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Assessment of Contamination Pattern of Municipal Solid Waste Dumpsites on Arid Soil: A Comparative Study of Maiduguri Metropolis

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Abstract Soil sample assessment was conducted on five dumpsites located within Maiduguri Metropolis, Nigeria. These includes; Bulunkutu (BLKT), Railway (RLWY), State Low-cost (STLC), Infectious Disease Hospital (IDH) and Nigerian National Petroleum Corporation (NNPC) depot. Soil samples were collected at each site while the controls were collected 10 m away from each site. Heavy metals were analyzed using AAS Perkin Elmer Model. These include; Cobalt, Arsenic, Cadmium, Chromium, Copper, Iron, Manganese, Nickel, Lead and Zinc. Physicochemical parameters such as pH, Electrical conductivity (EC) and Temperature were also determined. The mean value and Standard Deviation (SD) of the results were calculated. Most of the dumpsite soils were found to be slightly alkaline with pH range of 8.09 ± 0.04 – 8.32 ± 0.03 recorded for IDH and Bulunkutu. Pearson correlation results showed strong and significant relationship between concentrations of some heavy metals and physicochemical parameters at α=0.05 levels. Bulunkutu soil sample pH correlates strongly and significantly with the concentrations of Cd and Cu respectively. Geoaccumulation index showed moderate to strong levels of contamination, Railway and NNPC Depot dumpsites showed no trace of contamination while Bulunkutu dumpsite indicated strong Co and P contamination.

Keywords: *Maiduguri, Bulunkutu, NNPC depot, pearson correlation, physicochemical parameters*

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1. Introduction

Solid wastes could be defined as non-liquid and non-gaseous products of human activities, regarded as being useless. It could take the forms of refuse, garbage and sludge [1]. There are fast growing cities in Nigeria that are faced with the problem of solid waste generation [2]. The implication is serious when a country is growing rapidly and the wastes are not efficiently managed. Waste generation scenario in Nigeria has been of great concern both globally and locally. Of the different categories of wastes being generated, solid wastes had posed a hydra-headed problem beyond the scope of various solid waste management systems in Nigeria [3]. Municipal solid waste (MSW), also called urban solid waste, is a waste type that includes predominantly household waste (domestic waste) with sometimes the addition of commercial wastes collected by a municipality within a given area. They are in either solid or semisolid form and generally exclude industrial hazardous wastes. The term residual waste relates to waste left from household sources containing materials that have not been separated out or sent for reprocessing [1].

Sources of solid waste generation in Nigeria among others are commercial, industrial, household, agricultural and educational establishments. The solid waste types include paper, nylon, wood, dust, cloth, metal scraps, electronic gadgets, bottles, food remnants and vegetables; saw dust, ashes, rubber, bones and plastics [4]. Several thousand used computers are imported to Nigeria through Lagos seaport monthly and many of them lose the desired value within a short time, ending up to build the e-waste pile in Nigeria [5].

Local farmers within and around the Maiduguri Metropolis are in the practice of using dumpsite soils on farms and vegetable orchards. This paper reports the heavy metal levels and other contamination parameters in the wastes dumpsites within Maiduguri metropolis in order to enlighten farmers on the dangers associated with the practice.

2. Materials and Method

2.1. Sample Collection

The soil samples were collected in 1.0 dm^3 plastic containers; they were randomly collected from the selected points within the metropolis. The controls were

collected at about 10 meters away from the refuse dump sites by digging about 1 - 30 cm into the soil. The samples were collected in the month of December 2010; Samples were collected in the morning and evening hours at the different locations.

2.2. Sample Preparation and Analysis

About 20 g of each of the soil sample was weighed into a pre-weighed crucible and then placed in a Carbolite Furnace. The temperature was raised to 1000°C and then maintained for two hours. The ashed soil samples were removed and cooled in a desiccator and then preserved for further studies.

