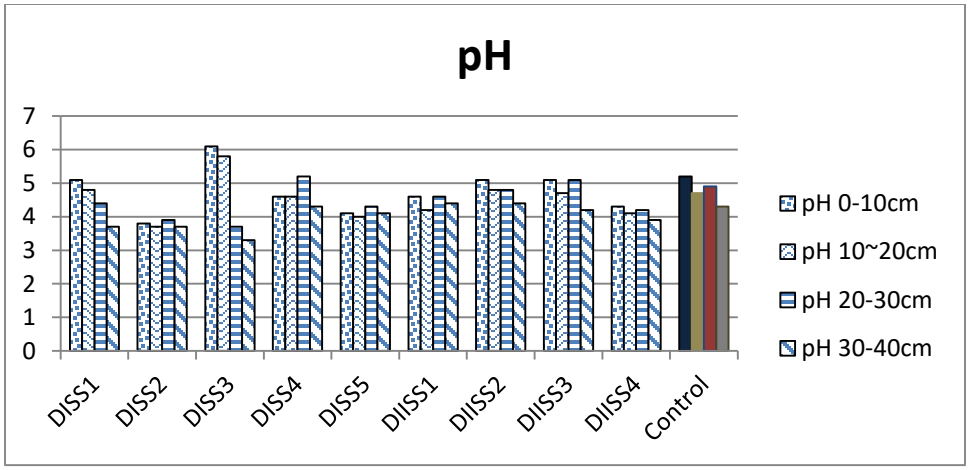

Figure 3: Comparative hydrogen Ion (pH) concentration in soil samples and control in dumpsites I and II within the study area.

Electrical Conductivity, Organic Matter and Sodium

There was no significant difference in electrical conductivity organic matter concentration between dumpsites I, II and control both at topsoil and subsoil depths.

The means observed for electrical conductivity concentration in soil samples were recorded as 1564.4 and 1388.9 µS/cm at topsoil depth of 0 – 10 cm and 10 – 20 cm and 1484.4 and 1386.7 µS/cm at subsoil depth of 20 – 30cm and 30 – 40 cm respectively. While the means observed for control were recorded as 1250, 2710, 240 and 190 µS/c at depths of 0 – 10 cm, 10 – 20 cm, 20-30 cm and 30-40 cm respectively. The maximum and minimum concentration values were observed in DISS2 and DIISS3. The distribution of Electrical conductivity in soil across the study area is presented in Figure 4

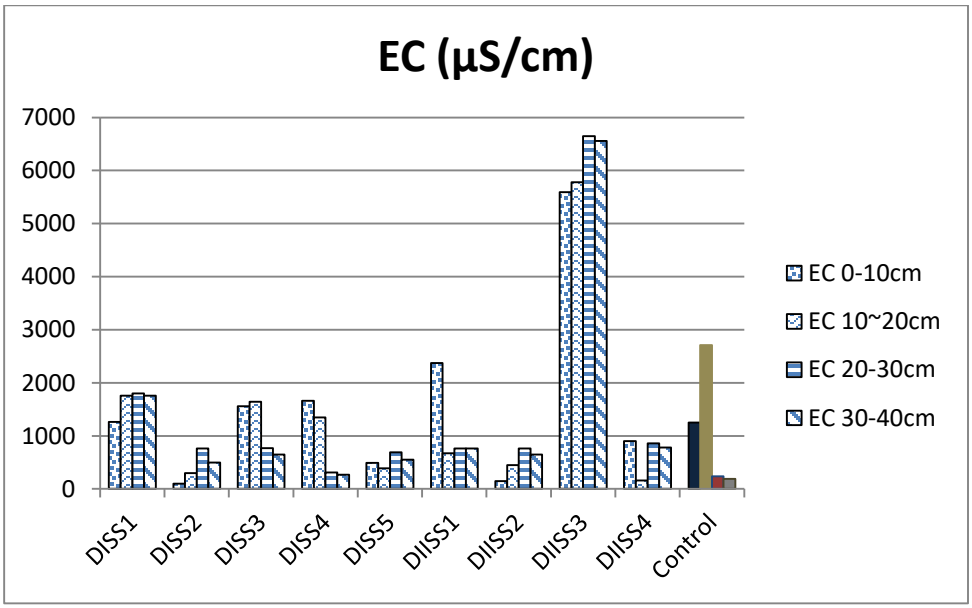

Figure 4: Comparative electrical conductivity concentration in soil samples and control in dumpsites I and II within the study area.

The levels of organic matter observed in both dumpsites ranges from 0.2 to 5.2 %. All sites have organic matter concentration lower than that of background (control) except for subsoil depths (20-30 cm and 30-40 cm) in DISS3, DIISS3 and DIISS4. This implies the presence of humus in these sites is due to lithogenic origin. The distribution of organic matter in soil across the study area is presented in Figure 5.

