

HEAVY METAL POLLUTION OF IN-SITU AND SURROUNDING SOILS PROFILES AT MUNICIPAL SOLID WASTE DUMPSITE

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ABSTRACT

Aims: The paper reports the investigations of status variability and degree of heavy metal pollution in municipal solid waste dumpsite (WDS) compared to adjoining area (CS) as a contribution to global knowledge of pattern of pollution and data base at dumpsite.

Study Design: Nine heavy metals (HM) were identified and assessed of degree of pollution in overall profile depth and its surface and sublayer soil at WDS and CS.

Place and Duration of Study: Uyo municipal solid waste dumpsite. It was done over a period of one year.

Methodology: Core sampling was made at 0-10cm and 10-20cm profile depths at 4 points. Acid digestion and Atomic Absorption Spectrometer were used to isolate and analyze the metals for assessment using contamination factor and heavy metal pollution index.

Results: mean concentration of nine heavy metals at municipal waste dumpsite soil manifested significantly higher ($P < 0.01$) concentrations than the undumped surrounding soils, giving mean metal pollution index of 1.75, 2.75 and 5.21 for the surface, sublayer and overall soils, respectively. Heavy metal to heavy metal correlations were very high but no significant correlation with sand, silt and clay except Al with silt and sand. Toxicity was indicated for four metals (Fe, Ni, Pb and Bo). Monosource of pollution was the organic material biodegradation and leachate percolation.

Conclusion: It was observed that dumpsite soil pollution was higher and deeper than control soil with contamination levels at WDS being between 3-22 times the values at CS depending on HM; the degree of soil profile pollution at WDS was 5.21. Pre-disposal, sorting and processing of solid waste is recommended.

Key words: heavy-metal contamination, dumpsite soil, anthropogenic source toxicity, metal pollution index.

1. INTRODUCTION

Heavy metals (HM) are a potential concern for human health when high levels of concentration are in the soil where humans are in close contact. Human beings may be harmed if high levels of HM enter their systems, such pathways may be ingestion of edible plants containing metals through normal food intake, ingestion of plant leaves splashed with contaminated soil, accidental direct swallowing of HM polluted soil such as happened to children or sewer cleaners and pit diggers, and, occasionally, by inhaling dust from contaminated soil [1,2]. Vegetables, especially leafy vegetables grown on soils having heavy metal contaminations were found with higher concentrations of heavy metals than crops grown at locations which soils were uncontaminated [3,4]. Consequently, consuming them by humans and livestock can pose serious health hazards [5,6,7,8]. At municipal solid waste dumpsites, human interaction abound, such as researchers, scavengers or sorters, farmers using old dumpsite and periphery of active dumpsite for planting vegetables for city markets obviously because of the expected high nutrient level from composting organic wastes; and crew men and labour handling waste collection and disposal as well as disposal site management (Fig. 1 shows municipal solid disposal site with a management staff at Uyo dumpsite).

Unorganized, indiscriminate and unprocessed municipal waste dumping is a common disposal method which adversely impacted on the environment [9]. The adverse impact indicated a higher level of heavy metals at the dumpsite soils than at distant surrounding [9]. Also soils and planted crops at a downslope farm adjoining a mixed-wastes generating site at Uyo were polluted by non-point source (NPS) drainage runoff resulting in a heavy metal pollution index (HPI) ≥ 2 [4,5]. Yet the peripheral areas to dumpsites play vital roles in small-scale farmers economy and in urban supply of green vegetables, which are affected by the physico-chemical properties of the degraded soil [1,10]. The physical properties and the adverse impact of such degraded soils also affect their use for other purposes. The organic matter content (O.M.), if it is high, has the tendency to decompose and develop voids which might affect the use of the soil for engineering purpose [11]. Due to the heterogeneity and complexities of the wastes, the dumpsite contains a variety of contaminants which have polluted the dumpsite soil profile, hence affected the immediate and long-term use of the dumpsite soil for other engineering purposes [12,13]. For instance, the foundation properties in the soil such as liquid and plastic limits, plastic index, clay content, dry density and optimum moisture content, and shear stress were degraded to the discredit of constructional use of the dumpsite soils, thereby needing time for restoration [14].