The already ashed soil samples were digested as follows; each ashed soil sample (20 g) was placed in to a 200 cm^3 beaker. Concentrated nitric and hydrochloric acids (10 cm^3) in a ration of 1:3 v/v were added to each. The beakers were covered with watch glasses and heated on hot plate until all the white fumes of nitric acid were expelled. They were removed, allowed to cool and content of each was washed with de-ionized water and placed into a 500 cm^3 volumetric flask and diluted to the mark with de-ionized water. The resulting sample solutions were used for heavy metal analysis.

3. Experimental Procedures

Analyst 400, Perkin Elmer model of the AAS was used for the analysis of the heavy metal in the samples. Standards were prepared for heavy metals of interest and the instrument was calibrated and then a calibration curves was plotted. Concentrations of the different metals were read from the computer screen.

4. Results and Discussion

The results of the physicochemical parameters, pH and EC, as well as the concentrations of the heavy metal in the soils sample such as Co, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn are presented on Table 1 & Table 2 respectively. The soils samples are found to be alkaline, with BLKT and IDH soil samples showing the highest and lowest pH values, 8.32 ± 0.03 and 8.09 ± 0.04 respectively. NNPC depot and RLWY dumpsite soil samples showed the highest (1.15 ± 0.04 mg/kg) and lowest (0.44 ± 0.00 mg/kg) concentrations for Co respectively. However, some control soil samples concentrations of Co were below detectable levels. Heavy metals like As, Cd, Ni and Pb were also found in varying degree of concentrations. Heavy metal concentrations in the various samples vary in the following order: Fe > Mn > Cr > Cu > As> Cd > Pb > Zn > Co > Ni.

Table 1. Mean Values of Physicochemical Parameters of Soil

SITES	pH		EC (us/cm)	
	Soil	**Control**	**Soil**	**Control**
BLKT	8.32±0.03	7.32±0.03	1438±11.31	853±33.23
RLWY	8.20±0.01	7.65±0.16	1353±18.38	632±11.31
STLC	8.17±0.02	7.81±0.10	1228±12.02	335±7.78
IDH	8.09±0.04	7.45±0.08	1245±13.43	351±9.19
NNPC	8.29±0.03	7.72±0.04	1392±8.48	652±25.45

BLKT →Bulunkutu, RLWY →Railway Area, STLC → State Low – Cost, IDH→ Infection Disease Hospital, NNPC → Nigeria National Petroleum Corporation Depot.

Table 2. Mean Concentration of Soil Heavy Metals from Municipal Dumpsite in mg/kg

SITES	Co		As		Cd		Cr		Cu	
	S	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**
BLKT	0.65±0.00	ND	3.48±0.07	0.08±0.00	0.54±0.02	0.03±0.00	0.24±0.02	0.07±0.01	0.41±0.01	0.01±0.00
RLWY	0.44±0.00	ND	3.91±0.04	0.36±0.28	2.29±0.06	0.05±0.03	1.79±0.04	0.07±0.00	2.69±0.09	0.01±0.00
STLC	0.85±0.01	0.01±0.00	2.69±0.22	0.05±0.00	1.61±0.03	0.02±0.00	1.90±0.04	0.06±0.01	2.39±0.06	0.07±0.00
IDH	0.68±0.03	0.05±0.00	2.38±0.03	0.06±0.01	1.48±0.06	0.01±0.00	1.42±0.05	0.02±0.00	1.76±0.04	0.02±0.00
NNPC	1.15±0.04	ND	3.42±0.10	0.11±0.00	1.20±0.03	0.03±0.01	8.39±0.24	0.80±0.00	4.02±0.08	0.05±0.00
SITES	Fe		Mn		Ni		Pb		Zn	
	S	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**
BLKT	74.22±2.33	9.51±0.08	32.19±0.11	4.32±0.06	0.53±0.01	ND	0.39±0.00	0.07±0.01	10.45±0.18	0.01±0.00
RLWY	8.51±0.04	2.72±0.05	2.19±0.04	0.34±0.01	2.43±0.01	0.01±0.00	1.78±0.08	0.63±0.02	5.64±0.13	0.01±0.00
STLC	63.99±1.09	4.96±0.95	22.43±1.08	3.56±0.16	1.45±0.11	0.05±0.00	1.31±0.05	0.03±0.00	4.29±0.09	1.76±0.12
IDH	4.69±0.07	1.53±0.01	1.60±0.08	0.06±0.01	1.41±0.04	0.88±0.05	1.60±0.08	0.06±0.01	4.07±0.06	1.48±0.04
NNPC	84.33±0.65	13.18±0.04	67.45±0.30	7.84±0.55	2.94±0.11	0.06±0.02	1.12±.014	0.04±0.00	16.94±0.59	0.21±0.02