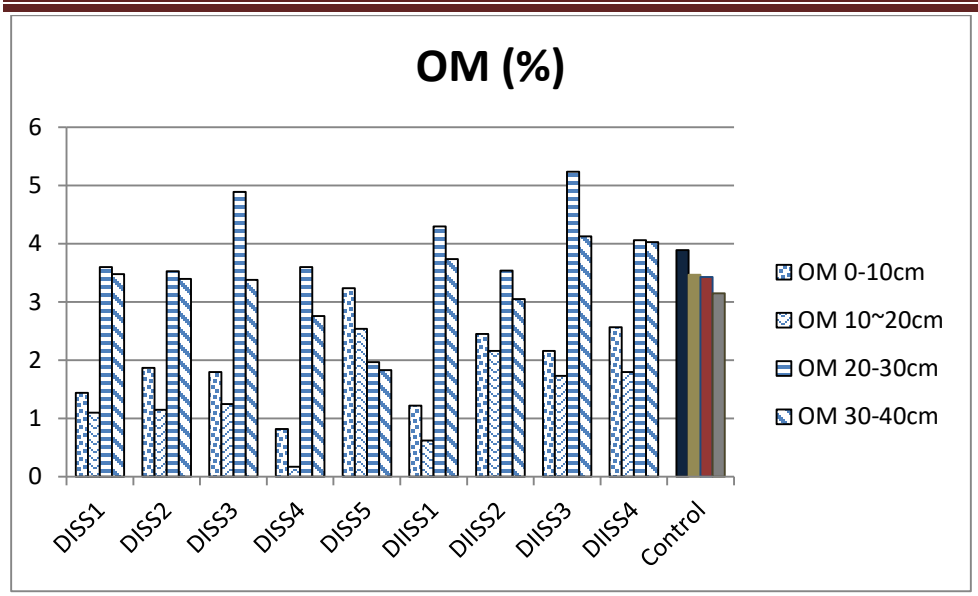

Figure 5: Comparative organic matter concentration in soil samples and control in dumpsites I and II within the study area.

The concentrations of sodium in these soils spanned from 0.83 mg/kg at subsoil of 30-40 cm DIISS1 to 10.57 mg/kg at topsoil depth of 0-10 cm DISS4 (Table 2). The levels of sodium found in these sites especially at topsoil depths of 0-10 cm and 10-20 cm were higher than background values reported in soils away from the dumpsites. The distribution of sodium concentration across the study area is presented in Figure 6.

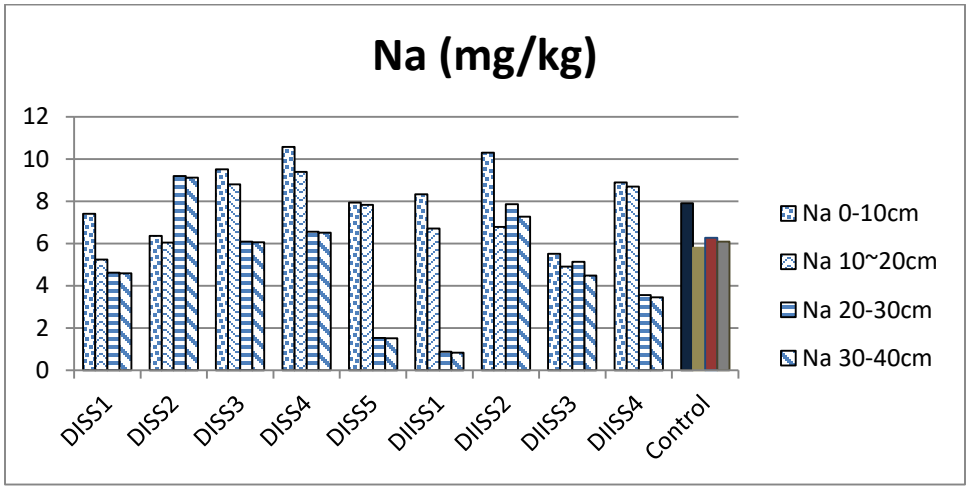

Figure 6: Comparative sodium concentration in soil samples and control in dumpsites I and II within the study area.

Magnesium

There was no significant difference in magnesium content at 0-10 cm, 10-20 cm, and 20-30 cm between dumpsites I, II and control. But at subsoil depth of 30-40 cm, control is similar to both dumpsites I and II which are significantly from each other.

The maximum and minimum values recorded in both topsoil (0-10 cm) and subsoil (30-40 cm) was observed in sample DISS4(11.81 mg/kg) and DIISS3 (4.03 mg/kg) respectively. The mean value recorded for control at topsoil (0-10 cm) is 6.94 mg/kg and subsoil (30-40 cm) is 4.11 mg/kg respectively. Most of the concentration value observed at various depths exceeds that of control value recorded. The distribution of Magnesium concentration across the study area is presented in Figure 7.

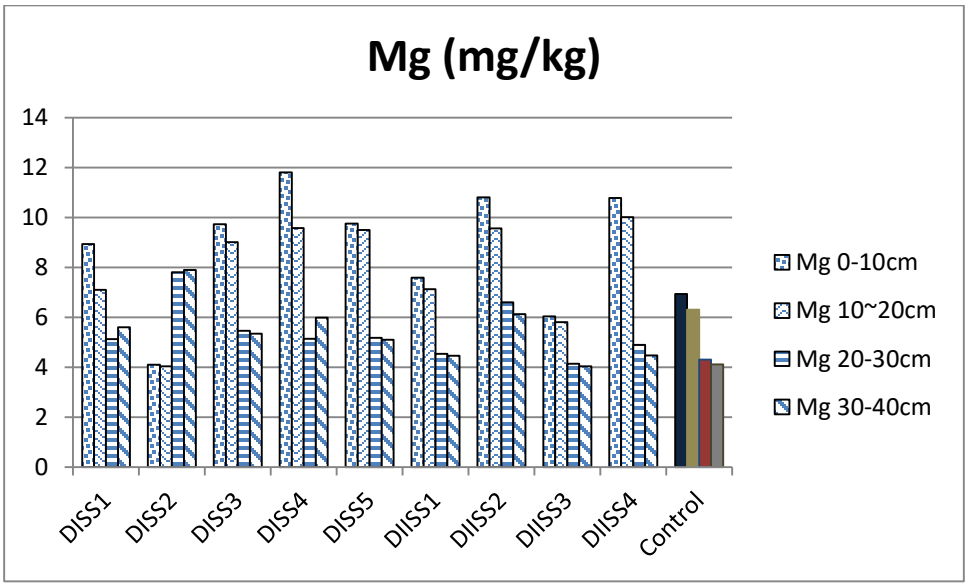

Figure 7: Comparative magnesium concentration in soil samples and control in dumpsites I and II within the study area.

