Journal of Environmental Protection, 2020, 11, 709-717
https://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

Heavy Metals Contents of Municipal Solid Waste Dumpsites in Potiskum, Yobe State Nigeria

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How to cite this paper: Ibrahim, G.D., Nwaichi, E.O. and Abu, G.O. (2020) Heavy Metals Contents of Municipal Solid Waste Dumpsites in Potiskum, Yobe State Nigeria. *Journal of Environmental Protection*, **11**, 709-717.
https://doi.org/10.4236/jep.2020.119043

Received: July 22, 2020
Accepted: September 8, 2020
Published: September 11, 2020

Abstract

The concentrations of As, Cd, Cr, Cu, Ni, Pb, Fe and Zn in selected dumpsites in Potiskum were determined with Buck Scientific 210VGB Atomic Absorption Spectrometer (AAS) AVG 210. One-way ANOVA was deployed at $p < 0.05$ level of significance for obtained triplicate values. It was found that the concentration ($mg \cdot kg^{-1}$) of studied heavy metals in Potiskum dumpsites ranged from 0.108 ± 0.02 - 262.536 ± 0.68 with pattern of accumulation Pb (262.536 ± 0.02) > Zn (183.369 ± 0.58) > Fe (159.453 ± 0.50) > Cu (111.382 ± 0.62) > Cr (43.523 ± 0.36) > Ni (6.419 ± 0.26) > Cd (0.679 ± 0.01) > As (0.108 ± 0.02) $mg \cdot kg^{-1}$. The concentrations of As, Cr, Ni, Fe and Zn fell below the WHO standards while those of Pb, Cd and Cu were above set limits by WHO. High acidity corresponds markedly with high levels of Cd, Cu, Cr and Zn and requires urgent attention as this trend is capable of groundwater contamination that will cause public health concern in affected areas.

Keywords

Heavy Metals Concentration, Uptake Pattern, Dumpsites, Municipal Solid Wastes

1. Introduction

Any undesirable item resembling trash/garbage or things not regarded as valuable by the owner is considered to be a waste. Municipal solid wastes are unwanted items originating from municipalities in the form of solid [1]. Litters/garbage along the streets of major cities is increasing due to urbanization and population sprawl across towns and cities in Nigeria [2].

The daily per capita waste generated in Nigeria is between 0.65 - 0.95 kg with an estimate of about 42 million tons of waste yearly out of which 52% are organic and only 20% - 30% are collected and managed [3] [4]. In most cases the wastes are indiscriminately disposed up, the net impact results in obstruction of drainages and causes pollution to water bodies due to lack of effective and efficient waste management program in many towns and cities [5]. According to Mikael *et al.* [6], there are enforcement bodies and laws at local, state and federal government levels but less achievement had been made to man and to manage waste properly. In Nigeria like most developing nations, open dumping and burning of municipal solid waste are usually considered as the easiest and the cheapest means of waste disposal [4]. There is no centralized and modern system of waste management; rather the system is based on collection, transportation and dumping as well as uncontrolled burning [4]. This action leads to the ejection of hazardous emissions/particles into the environment [7] among which are volatile organic compound (VOCs), particulate matter and semi volatile organic compounds (SVOCS) that result from open burning of waste [8].

Studies by Aboyeji and Eigbokhan [9] indicated indiscriminate burning and dumping of waste as a potential source of leachates contain melted organic matter, inorganic compounds (such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals like cadmium, chromium, copper, lead, zinc and nickel) and can easily infiltrate and pollute the soil and ground water. The extent of the pollution depends on the concentration and toxicity of the contaminants, type and depth of water table as well as direction of groundwater flow. The leachate produced from the municipal solid waste residues can easily leak into water bodies and when consumed by animals transferred to humans through the food chain; they can also serve as a potent source of pollution for both soil and underground water [10]. Soil pollution with heavy metals has become a critical environmental concern [11] [12] due to its potential adverse ecological effects. Heavy metals occur naturally at low concentrations in soils. However, they are considered as soil contaminants due to their widespread occurrence, acute and chronic toxicity. These metals are extremely persistent in the environment. They are non-biodegradable, non-thermo-degradable and thus readily accumulate to toxic levels. Since they do not break down, they might affect the biosphere for a long time. It is known that heavy metals form an important polluting group. They have not only toxic and carcinogenic effects but also tend to accumulate in living organisms [13] (Chopra *et al.*, 2009). Therefore, it is necessary to evaluate the availability of heavy metals in municipal solid waste dumpsite considering it potential degrading potentials on the inhabitants adjacent to dumpsites [14].