BLKT - Bulunkutu, RLWY - Railway, STLC - State Low–Cost, IDH - Infection Disease Hospital, NNPC – Nigeria National Petroleum Corporation Depot, S - Soil and C - Control and ND - Not Detected

Two heavy metals that are found in greater concentrations are iron (84.33 ± 0.65 mg/kg) and manganese (67.45 ± 30 mg/kg), in NNPC Depot dumpsite samples. The high concentrations of iron and manganese in these dumpsites may be attributed to the metal scraps dumped there by the activities of automobile mechanics workshops clustered around them.

Bulunkutu Municipal dumpsite showed that Fe and Mn are the two prominent heavy in metals present (Figure 1) Zn and Cu come next but they do not appear in the controls. The correlation coefficient showed that there is strong correlation between the two metals ($r = 0.987$) but is not significant at $\alpha = 0.05$ and $p = 0.103$ levels of significance.

In Railway Municipal dumpsite all the heavy metals analyzed are found to be in relatively equal amounts but Fe, Zn and As are higher. There is no significant correlation between either Fe/As or Fe/Zn at $\alpha = 0.05$ levels; Fe/As $r = 0.991$, $p = 0.087$ and Fe/Zn $r = 0.771$ $p = 0.439$.

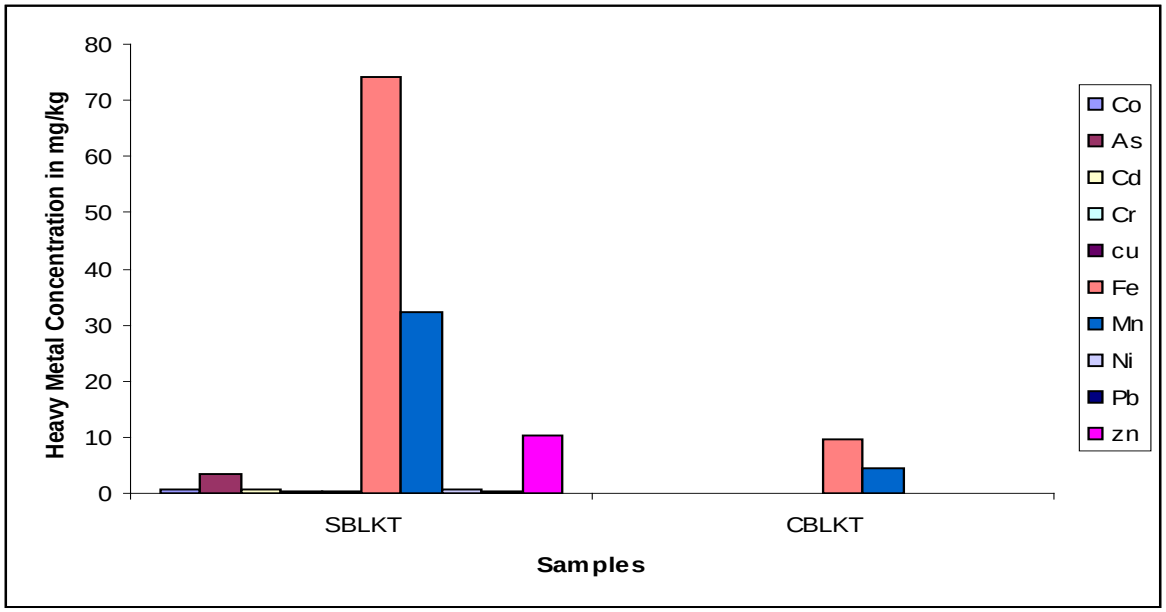

Figure 1. Variation of Heavy Metals at Bulunkutu Municipal Dumpsite

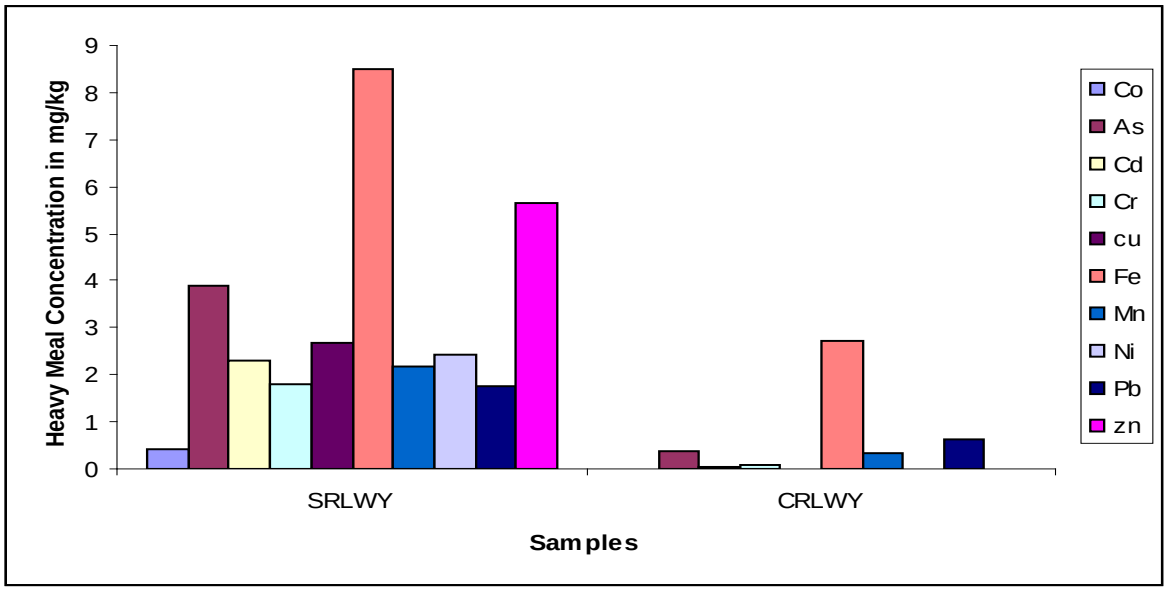

Figure 2. Variation of Heavy Metals at Railway Municipal dumpsite

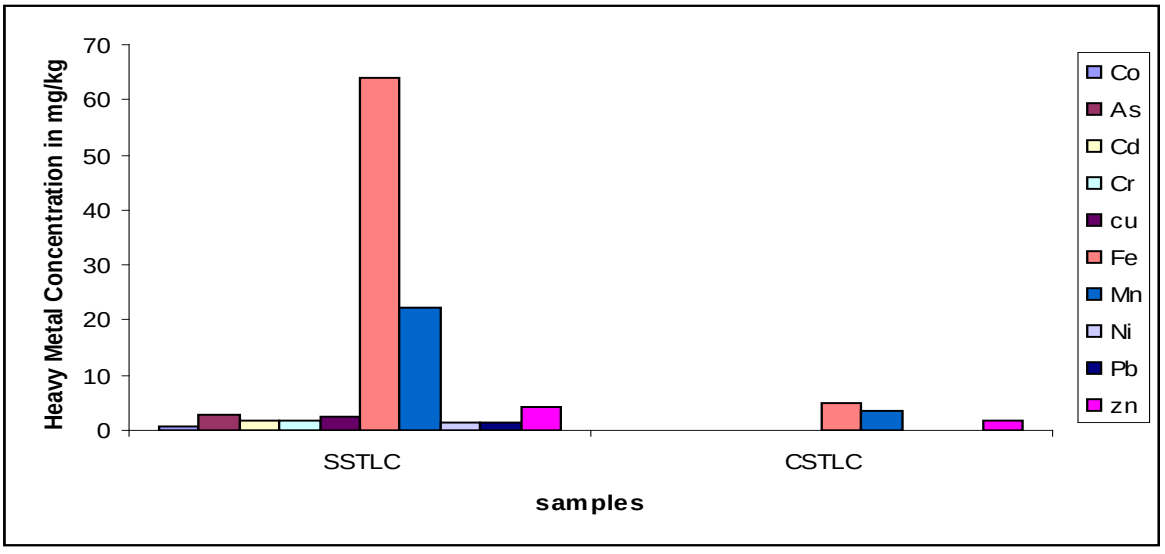

Figure 3. Variation of Heavy Metals at State Low – cost Municipal dumpsite

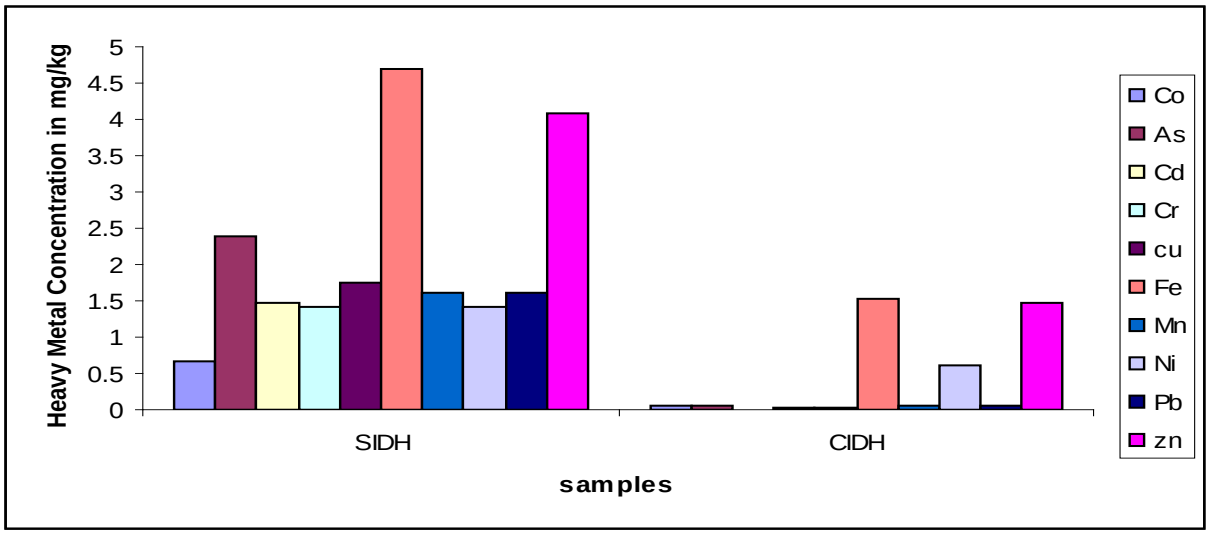

Figure 4. Variation of Heavy of Metals at IDH Municipal Dumpsite

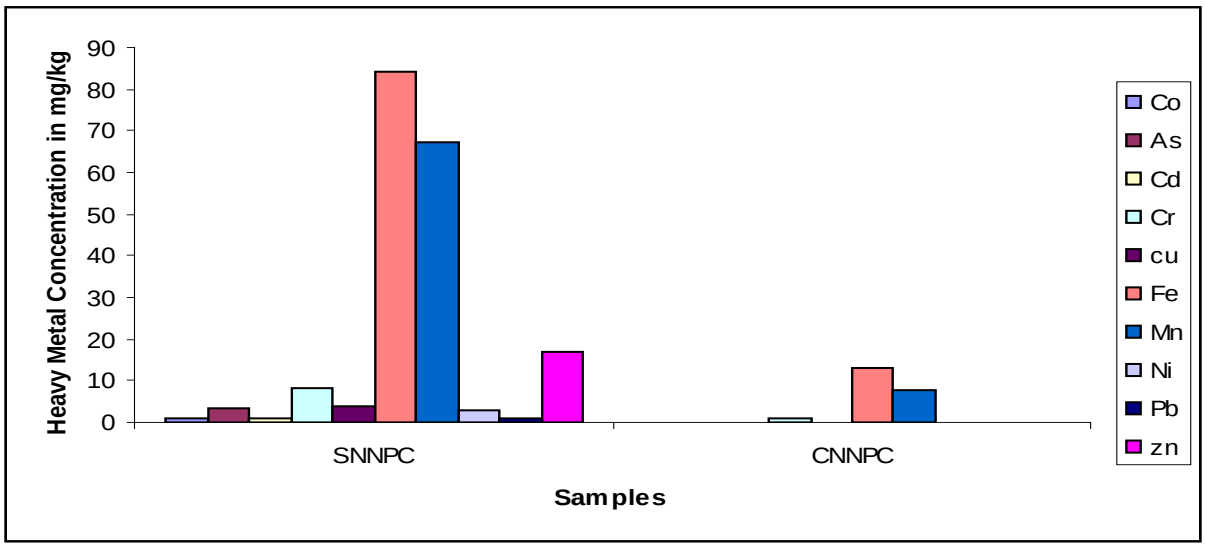

Figure 5. Variation of Heavy Metals at NNPC Depot Municipal dumpsite

Iron concentration was observed to be high (63.99 ± 1.09 mg/kg) followed by manganese (22.43 ± 1.08 mg/kg), the remaining eight heavy metals are relatively low with concentrations below 10 mg/kg. The product moment correlation coefficient for State Low-cost revealed that there is was a strong linear relationship between Fe/Mn, r = 0.960 but is not significant at $\alpha = 0.05$ and p = 0.181.