Calcium

The calcium content at 0-10 cm, control was observed to be similar to both dumpsites I and II. But at depths of 0-10 cm, 20-30 cm, and 30-40 cm, the calcium content was observed to be similar.

The levels of Calcium in the soils from both dumpsites spanned from 5.25 mg/kg at subsoil of 30-40 cm DIISS4 to 15.6 mg/kg also at subsoil depth of 20-30 cm DISS2. The concentrations of sodium found in these sites especially at topsoil depths of 0-10 cm and 10-20 cm were higher than background values while the sodium levels in profile depths in DIISS2 all exceeded the threshold

value reported in soils away from the dumpsites (pristine environment). The distribution of sodium concentration across the study area is presented in Figure 8.

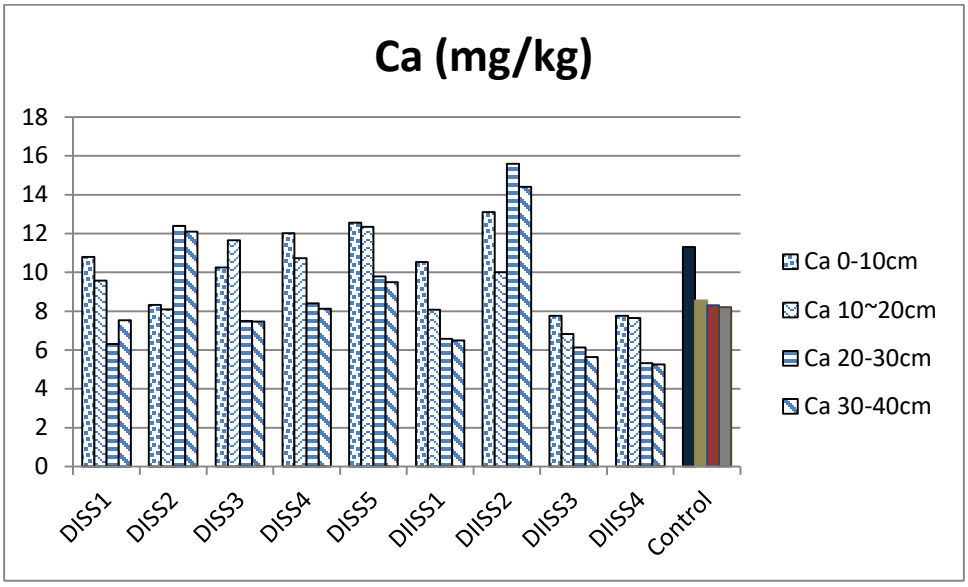

Figure 8: Comparative calcium concentration in soil samples and control in dumpsites I and II within the study area.

Phosphate

At topsoil and subsoil depths, the sodium and phosphate content were observed to be similar. The minimum and maximum values for phosphate in topsoil depth of 10-20 cm are recorded as 13.10 and 85.2 mg/kg in subsoil depth of 20-30 cm respectively. The maximum and minimum values recorded in both topsoil and subsoil was observed in sample DISS1 and DISS2 respectively. The mean values recorded for control at topsoil and subsoil depths are 27.57, 24.13, 47.11 and 41.07 mg/kg respectively. The distribution of phosphate concentration across the study area is presented in Figure 9.

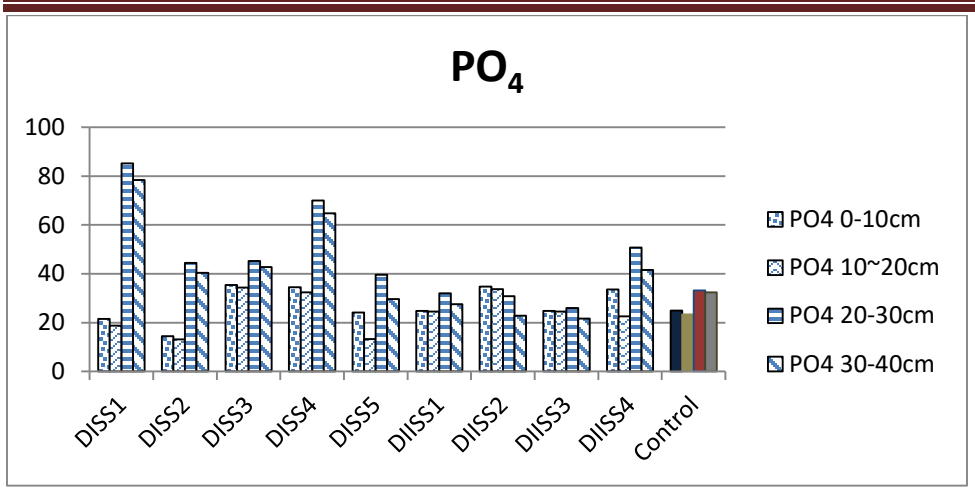

Figure 9: Comparative phosphate concentration of soil samples and control in dumpsites I and II within the study area.