Generally, heavy metals do not decay but accumulate and may be fixed to anions in in-situ soils thereby creating new chemical compounds in which heavy metals become less available to living things even though they may be needed in trace amount. Soil contamination can be caused by many factors, including metal-enriched parent materials, soil pH and rainfall, point source leachate and non-point source effluents such as NPS runoff, industrial wastewater, municipal solid waste containing dumped electronics and other white goods, automotive emission and chemical fertilizers [15,16,17,18]. Parent material varies with geographical location and geological formations. The pH is also affected by rainfall which is different at different ecological locations [19]. Also the composition of mixed waste varies with locality residences and regions of the world. The status of the heavy metals and other soil properties depends on the age of the waste dump, the level of leaching and solubility of the metals under pH which controls the metal dynamics of adsorption and precipitation [20]. The HM effect on the locality soils (type and use from different localities) are not the same on magnitude and variability, indicating the need to investigate the specific locality effect on the general trend and pattern of soil degradation under solid waste disposal and effect on adjoining land [1,9,21,22].

Therefore the objective of the research was to investigate the status, variability and pollution index of heavy metal contamination of soils at municipal solid waste open dumpsite and adjoining land at Uyo, as a contribution to knowledge of pattern of effect and data base of MSW pollution of resources at localities of the world.

2. MATERIALS AND METHODS

2.1 Sampling and Analyses

Soil samples were collected using acid-cleaned soil auger and packed in a well-labeled black polythene bag, and transported to the heavy metal analytical laboratory at RUSAL- Aluminum



Fig.1: The municipal solid waste dump site at Uyo showing disposal site management staff

Smelting Plant at Ikot Abasi; Akwa Ibom State. The random core samples were collected from four points (P₁, P₂, P₃ and P₄) at two depths of 0 – 10 and 10 – 20 cm soil profile of the municipal waste dumpsite (WDS) and, for comparative purposes, of the surrounding area soil (CS). The samples were dried in an oven at 105°C overnight; then cooled and pulverized to homogenize and ground to 0.063mm fine powder because metals are known to adhere to fine particles, and sieved mechanically using 0.5mm sieve. Afterwards, 1.25g of each sample was digested with 20ml aqua regia (HCl/HNO₃ 3:1) in a beaker (for open beaker digestion) on a thermostatically controlled hot plate. Each digest was heated to near dryness and cooled to ambient (room) temperature. Then, 5.0ml of perchloric acid was added in parts to complete the digestion and the resulting mixture was heated again to near dryness in a fume cupboard. The beaker walls were washed with 10ml of de-ionized water and 5ml HCl were added, mixed and heated again. The resulting digest was allowed to cool and transferred into a 50ml standard flask and made up to the mark with de-ionized water. Pb, Cd, Cu, Zn, Mn and Fe heavy metal elements were then analyzed by direct aspiration of the sample solution into a UNICAM Model 939 A.S. flame atomic absorption spectrophotometer (AAS). All metals were analysed using lean blue acetylene flame at different wave lengths: 324.8 nm, slit width 0.2nm for Cu; 228.8 nm, slit width 0.7 nm for Cd; 213.9nm for Zn; 217.0 nm, slit width 0.7nm for Pb; 279.5nm, slit width 0.2nm for Mn and wavelength 510 nm for iron.