2. Materials and Methods

2.1. Study Area

Potiskum is a town located on latitude 11˚43'N and longitude 11˚04'E and is a local government capital of Potiskum local government area in (**Figure 1**), Yobe state, Nigeria with an estimated area of about 559 Km and a total population of about 205,876 as at 2006 [15]. The selected dumpsites are provided and controlled by local government authority, open burning and deposition is the waste management practiced in these selected dumpsites. In addition, these dumpsites contain similar kind of waste mainly household, animal dung and waste from commercial facilities.

2.2. Samples and Sampling

Table 1 provides the GPS location, dimension and the number of soil samples collected from each dumpsite. Soil samples were collected at a depth of 15 - 30 cm with soil auger using grid soil sampling from the selected dumpsites based on

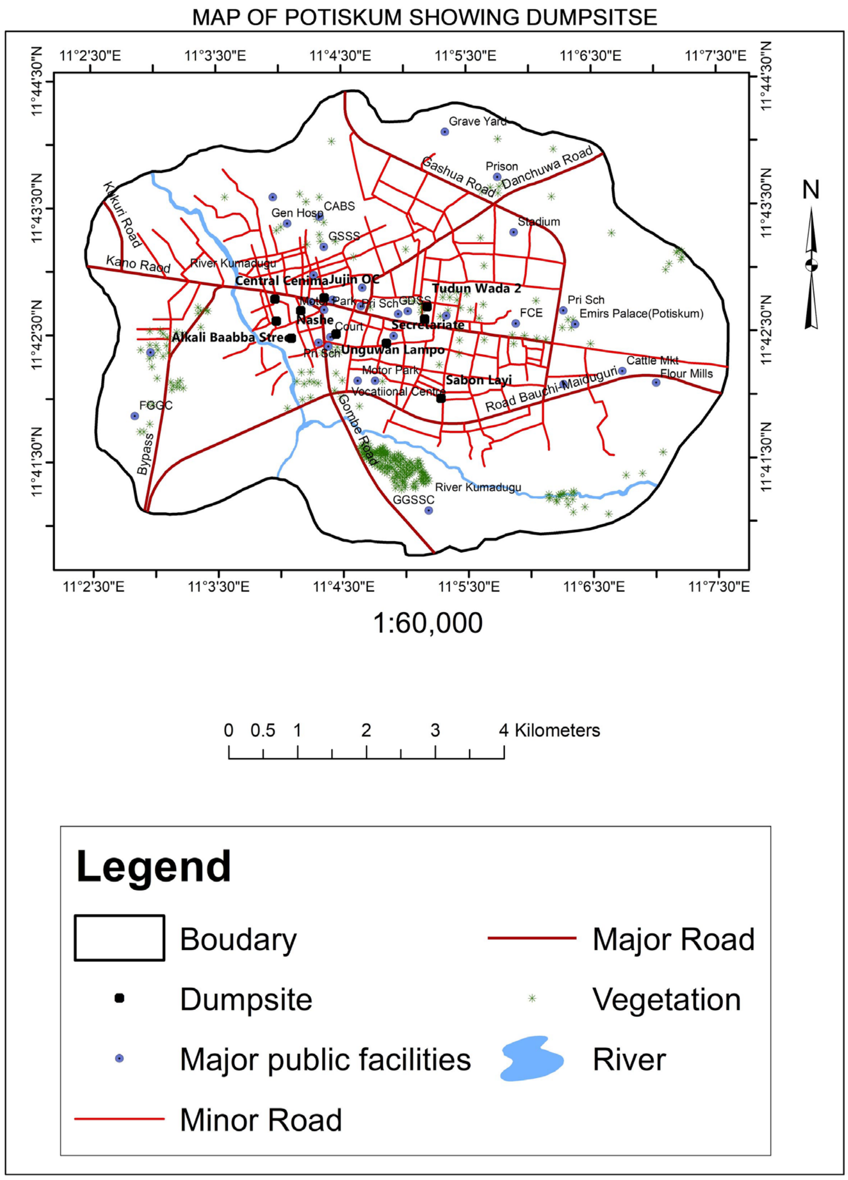

Figure 1. Map of Potiskum local government area showing the chosen dumpsites (map created by authors).

Table 1. Dumpsites location, size and the numbers samples collected per dumpsites.

S/No	Dumpsites	Longitude	Latitude	Dimension	No. of Samples Collected
1	DS1	11˚05'17.2"E	11˚41'59.4"N	9 m length 7 m width	24 replicates
2	DS2	11˚05'09.3"E	11˚42'37.0"N	4 m length 4 m width	18 replicates
3	DS3	11˚05'10.6"E	11˚42'42.7"N	9 m length 5 m width	18 replicates
4	DS4	11˚04'51.0"E	11˚42'25.4'"N	7.1 m length 6.5 m width	12 replicates
5	DS5	11˚04'27.2"E	11˚42'30.2"N	17.5 m length 28 m width	24 replicates
6	DS6	11˚04'05.3"E	11˚42'27.9'"N	10.5 m length 10.5 m width	38 replicates