Infectious diseases hospital dumpsite samples had all heavy metals of interest in moderate amounts with iron, zinc and Arsenic in higher ranges. Fe/Zn r = 0.435, p = 0.714 and As/Zn r = 0.685, p = 519 correlation coefficients for IDH dumpsite samples showed that there was no significant relationship at $\alpha = 0.05$. Fe/As correlation for the same site showed strong linear relationship but was not significant at $\alpha = 0.05$.

Concentrations of iron (84.33 ± 0.65 mg/kg) and manganese (67.45 ± 0.30 mg/kg) for NNPC Depot dumpsite are higher compared with the other heavy metals from the same site. These results are however, far lower to than that reported by David et al.; 2008 (56.42 – 280 ppm) iron and Eddy et al.; 2006 [6] (200 – 9000 ppm) respectively. Correlation coefficient for iron and manganese for the site showed r = 0.751 and p = 0.459 but the relationship was not significant at $\alpha = 0.05$ levels.

5. Conclusion

Variation of heavy metal concentration between the different study areas could be generally attributed to the population densities and the degree of commercial and industrial activities in the respective areas. The elevated levels of Cd (2.29 ± 0.06mg/kg), Co (1.15 ± 0.04) and As (3.91 ± 0.04mg/kg) in Railway, NNPC Depot and Bulunkutu dumpsites respectively is of great concern, since those metals constitutes serious health hazards. All the heavy metals do have health factors too, at high concentrations.

The independent t – test result for Bulunkutu and State Low – cost showed that with the exception of Pb and Zn, all other soil parameters determined in the two sample sites had no significant difference. Bulunkutu and IDH t – test result however, indicates that Fe, Mn and Zn are significantly different for the two dumpsites.

In general, the t – test result for the five dumpsite soils analyzed, showed no significant difference, only Pb indicates significance.

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