Chloride and Sulphate

Chloride and sulphate concentration at topsoil depth of 0-10 cm, dumpsite I was observed to be similar to both control and dumpsite II. But dumpsite II and control are significantly different, while at other depths there was similarity.

The chloride concentration levels at subsoil depths of 20-30 cm and 30-40 cm were found to be higher than background value 0f 86 mg/kg 68 mg/kg respectively. While at topsoil depth of 0-10 cm and 10-20 cm, only soil sample at DISS3 exceeded the threshold value recorded. This could be attributed to degree of leaching at various locations from the wastes. The distribution of chloride concentration across the study area is presented in Figure 10.

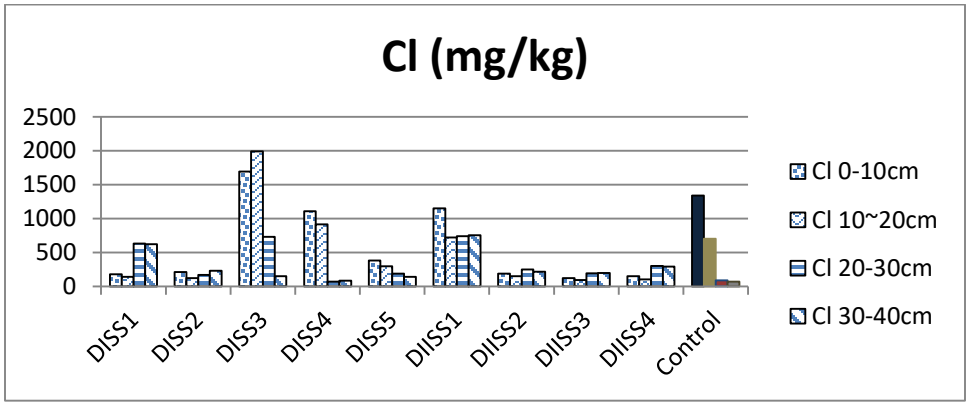

Figure 10: Comparative chloride concentration in soil samples and control in dumpsites I and II within the study area.

The concentrations of sulphate in these soils spanned from 116 mg/kg at subsoil of 30-40 cm DISS4 to 1811 mg/kg at topsoil depth of 0-10 cm DISS3. The levels of sulphate found in these sites especially at subsoil depths of 20-30 cm and 30-40 cm were higher than background values recorded in soils in the pristine environment. The distribution of sulphate concentration across the study area is presented in Figure 11.

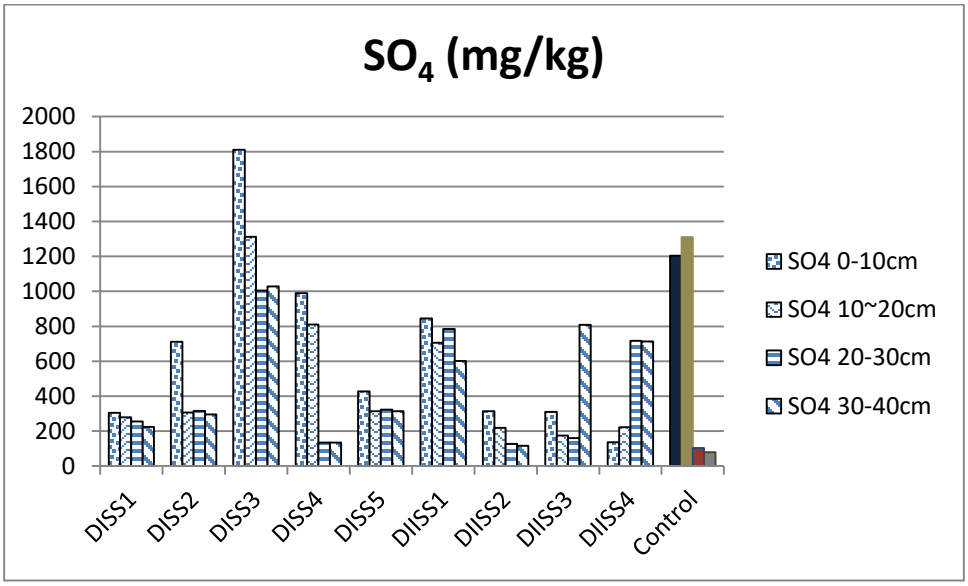

Figure 11: Comparative sulphate concentration of soil samples and control in dumpsites I and II within the study area.

Manganese

Dumpsites I and II showed no significant difference in manganese concentration but are different from control at topsoil depth (0-10 cm, and 10-20 cm). At subsoil depth (20-30 cm and 30-40 cm), dumpsite I is similar to both dumpsites II and control.