7	DS7	11˚03'57.7"E	11˚42'36.4"N	17 m length 9 m width	18 replicates
8	DS8	11˚03'58.0"E	11˚42'46.3"N	16 m length 5 m width	14 replicates
9	DS9	11˚04'09.9"E	11˚42'41.7"N	14.5 m length 11 m width	18 replicates
10	DS10	11˚04'21.1"E	11˚42'47.5"N	17.5 m length 4.5 m width	12 replicates

n; the numbers of sample collected on each dumpsite depends largely on the size of the dumpsite as shown in Table 1 and they were collected at random to ensure adequacy and representativeness of the samples and sampling. The bulked sample collected from each dumpsite were then placed in a labelled polyethylene bag and transported to the laboratory for pretreatment.

The dumpsites are represented with DS while subscript attached represents the number of the dumpsites.

2.3. Analysis

Soil samples were digested by dissolving 0.2 g soil in 6ml of concentrated nitric acid (HNO_3), 2 ml of concentrated hydrochloric acid (HCl) and 2 ml of hydrofluoric acid (HF) in a SINEO MASTER 40 microwave digester at a temperature of 120˚C for 15 m, 160˚C for 10 m, 180˚C for 20 m and 200˚C for 30 m respectively. The concentrations of the heavy metals As, Fe, Cd, Cr, Cu, Ni, Pb and Zn in the solution were analyzed with Buck Scientific 210VGB Atomic Absorption Spectrometer (AAS) following manufacturers' protocol.

2.4. Statistical Analysis

One-way ANOVA was deployed to establish significance variations at $p < 0.05$ in the concentration of heavy metals in the soil samples from the selected dumpsites.

3. Results and Discussion

Figure 2 presents the mean dumps soil pH and electrical conductivities in ($mS{\cdot}m^{-1}$).