2.2 Assessment of heavy metal (HM) Contamination in Soil Profile

Assessment of heavy metals and contamination levels in soils require pre-anthropogenic pristine values of the heavy metal concentrations. These were obtained from the control soil for use in computing the contamination factor (CF) and heavy metal pollution index (HPI). Contamination factor is the ratio of the concentration of heavy metals in contaminated soil at each depth interval to the concentration of heavy metal in natural local or background soil (i.e. the pristine values) and is calculated as [22,23,24,25].

$$CF = \frac{\text{HM concentration found on soil (mg/kg)}}{\text{HM concentration of natural local background soil (mg/kg)}} \quad (1)$$

where $CF < 1$ means low contamination, $1 < CF < 3$ means moderate contamination; $3 \leq CF \leq 6$ indicates considerable contamination and $CF > 6$ indicates very high contamination [26]. Also, the overall degree or extent of metal pollution of each layer of soil profile at the dumpsite was evaluated by using HPI [27] as:

$$HPI = (CF_1 \times CF_2 \times CF_3 \times CF_4 \times \dots \times CF_n)^{1/n} \quad (2)$$

where HPI is the heavy metal pollution index; CF is the contamination factor of each pollutant obtained from equation 1; n is the number of heavy metals used. Thus, HPI is also the geometric mean of the studied pollutants contamination factors (CF) and has the following gradation [26,27]:

- HPI < 1.5 is nil to very low degree of contamination
- $1.5 \leq HPI < 2$ is low degree of contamination
- $2 \leq HPI < 4$ is moderate
- $4 \leq HPI < 8$ is high
- $8 \leq HPI < 16$ is very high
- $16 \leq HPI \leq 32$ is extremely high
- $HPI \geq 32$ is ultra high degree of contamination.

Statistical analysis of data of samples for means, variance, coefficient of variation and correlation coefficient utilized the SPSS software, version 17 windows. Penetration of profile pollution is defined by ratio $K = \text{HM concentration in subsoil layer} / \text{HM in surface soil}$. $K = 1$ indicates homogenous elemental penetration, $K \geq 1$ indicates subsoil accumulation, while $K < 1$ indicates superficial distribution.

Since pH and soil texture are relevant contributors to HM presence in soils [17,28] the pH and soil particle size distribution were also determined. The pH was measured from soil solution in place using digital pH meter with glass electrode (HANNA Model 209) while sand, silt and clay particle sizes and properties were determined by mechanical sieving and hydrometer analysis of the dried soil samples and using the USDA soil triangle for the texture identification [29].

3. RESULTS AND DISCUSSION

3.1 Heavy Metal (HM) Content of the Soils

The concentrations of the nine heavy metals (Cu, Mn, Ni, Fe, Pb, Ar, Cr, and Bo) studied in the soil at WDS and in the surrounding (control) area are shown in Table 1. Their means were in the following increasing order :Cd < Cr< Bo < Pb< Mn < Ar < Cu < Ni < Fe for WDS soil and CB but Cd's mean concentrations were greater in the WDS soil than in the control soil (CS). The concentrations varied from slightly to moderately (Cv = 4-32%) in WDS and (Cv = 9-32%) in control soil; however while Boron was homogenous in WDS, it was extremely heterogeneous in CS. For Fe, the variation was high (Cv = 48%) on WDS but slight (Cv = 17%) in CS while the reverse was the case for Pb in WDS (slight at Cv = 9%) and in CS (high variation, Cv = 47%). It would appear that Pb and Fe were complimentary in quantity.

The concentration of Cu ranged from 536.8 – 1126.0mg/l in WD (mean of 809.00mg/l) and was significantly higher than that of CS (268.36mg/kg); the high concentration in WDS was attributable to Cu content of the wastes. Hence, solid waste accumulation increased the concentration of Cu in the soils, and the variation in WDS was more homogenous (Cv = 28.92%) than CS (Cv = 31.88%).

The variation of individual HM in the two soils are further compared below:

Table 1: Heavy Metal Contents of the Polluted and Control Soils at Old Stadium Road Dumpsite, Uyo.