The concentrations of manganese ranged between 13.1 to 25.1 mg/kg in all sites and depths. The maximum value for manganese was observed at topsoil (10-20 cm) of site DIISS4. The entire sampled depths exceeded the background values recorded at various depths except at topsoil depths in site DISS1and DISS2. The major source of manganese is considered anthropogenic but in this study, the computed anthropogenic levels of manganese in these soils ranged from 18.8.2-78.4 mg/kg The concentrations of manganese in sites DISS1 and DISS2 are purely lithogenic. The distribution of manganese concentration across the study area is presented in Figure 12**.**

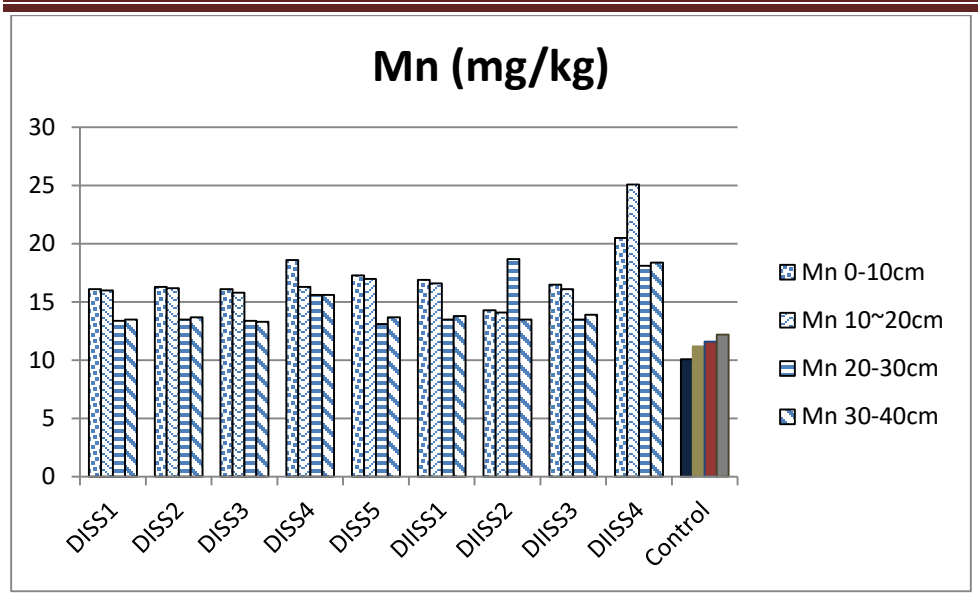

Figure 12: Comparative manganese concentration of soil samples and control in dumpsites I and II within the study area.

Arsenic

There was no significant difference in arsenic concentration between dumpsite I and control at topsoil depth of 0-10 cm; at depth 10-20 cm, dumpsite I is similar to both dumpsite II and control; at 20-30 cm, arsenic concentration in control is similar to both dumpsite I and II; while at depth 30-40 cm, the concentration of manganese in dumpsite II and control are similar but different from dumpsite I. The levels of arsenic in the soils from both dumpsites spanned from 4.4 mg/kg at subsoil of 20-30 cm DISS4 to 12.3 mg/kg at topsoil depth of 20-30 cm DIISS4. The concentrations of arsenic found in these sites especially at topsoil depths of 0-10 cm and 10-20 cm were higher than background values while the concentration levels in subsoil depths in were slightly above the threshold value reported in soils away from the dumpsites (pristine environment). The anthropogenic arsenic concentration levels recorded at topsoil depths could be attributed wastes at the dumpsites while the low levels could be attributed to poor leaching. The distribution of arsenic concentration across the study area is presented in Figure 13.

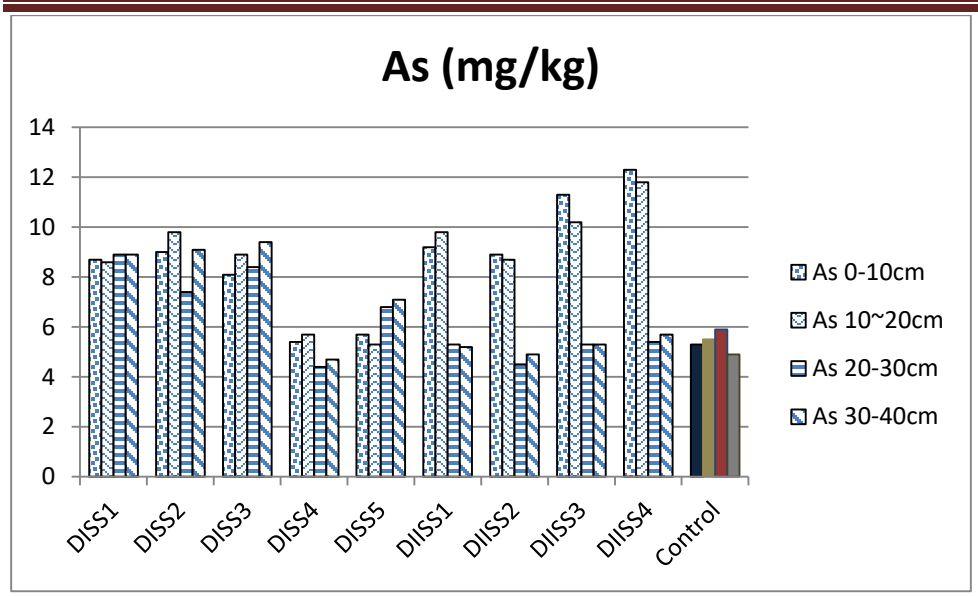

Figure 13: Comparative arsenic concentration of soil samples and control in dumpsites I and II within the study area.

Zinc, Mercury and Nickel

The concentration in zinc, mercury and nickel showed no significant difference at both topsoil and subsoil depths.

Zinc is ranked as third most abundant metal in this study. The concentrations of Zn in these soils ranged from 6.0 to 18.4 mg/kg. The solubility of Cu and Zn is governed by the pH and redox conditions. In the pH range of 5.4-6.5, Cu and Zn are distinctly more soluble under oxidizing conditions than reducing conditions. The amounts of zinc that are of anthropogenic origin in these sites ranged from 13.60 to 18.40 mg/kg. Majority of the sites especially at topsoil depths (0-10 cm and 10-20 cm) have anthropogenic zinc fraction greater than the background value. The levels of zinc in these soils fits into the moderately contamination to severe contamination range. The distribution of zinc concentration across the study area is presented in Figure 14.