3.1. Physicochemical Parameters of Some Dumpsites

The mean soil pH ranged from slightly acidic to strongly alkaline with an average

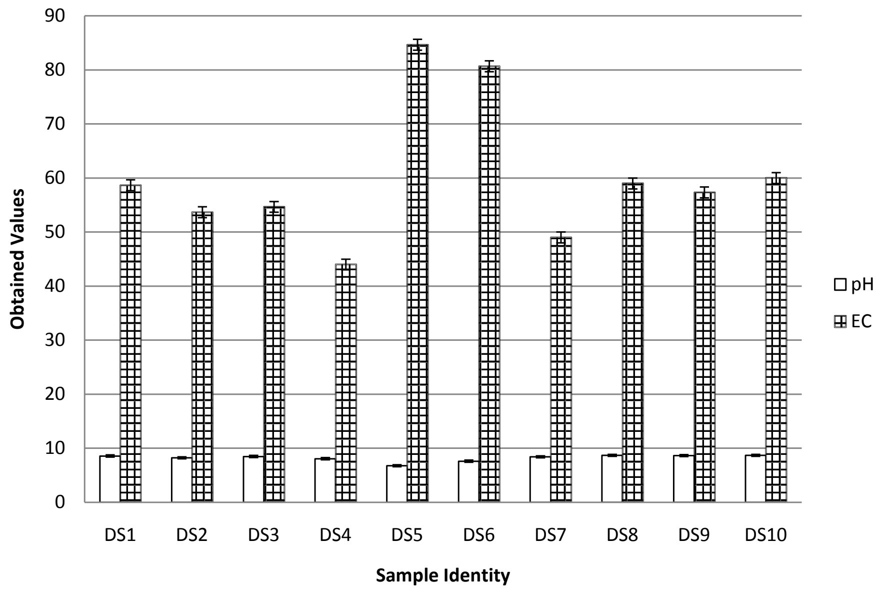

Figure 2. Mean ± SE (n = 10) values for pH and EC of soil samples from studied dumpsites. DS means dumpsites and the assigned numbers show they were ten dumpsites.

values ranged between 6.770 ± 0.05 - 8.677 ± 0.01, the soils are mostly alkaline except in DS5 and DS6 which are slightly acidic and slightly neutral with pH values of 6.770 ± 0.05 and 7.610 ± 0.18 respectively (**Figure 2**). The mean pH values of dump soil obtained in Potiskum dumpsite DS5 was found to be lower than the mean values reported by Anake *et al.* [16] for similar sites in Kano and Kaduna. The dumps soil in some of the dumpsite in Potiskum were found to be more acidic than dumps soils reported in [16]. The mean electrical conductivity (E.C) of dumps soil in Potiskum ranged from 44.000 ± 0.58 - 84.667 ± 0.33 in DS4 and DS5 respectively, values that are lower than the range obtained in Adesewa and Morenikeji [17] and Emereibeole *et al.* [18]. Anake *et al.* [16] found the pH of some dumpsites in Kano and Kaduna range between 7.23 ± 0.17 - 7.75 ± 0.47. Studies on physicochemical properties of soils from choice dumpsites in Owerri revealed mean pH level of 3.60 - 6.90 with E.C ranging from 10.00 - 95.00 $mS \cdot m^{-1}$ [18]. The analysis of pH and E.C of soil from Awotan dumpsites in Ibadan revealed 8.0 ± 1.8 - 8.2 ± 0.2 and 327.1 ± 87.2 - 724.2 ± 226.4 $mS \cdot cm^{-1}$ respectively [17].

3.2. Concentration of Heavy Metals in the Selected Dumpsites

Table 2 showed the concentration of the selected heavy metals in these dumpsites, As and Cd concentrations were the least among the studied metals. The concentrations were found to be 0.270 ± 0.00, 0.067 ± 0.01, 0.130 ± 0.02, 0.197 ± 0.04, 0.100 ± 0.02, 0.070 ± 0.02, 0.080 ± 0.00, 0.077 ± 0.01, 0.053 ± 0.01, 0.033 ± 0.02 ($mg \cdot kg^{-1}$) respectively for DS1, DS2, DS3, DS4, Ds5, DS6, DS7, DS8, DS9 and DS10. While that of Cd ranged between 0.073 ± 0.01, 0.737 ± 0.03, 1.150 ± 0.00, 0.700 ± 0.02, 1.750 ± 0.00, 1.140 ± 0.00, 0.580 ± 0.00, 0.413 ± 0.01, not detected and 0.247 ± 0.01 ($mg \cdot kg^{-1}$) in DS1, DS2, DS3, DS4, DS5, DS6, DS7, DS8,

Table 2. Mean ± SE levels of heavy metals in the selected dumpsites (mg·kg⁻¹).