Property	Polluted soil						Control soil						Overall CF
	0 – 10cm	10 – 20cm	Mean	Sd	Cv	K ₂	0 – 10cm	10 – 20cm	Mean	Sd	Cv	K ₁	
Cu	536.80	1125.00	809.00	234.35	28.97	2.10	195.29	3461.00	268.36	85.55	31.88	1.80	3.10
Mn	388.50	864.30	681.70	191.80	28.13	2.20	168.19	264.30	215.30	48.86	22.69	1.60	3.10
Ni	1024.00	1859.00	1427.00	368.70	25.84	1.80	163.60	254.50	206.20	49.21	23.87	1.60	7.10
Fe	1043.00	3534.00	2027.00	776.44	38.17	1.00	93.46	120.50	105.96	10.25	9.67	1.30	19.10
Pb	115.00	193.64	154.00	26.66	17.31	1.70	2.45	12.64	6.90	3.25	47.10	5.00	22.10
Ar	63.40	85.30	751.90	89.87	11.95	1.30	231.40	483.30	366.60	75.98	20.72	2.10	2.10
Cr	0.14	0.34	0.25	0.08	32.00	2.40	0.10	0.26	0.19	0.05	26.32	2.60	13.10
Cd	0.12	0.25	0.16	0.04	25.00	2.10	0.05	0.34	0.16	0.09	56.25	6.80	1.10
Bo	0.05	0.15	0.96	0.04	4.16	3.00	0.01	0.08	0.03	0.03	100.00	8.03	2.10

N/B: Cu: Copper, Mn: Manganese, Ni: Nickel, Fe: Iron, Pd: Lead, Ar: Argon, Cr: Chromium, Cd: Cadmium, Bo: Boron
 BoronN/B: Cu: Copper, Mn: Manganese, Ni: Nickel, Fe: Iron, Pd: Lead, Ar: Argon, Cr: Chromium, Cd: Cadmium, Bo: Boron

The lower limits of the range are for the 0 – 10cm depth and represent the spatial mean value for the 4 spatial points (PT1 – PT4) in the respective soils.

Values for Manganese (Mn) ranged from 1024.0 – 1059.0 mg/l with a mean of 1426.8mg/l in WDS and 163.6 – 254.5 mg/l with a mean of 206.1mg/l in CS, giving a significantly (P = 0.05) higher mean in WDS than in CS, and varied in WDS (Cv = 28.13%) than in CS (Cv = 22.69%). Concentration of Ni in WDS was very high and more than in CS, ranging from 1024.0 – 1859.0 mg/l with mean 1426.8mg/l in WDS and between 163.6 and 254.5 mg/l with mean of 206.18mg/l in CS. Thus, waste accumulation may lead to Ni toxicity in soil. The variation of Ni was not very high both in WDS and CS (Cv = 25.84 and 23.8% respectively). Iron (Fe) had higher concentration in WDS than in CS (Table 1); the values in WDS ranged from 1043.0 – 3534.0 mg/l with mean of 2027.0mg/l and from 93.5 – 120.5mg/l in CS with mean of 105.96 mg/l. The significantly higher Fe in WDS than CS could be attributed to the influence of the wastes on the soil. This could results in Fe toxicity. The Cv was 48.17% in WDS and 9.67% in CS. Comparatively, the soil at CS was more homogenous in terms of Fe content than the soil at WDS. Lead (Pb) was among the heavy metals considered, the value (Table 1) ranged from 115.0 – 193.0 mg/l with mean of 154.0mg/l in WDS and between 2.453 and 12.637 mg/l in CS which was significantly higher at WDS than that at CS (P = 0.05). This implies that waste accumulation could result in Pb toxicity on the soil. It however, varied slightly within WDS (Cv = 17.31%) but strongly in CS (Cv = 47.00%). Argon (Ar) content at WDS was significantly higher than CS and ranged from 634.0 – 853.0 mg/l with mean of 737.87mg/l in WDS and from 231.4 – 483.3 mg/l with mean of 366.6 mg/l in CS; WDS showing superiority over CS in Ar content (Table 1).