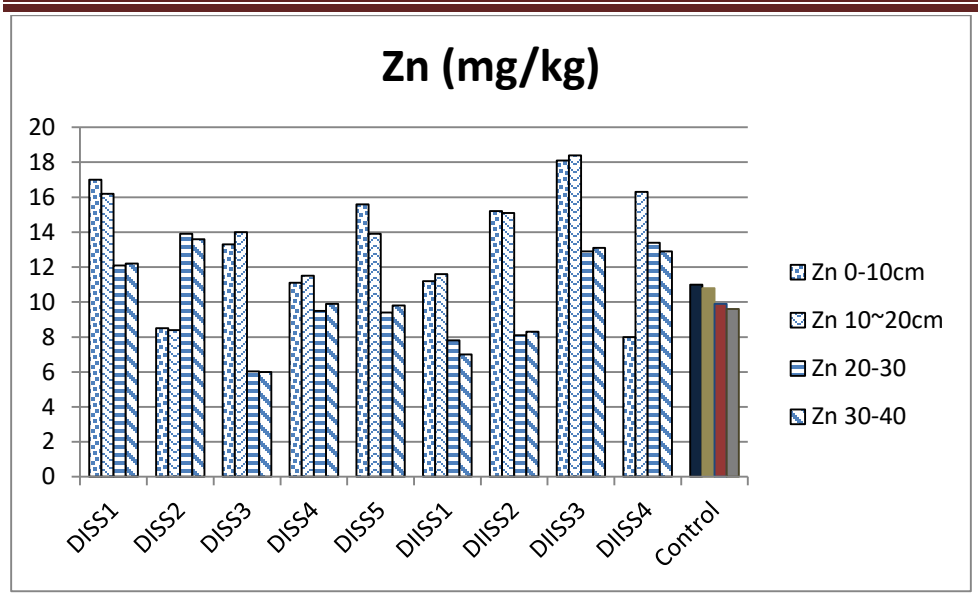

Figure 14: Comparative zinc concentration of soil samples and control in dumpsites I and II within the study area.

The concentrations of mercury in these soils spanned from 0.001 to 0.008 mg/kg (Figure 15). However, the amounts of copper due to anthropogenic origin ranged from 0.5-0.008 mg/kg. Majority of the sites at subsoil depths have anthropogenic mercury fraction greater than 0.001 mg/kg (control value). The possible sources of anthropogenic mercury at these depths in the dumpsites could be attributed to mercury-containing products.

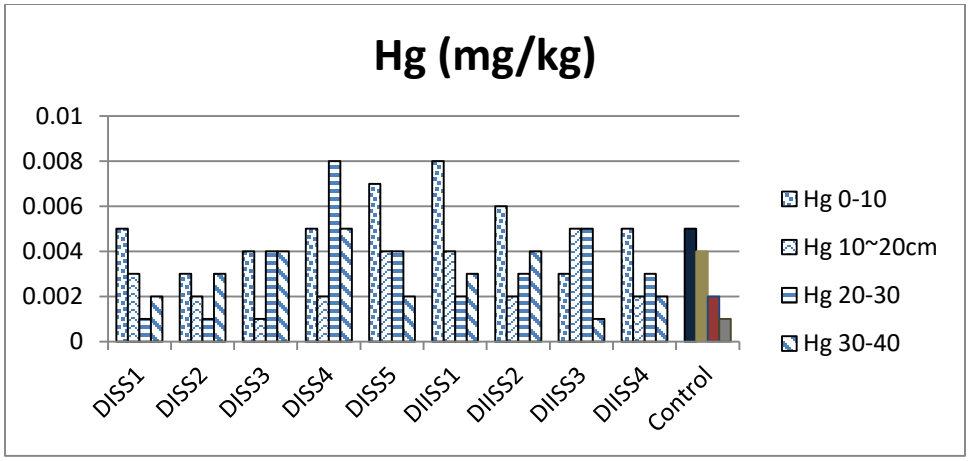

Figure 15: Comparative mercury concentration of soil samples and control in dumpsites I and II within the study area

Chromium

At topsoil depth (0-10 cm and 10-20 cm), there was similarity in chromium concentration between dumpsite I and II but they are different from control. While at subsoil depth (20-30 cm and 30-40 cm), no significant difference was recorded in chromium concentration between dumpsite I, II and control.

Lead

There was similarity in lead concentration among dumpsites I, II and control at 0-10 cm. At depth 10-20 cm, dumpsite I and control are similar from dumpsite II. While at subsoil depths (20-30 cm and 30-40 cm), there was similarity in lead concentration among dumpsites I, II and control.

The highest level of lead was found to be 19.4 mg/kg at topsoil in site DISS5 while the lowest concentration level was observed in site DIISS1 to be 10.7 mg/kg. The contribution of the refuse dumpsite was slightly above that of the background (control) value. This higher percentage difference could be due to the fact that condemned car batteries are part of the waste dumps in the studied locations. The distribution of lead concentration across the study area is presented in Figure 16.