Dumpsite	As	Cd	Cr	Cu	Ni	Pb	Fe	Zn
DS1	0.270 ± 0.00	0.073 ± 0.01	28.067 ± 0.19	63.008 ± 1.38	5.668 ± 0.52	11.538 ± 0.00	193.056 ± 0.37	201.564 ± 0.33
DS2	0.067 ± 0.01	0.737 ± 0.03	34.337 ± 0.30	117.886 ± 0.07	7.1685 ± 0.45	312.821 ± 0.70	213.856 ± 0.56	180.468 ± 0.65
DS3	0.130 ± 0.02	1.150 ± 0.00	35.537 ± 0.31	77.236 ± 2.03	6.2724 ± 0.12	207.407 ± 0.10	104.412 ± 0.90	168.161 ± 0.87
DS4	0.197 ± 0.04	0.700 ± 0.02	60.870 ± 0.37	113.821 ± 1.07	7.661 ± 0.21	146.51 ± 1.28	172.600 ± 0.34	195.411 ± 0.57
DS5	0.100 ± 0.02	1.750 ± 0.00	59.840 ± 0.50	130.081 ± 1.03	6.944 ± 0.11	295.014 ± 0.56	193.056 ± 0.36	212.992 ± 0.83
DS6	0.070 ± 0.02	1.140 ± 0.00	46.637 ± 0.44	123.984 ± 0.03	6.272 ± 0.22	112.322 ± 0.36	227.150 ± 0.09	197.170 ± 0.34
DS7	0.080 ± 0.00	0.580 ± 0.00	42.220 ± 0.65	81.301 ± 0.04	8.286 ± 0.12	111.966 ± 0.00	124.869 ± 0.93	38.942 ± 0.89
DS8	0.077 ± 0.01	0.413 ± 0.01	42.463 ± 0.32	150.407 ± 0.01	4.0323 ± 0.00	336.325 ± 3.70	186.242 ± 0.02	196.290 ± 0.33
DS9	0.053 ± 0.01	ND	45.507 ± 0.26	115.854 ± 0.00	2.912 ± 0.22	850.570 ± 0.03	158.962 ± 0.65	265.735 ± 0.95
DS10	0.033 ± 0.02	0.247 ± 0.01	39.750 ± 0.26	140.244 ± 0.52	8.961 ± 0.59	240.883 ± 0.10	220.331 ± 0.74	176.952 ± 0.05

DS1 - Dumpsite 1, DS2 - Dumpsite 2, DS3 - Dumpsite 3, DS4 - Dumpsite 4, DS5 - Dumpsite 5, DS6 - Dumpsite 6, DS7 - Dumpsite 7, DS8 - Dumpsite 8, DS9 - Dumpsite 9 and DS10 - Dumpsite 10 and ND - not detected. The Standards Set for studied heavy metals in soils by WHO are; As: 40 mg·kg⁻¹, Cd: 0.8 mg·kg⁻¹, Cr: 100 mg·kg⁻¹, Cu: 100 mg·kg⁻¹, Ni: 35 mg·kg⁻¹, Pb: 85 mg·kg⁻¹, Fe: 7000 mg·kg⁻¹ and Zn: 300 mg·kg⁻¹.

DS9 and DS10 respectively. Observed arsenic concentrations in these dumpsites were below the WHO permissible limits in mg·kg⁻¹ of 40 set by the world health organization for soils while concentration of Cd was below the standards of 0.8 mg·kg⁻¹ in DS1, DS2, DS4, DS7, DS8 and DS10, exceeded in DS3, DS5, DS6 and not detected in DS9 [19]. Results of the correlation analysis also showed strong negative correlation between As with Cd, Cr, Cu, Ni, Pb and Fe but have weak negative correlation with Zn (Table 3).