Variation was low in both WDS (Cv = 11.95% and CS (Cv = 20.72%). Concentration of Cr in both soils was low, ranging from 0.14 – 0.34 mg/l with mean of 0.25mg/l in WDS and between 0.10 and 0.26 mg/l with mean of 0.19mg/l in CS. There was no significant difference between its mean concentration in WDS and CS suggesting that municipal solid waste (MSW) may not significantly affect the Cr content of the soil. Nevertheless, variation of Cr was high at 32.00% and 26.32% in WDS and CS respectively. Cadmium (Cd) concentration ranged from 0.12 – 0.25mg/l with mean of 0.16mg/l in WDS and from 0.05 -0.34mg/l with mean of 0.16mg/l also in CS. The variation in CS was 56.25% while in WDS was 25%; thus both soils were not homogenous. Boron (Bo) which values ranged from 0.05 -0.15mg/l with a mean of 0.96mg/l in WDS, and between 0.01 and 0.08mg/l with a mean of 0.03mg/l in CS was significantly higher in WDS than in CS, suggesting that the waste could cause Botoxicity in the soil.

3.2 Correlations

Correlation coefficients of the relationship of HM to HM, and HM with grain size distribution (sand, silt and clay) are in Table 2. Very significant ($P \leq 0.01$) and very high correlation were observed between Fe and Pb, Al, Cr ($r = 85 - 91\%$); between Pb and Al ($r=87.9\%$) and, between Al and Cr ($r = 94.9\%$). In addition Pb had a high correlation with Cr also; which means that Pb was influenced positively by the presence of Al, Cr, and Fe and vice versa. Increase in Pb was based on their increases and vice versa. Therefore, these bilaterally correlated metal pairs have likely identical source in the municipal solid waste dumpsite. When such a common source is controlled, the contamination degree is likely to be regulated or reduced, as it is likely a monosource of MWS/leachate Cd and Bo had negative and no significant influence on Pb or any other HM for that matter (Table 2)

Observation further showed that for particle sizes, only sand and silt had positive ($r = 72.4\%$) and negative ($r = 73.5\%$) correlations respectively with Al only. Clay had no significant correlation. Sand, silt and clay had no significant correlation with other HMs rather they had non-significant and negative correlations (Table 2). This may mean that the source of the HM was not from parent material but mainly anthropogenic source of municipal solid waste biodegradation at dumpsite and leachate percolation [18]. Also, pH showed only negative and no significant correlation with the HM ($r = -3.6\%$ for Cr to -57.6% for Pb).

Table 2: Pearson Correlation Coefficients of Heavy Metals themselves and with Particle Sizes and Soil pH at Dumpsite Soil

	pH	Sand	Silt	Clay	Fe	Pb	Al	Cr	Cd	Bo
Ph	1									
Sand	0.409	1								
Silt	-.370	-.975	1							
Clay	-.425	-.938	.837"	1						
Fe	-.361	0.384	-.451	-.234	-1					
Pb	0.576	0.423	-.459	-.323	.850"	1				
AIL	-.176	-.724	-.735	-.630	-.878"	.879"	1			
Cr	-.36	-.663	-.680	-.560	.908"	-.769	.949"	1		
Cd	-.405	-.247	-.337	-.93	-.413	-.585	-.489	-.272	1	
Bo	0.287	0.302	-.183	-.450	-.363	-.64	-.57	-.72	0.456	1

3.3 Comparing the Concentrations of Heavy Metals between WDS and CS

Table 3 shows the t-statistic of significant difference between mean HM at WDS and CS, with positive mean difference obtained in all cases, indicating that mean concentration of the entire heavy metal was higher in WDS than CS. The magnitude of the difference showed that the least mean difference was 147.01 obtained in Pb while the highest was 1921.04 obtained in Fe; only the concentrations of Cr and Cd in the two soils were almost similar (but not significantly different). Hence, municipal solid waste at dumpsite soil significantly increased the concentration of heavy metals in the in-situ soil.

This conclusion was also observed by researchers in similar circumstance at other places on the organic soil.

Table 3: t – Statistics for significant difference in Heavy Metals between WDS and CS at Uyo urban dumpsite, Nigeria.