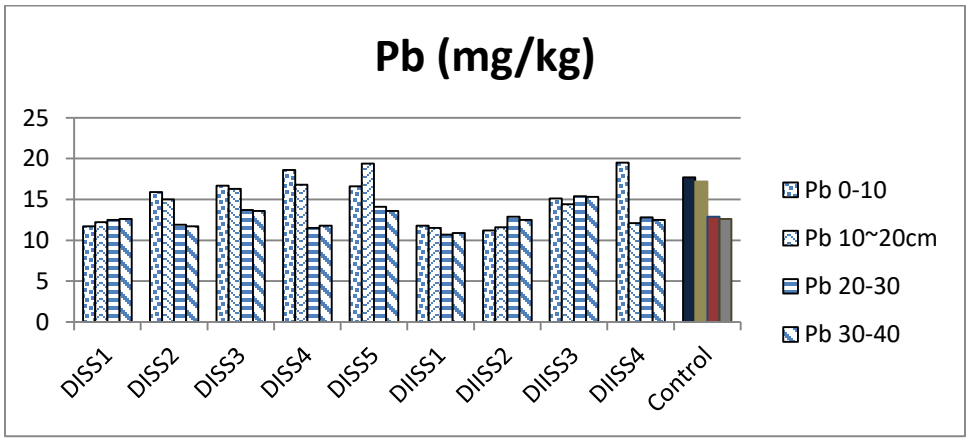

Figure 16: Comparative lead concentration of soil samples and control in dumpsites I and II within the study area.

Potassium

The highest level of potassium was found to be 8.13 mg/kg at topsoil depth of 0-10 cm in DISS5 and the lowest concentration value was found at subsoil depth of 30-40cm with a concentration

value of 1.08 mg/kg in DIISS3. The level of concentration decreased with depth. The contribution of both dumpsites is quite similar The distribution of potassium in soil across the dumpsites soils is presented in Figure 17.

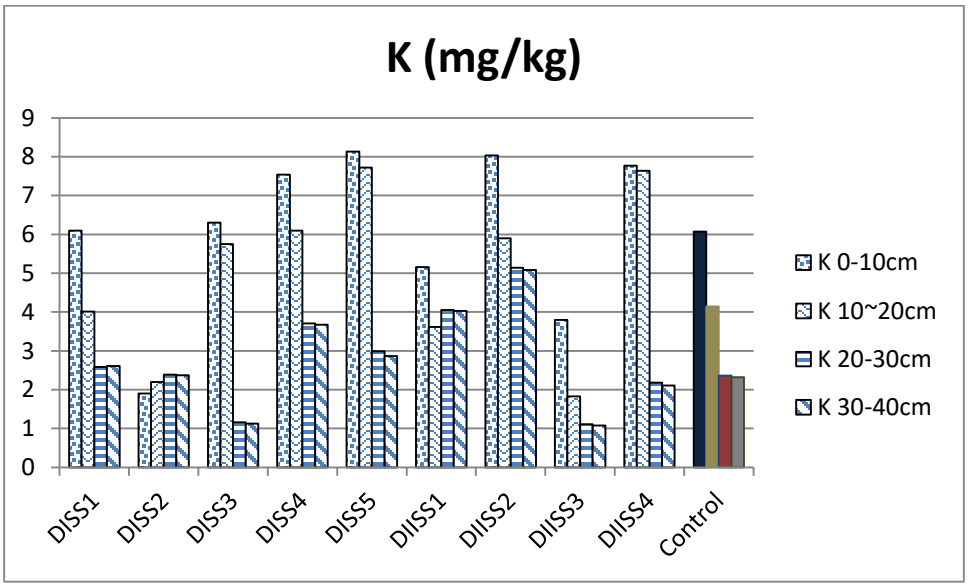

Figure 17: Comparative potassium concentration soil samples and control in dumpsites I and II within the study area.

Cadmium

There was no significant difference recorded in cadmium concentration between dumpsite I and control but they were significantly different from dumpsite II.

The highest level of cadmium was found to be 3.43 ± 0.13 mg/kg at the subsoil in site DIISS4. The level of concentration increased with distance. The contribution of the refuse dumpsite-II was far above that of the background value (table 4.2). This higher percentage difference could be due to the fact that dumpsite-II is older than dumpsite-I and its increase could be attributed to age. Other factors could be traced to condemned car batteries deposited at the site. The distribution of cadmium concentration across the study area is presented in Figure 18.

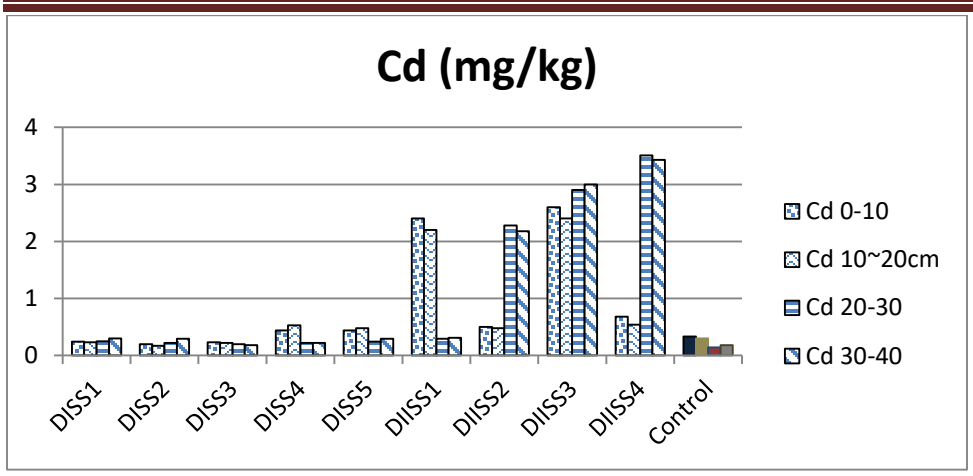

Figure 18: Comparative cadmium concentration of soil samples and control in dumpsites I and II within the study area.