Chromium, nickel, iron and zinc concentrations in mg·kg⁻¹ of 100, 35, 7000 and 300 permissible limits set by WHO respectively were not exceeded in all the dumpsites, Cu concentration exhibit strong negative correlation with Ni but has weak positive correlation with Pb and Zn (Table 3). The concentrations of Cr and Ni in these dumpsites ranged between 28.067 ± 0.19, 34.337 ± 0.30, 35.537 ± 0.31, 60.870 ± 0.37, 59.840 ± 0.50, 46.637 ± 0.44, 42.220 ± 0.65, 42.463 ± 0.32, 45.507 ± 0.26 and 39.750 ± 0.26 while the observed concentration of Ni were 5.668 ± 0.52, 7.1685 ± 0.45, 6.2724 ± 0.12, 7.661 ± 0.21, 6.944 ± 0.11, 6.272 ± 0.22, 8.286 ± 0.12, 4.0323 ± 0.00, 2.912 ± 0.22 and 8.961 ± 0.59 respectively for DS1, Ds2, DS3, DS4, DS5, DS6, DS7, DS8, DS9 and DS10 (Table 2).

The content of copper observed in these dumpsites exceeded the WHO permissible limits in mg·kg⁻¹ of 100 except in DS1, DS3 and DS7. Observed copper concentration showed strong negative correlation with Ni but has weak negative correlation with Pb, Fe and Zn (Table 3). The concentration was 63.008 ± 1.38, 117.886 ± 0.07, 77.236 ± 2.03, 113.821 ± 1.07, 130.081 ± 1.03, 123.984 ± 0.03, 81.301 ± 0.04, 150.407 ± 0.01, 115.854 ± 0.00 and 140.244 ± 0.52 mg·kg⁻¹ for DS1, DS2, DS3, DS4, DS5, DS6, DS7, DS8, DS9 and DS10 respectively.

Table 2 showed that Pb concentration in the selected dumpsites fell above the WHO permissible limits of 85 mg·kg⁻¹ of except in DS1 with concentration of 11.538 ± 0.00, 312.821 ± 0.70, 207.407 ± 0.10, 146.51 ± 1.28, 295.014 ± 0.56,

Table 3. Correlation coefficient (r) for selected heavy metals in Potiskum dumpsites.

	As	Cd	Cr	Cu	Ni	Pb	Fe	Zn
As	1							
Cd	−0.09356	1						
Cr	−0.11095	0.487347	1					
Cu	−0.63995	0.118235	0.462966	1				
Ni	−0.01617	0.294681	0.109406	−0.07221	1			
Pb	−0.51002	−0.26666	0.150556	0.373851	−0.6346	1		
Fe	−0.15099	−0.02691	0.051028	0.575319	0.112785	−0.09179	1	
Zn	0.069744	−0.07915	0.178475	0.366681	−0.61707	0.544059	0.398163	1

The value of correlation coefficient (r) was calculated using SPSS v 20.

112.322 ± 0.36, 111.966 ± 0.00, 36.325 ± 3.70, 850.570 ± 0.03 and 240.883 ± 0.10 for DS1, DS2, DS3, DS4, DS5, DS6, DS7, DS8, DS9 and DS10 respectively. Lead concentration showed strong negative correlation with Fe but have weak positive correlation with Zn (Table 3).

4. Conclusion

The concentrations of As, Cd, Cr, Cu, Ni, Pb, Fe and Zn were evaluated in selected dumpsites from Potiscum; the mean concentrations of metals from these dumpsites in $mg \cdot kg^{-1}$ were found to be in the sequence Pb > Zn > Fe > Cu > Cr > Ni > Cd > As with strong positive correlations between Pb and Zn. Elevated concentrations of Pb, Cd and Cr above WHO standards call for reasoned and careful monitoring as these persistent metals are capable of accumulation over time along the food chain. These worrisome levels of Pb, Cd and Cr suggest that municipal solid wastes are sinks of heavy metals and therefore require treatment before application as soil conditioners.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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