Soil properties	Mean difference	t-value	Remark
Cu	540.63	5.422	**
Mn	466.40	7.064	**
Ni	1220.70	9.391	**
Fe	1921.04	5.547	**
Pb	147.09	14.692	*
Ar	385.23	16.210	*
Cr	0.06	1.459	ns
Cd	0.00	0.093	ns
Bo	0.06	3.571	**

Comparison of the soil surface and bottom layer of top soil also showed profile variation as ratios K_1 and K_2 , defined in Eqn. 3, also indicated. The ratio of HM at bottom layer to the HM concentration at soil surface which HM concentration showed an increase down the depth, increased in the following order. For WDS soil, K_2 increased in the sequence $Bo > Cr > Mn > Cu = Cd > Ni > Pb > Ar > Fe$. For CS soil, the following sequence for K_1 was obtained $Bo > Cd > Pb > Cr > Ar > Cu > Ni = Mn > Fe$ (Table 1). In both cases Bo was the highest ratio and Fe the least ratio, while Cu and Cd had equal ratio of 2.1 in WDS, Ni and Mn had equal ratio of 1.6 of profile contamination in CS. The difference between HM concentration at the bottom layer and soil surface was significant ($p = 0.05$) (Table 3) showing higher HM concentration at the bottom soil than on the soil surface. The HM were heterogeneous in their concentration down the soil profile especially in four HM at CS, namely Fe, Pb, Cd and Bo (with $30 < Cv \leq 100\%$) and in Fe and Cr at WDS with $Cv = 38$ and 32% (Table 1) respectively.

Using t-statistics, significant differences were recorded between the mean of HM in control (CS) and dumpsite (WDS) soils (Table 3). Five heavy metals, Cu, Mn, Ni, Fe and Bo showed very significant difference ($P < 0.01$) between WDS and CS soil (Table 3) and two HM, (Pb and Ar) showed significant difference at $P = 0.05$, while the remaining two HM, Cr and Cd, recorded no significant difference at $P = 0.05$.

The municipal waste dumpsite greatly polluted the 0 – 20cm profile depth of the WDS significantly more than any pollution at CS, resulting in homogenous elevated concentration of all its HM ($Cv \leq 38\%$) in the profile. The degree of the anthropogenic pollution was differentiated by the overall mean contamination factor (CF) between WDS, as the polluted (treatment) soil, and CS as the background soil.

3.4 Contamination Factor (CF)

The level of soil contamination by pollutants from municipal solid wastes decay and its component leachate egress and infiltration into insitu soil at WDS compared to the background station of HM at undumped site soil was the contamination factor (equation 1). The results are shown in Table 4. The values are indicated for the overall soil depth studied (0-20cm), for the soil surface (0-10cm) and bottom depth of root-zone (10-20cm).

CF indicator (Table 4) suggests that in the overall depth of the WDS, soil suffered anthropogenic pollution with HM in the order $Bo > Pb > Fe > Ni > Mn > Cu > Ar > Cr > Cd$. The contamination level varied amongst metals from moderate contamination with Cd, Cr, Ar and Cu, to considerable contamination with Mn and Ni and very high contamination with Ni, Fe, Pb and Bo. The varied levels of different HM contaminations are indicative of the heterogeneous make-up of municipal solid wastes at dumpsite. Many white goods like old fridges, generators, plastics, foams, electronics, cans (paint cans and food cans) amongst other items, are usually disposed at the dumpsite to rust and decay

along with biodegrading garbage, and the egress leachate is often alkaline setting off reduction reaction in the soil [19]. HM toxicity of Bo is very injurious to agricultural production while others

Table 4: Contamination factor for heavy metal and metal pollution index in municipal solid waste dumpsite soil

HM	0 - 20cm	0- 10cm	10-20cm
Cu	3.02	2.75	3.25
Mn	3.17	2.31	3.27
Ni	6.92	6.26	7.36
Fe	19.13	1.01	1
Pb	22.32	46.88	15.32
Ar	2.05	0.27	0.18
Cr	1.32	1.4	1.31
Cd	1	2.5	0.74
Bo	32	5	1.88
HPI	5.21	2.75	1.94

would have profound adverse health effect on farmers and urban consumers of crops produced from such a soil [5,7,30]. Fig. 2 shows the composite bar chart of the mean HM concentrations with toxicity implications composing the WDS and CS soils.