Chromium

The levels of chromium observed in these sites ranges from 0.05 to 1.61 mg/kg. All sites have chromium concentration equal to slightly above background (control) at subsoil depths. But at topsoil depths (0-10 cm and 10-20 cm), the levels of concentration far exceed that of background valuesexcept for site DISS4. This implies the presence of anthropogenic chromium in these sites at subsoil depths to be of anthropogenicactivities from the wastes in both dumpsites I and II respectively. The distribution of chromium concentration across the study area is presented in Figure 19.

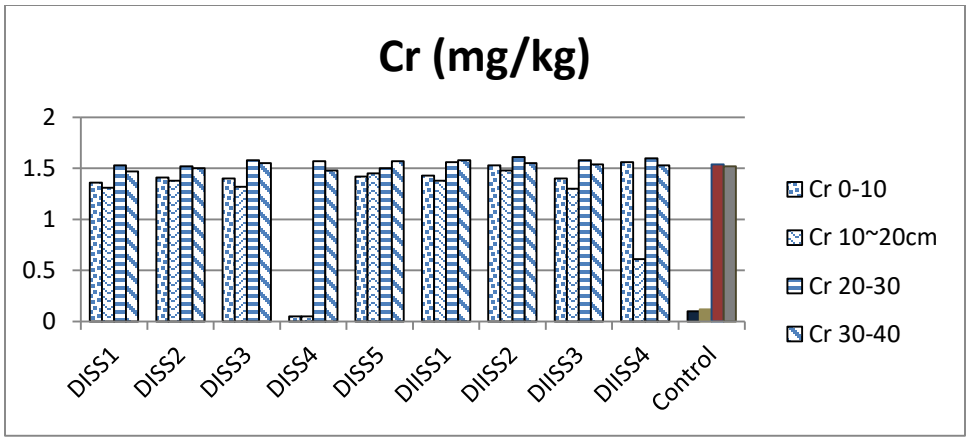

Figure 19: Comparative chromium concentration of soil samples and control in dumpsites I and II within the study area.

Nickel

With reference to Table 2 and Figure 20, nickel concentration was found to be higher at Site DISS3 at topsoil depth of 0-10 cm to be 15.80 mg/kg which is far above the background value of 8.60 mg/kg. The lowest level was observed to be 2.60 mg/kg at site DISS1 at subsoil depth of 20-30 cm. The distribution of lead concentration across the study area is presented in Figure 20.

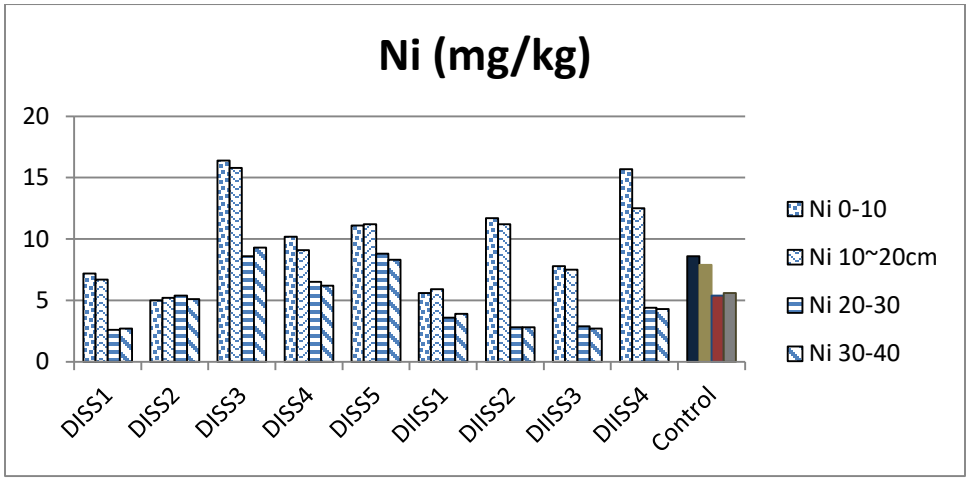

Figure 20: Comparative nickel concentration of soil samples and control in dumpsites I and II within the study area.

CONCLUSION

Result from the analysis shows that both the topsoil subsoil in the study area is acidic in both dumpsites. ANOVA results at $P<0.05$, indicated significant differences in concentrations among Mg, Ca, Cl, SO_4, Mn, As, Cd, Cr and Ni at topsoil and subsoil depths between the dumpsites and control in the study area which were higher than their respective control values. This confirmed that the soils in studied locations at several depths are facing probable environmental pollution with dangerous heavy metals (As, Mn, Cr, Cd, and Ni). Based on the study, it is concluded that the intrinsic topsoil and subsoil quality at both dumpsites are polluted. This is a reflection of anthropogenic contribution from the indiscriminate dumping of solid wastes in the dumpsites.

RECOMMENDATIONS

The study assessed heavy metal contamination in topsoil and subsoil in the sediments at two dumpsites. Consequent upon our findings, it is recommended that:

- Waste sorting into biodegradable and non-biodegradable ones before deposition should be encouraged.
- Education and legislation on management of dumpsite should be intensified to forestall waste related problems.
- Efforts should be intensified to discourage the practice of open dumpsites in residential areas. Hence the dumpsite should be closed as this could have serious adverse effect to groundwater through the soil, food chain, and humans.

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