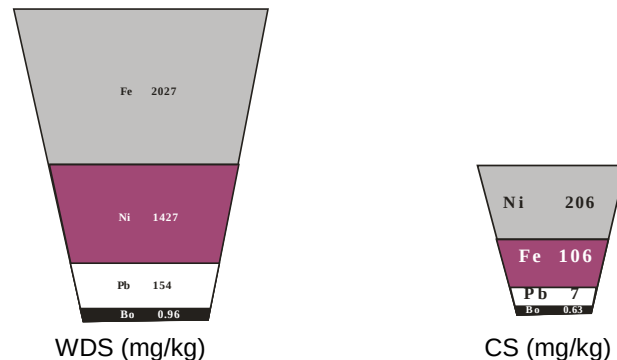


Fig.2: Comparative bar charts of four toxic heavy metals at WDS and CS soils

3.5 Heavy Metal Pollution Index (HPI)

HPI measures the degree of overall HM contamination in the studied soil. The results are shown in Table 3, showing a variation between the HPI of the HM at soil surface (2.75) and a lower value HPI (1.94) at the lower soil profile, and the higher overall HPI which indicated a synergy effect of the combined or distributed HM in the profile depth.

3.6 Essential of HM to Crop Production

Heavy metals which are important for plant growth although needed in trace amount and are present in the WDS soil are Fe, Mn, Bo. Cu [31,32]. Only Iron (Fe) and Boron (Bo) were observed to show prospect of toxicity in MSW due to MSW sustained deposit as compared to their applicable limits to plants [31,33]. On the other hand the largely non-essential elements identified Ni and Pb as being toxic from municipal solid waste accumulation on dumpsite soil. Ar, Al, Mn, Cr and Cd although non-essential, were found in the WDS soil (Table 1).

4. CONCLUSION

Heavy Metal (HM) distribution in municipal solid waste dumpsite and adjoining land which was used as the background soil, was investigated, HM was analysed using acid digestion and AAS spectrophotometer, samples were collected from the soil surface and sublayer soil at 10-20cm profile depth. The pH and particle size distribution were also analysed. Assessment utilized mean significant differences, contamination factor (CF) and heavy metal pollution index (HPI), and correlation coefficient. Significant variations were obtained between HM in the soil surface and sub-layer indicating profile heterogeneity in most metals. Also higher concentrations of HMs were recorded at dumpsite soil (WDS) than the background control soil showing that sources (municipal solid waste and leachates) at dumpsite caused HM pollution more than the status at control soil. The level of contamination were very significant ($p \leq 0.1$) for five (Cu, Mn, Ni, Fe and Bo) out of 9 heavy metals, while Ni, Fe, Pb and Bo indicated likely toxicity. The degree of pollution indicated by heavy metal pollution index (HPI) was high (1.94) on the subsoil (10-20cm), higher in the surface soil (2.75) and highest (5.21) in the overall indicating a higher synergy effect of the combined HM distribution in the studied profile. Correlation coefficient was very significant and very high between four (Fe, Pb, Al, Cr) HMs @ $r = 85 - 94.9\%$ while negative and no significant relation existed between HM and grain sizes and pH. Only sand and silt had significant correlation with Al only. These indicated that HM pollution in soil profile stemmed from anthropogenic source (solid waste and leachate at dumpsite soil) and not from parent material of the soil.

COMPETING INTEREST:

We the authors declare that no competing interests exist. The works were carried out solely by us.

AUTHOR'S CONTRIBUTION: Author 1 designed the study, identified the study location and carried out all liaison protocol; analysed the data; drafted and corrected the manuscript. He also supervised field sampling. Author 2 carried out field sampling

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