Concentration of Heavy Metals in Soil around Dumpsites in Jimeta and Ngurore, Adamawa State, Nigeria

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Abstract

Rapid urbanization and industrialization in developing countries have been associated with production and deposition of hazardous wastes in the soil environments. Heavy metals are major components of these wastes and have been implicated in several metal-related diseases and food poisoning in man. This study examined the concentration of Iron (Fe), Lead (Pb), Copper (Cu), Chromium (Cr), and Cadmium (Cd) heavy metals in soil near dumpsites of Jimeta and Ngurore, Yola North Local Government Areas (LGAs), Adamawa State. Soil samples from 0-20cm layer depth were collected in triplicates and analyzed using atomic absorption spectrophotometer (AAS). Results reveal that Fe, Pb, Cu and Chromium were detected, while Cadmium was found to be below the limit of detection. The mean concentration of the exchangeable cation in mg/kg in soil at Jimeta sites were: Fe (31.4 mg/kg) >Pb (0.92 mg/kg) > Cu (0.34 mg/kg) > Cr (0.11 mg/kg) >Cd (below limit of detection), while the mean concentration of the heavy metals in soil at Ngurore sites were: Fe (32 mg/kg) >Pb (0.83 mg/kg) > Cu (0.28 mg/kg) > Cr (0.07 mg/kg) >Cd (below limit of detection), respectively. Iron (Fe) was the most abundant element in both sites, followed by Pb. Heavy metal concentrations in soil followed the order of Fe>Pb>Cu>Cr>Cd, respectively. The paired T-test analyses for concentration of Cr, Fe, and Pb in soil near the two dumpsites show that there were statistically significant differences in the concentration levels of Cr, Fe, and Pb, while Cu showed no statistically significant difference between the two dumpsites. However, all the metals detected were below the permissible limit of WHO international standard with the exception of Pb whose concentration was above maximum permissible concentration (MPC). Persistent heavy metals accumulation in soils near these dumpsites may lead to increase uptake by vegetables grown near thedumpsites and this may pose a threat to its quality and safety and ultimately human health. The need to replace open dumpsites with well-designed landfills is advised.

Keywords: Heavy metals, Soil contamination, Dumpsite, Solid waste. Jimeta-Ngurore.

Introduction

Heavy metals are non-biodegradable and their persistent contamination of the environment is a great source of concern. The use of dumpsite soils as organic manure is widespread, this practice have been known to improve soil properties such as organic matter, nutrients, porosity, aggregate stability, bulk density and water retention, and as a result, increase plant productivity (Oluyemi *et al.*, 2008; Olarinoye *et al., 2010*). However, it is a known fact that some of the waste products contain hazardous metals such as Cr, Pb, Cd, Fe, and Cu, which perturb the distribution and concentration of these metals in the environment. Recent studies have also revealed that the waste dumpsite can transfer significant levels of these toxic and persistent metals into the soil environment (Adelekan and Alawode, 2011; Abdallah*et al.*, 2011). The presence of heavy metals such as cadmium (Cd), lead (Pb) and chromium (Cr) in agricultural soils are mostly influenced by anthropogenic activity (Fytianos*et al.*, 2001). Elevated concentrations of these metals inhibit plant growth parameters; including respiration, photosynthesis, water and nutrient uptake, resulting in reduction of plant production (Ali *et al.*, 2015). Elevated concentration of toxic elements in soil are result of different anthropogenic activities, environmental pollution from industrial emission, utilization of waste water for irrigation, certain agricultural practices, application of nitrogen and phosphorous fertilizers, atmospheric depositions during transportation and marketing, etc. (Sharma *et al.*, 2006; Nikolic*et al.*, 2014). The rapid urbanization and industrialization have caused elevation of heavy metals content in urban environments in different developing countries (Radwan and Salama 2006; Sharma *et al.*, 2008a; Kiende *et al.*, 2012). Rapid and unorganized urban and industrial developments have contributed to the elevated levels of heavy metals in the urban environment of developing countries such as Egypt (Radwan and Salama, 2006), Iran (Maleki and Zarasvand, 2008), China (Wong *et al.*, 2003) and India (Marshall, 2004; Sharma *et al.*, 2008b).

Emissions of heavy metals from industries and vehicles may be deposited on soil surfaces increasing soil contamination (Al Jassir*et al.*, 2005). Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Khan *et al.*, 2008). Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those most commonly found at contaminated sites are: Lead (Pb), Chromium (Cr), Arsenic (As), Zinc (Zn), Cadmium (Cd), Copper (Cu), Mercury (Hg), and Nickel (Ni). Soils are the major sinks for heavy metals released into the environment by aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (iv) oxide by microbial action, most metals do not undergo microbial or chemical degradation, and their total concentration in soils persists for a long time after their introduction (Adriano, 2003). The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants. Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated ground water, reduction in food quality (safety and marketability) through phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems (McLaughlin, 2000).

The adequate protection and restoration of soil ecosystems contaminated by heavy metals require their characterization and remediation. Contemporary legislation respecting environmental protection and public health, at both national and international levels, are based on data that characterize chemical properties of environmental phenomena, especially those that reside in our food chain (Kabata and Pendias, 2001). While soil characterization would provide an insight into heavy metal speciation and bioavailability, attempt at remediation of heavy metal contaminated soils would entail knowledge of the source of contamination, basic chemistry, and environmental and associated health effects (risks) of these heavy metals. Risk assessment is an effective scientific tool which enables decision makers to manage sites so contaminated in a cost-effective manner while preserving public and ecosystem health (Zhao and Kaluarachchi, 2002).

Immobilization, soil washing, and phytoremediation techniques are frequently listed among the best demonstrated available technologies (BDATs) for remediation of heavy metal-contaminated sites. In spite of their cost-effectiveness and environment friendliness, field applications of these technologies have only been reported in developed countries. In most developing countries, these are yet to become commercially available technologies possibly due

to the inadequate awareness of their inherent advantages and principles of operation. With greater awareness by the governments and the public of the implications of contaminated soils on human and animal health, there has been increasing interest amongst the scientific community in the development of technologies to remediate contaminated sites. In developing countries with great population density and scarce funds available for environmental restoration, low-cost and ecologically sustainable remedial options are required to restore contaminated lands so as to reduce the associated risks, make the land resource available for agricultural production, enhance food security, and scale down land tenure problems (Zhao and Kaluarachchi, 2002).

Permissible levels of heavy metal content in soilwere compared with Maximum permissible concentrations (MPC) values recommended by WHO.

Heavy metal	Cd	Pb	Cr	Fe	Cu
Permissible levels in soil set up by WHO	0.2	0.3	2.3	65	0.3

There is lack of studies which determine the pollution level created due to the dumpsite at any particular location in most of the developing countries. Therefore, this study was designed with the aim of assessing the pollution level of the dumpsite due to the application of solid waste, through the determination of selected physicochemical parameters in the soil of the dumpsite and its surrounding areas located at Jimeta and Ngurore with potential ecological and public health risk. It will further provide basis for further actions in regards to existing environmental challenges.

Materials and methods

Description of the Study Area

The study was conducted in Jimeta and Ngurore, Yola-North LGA, respectively, Adamawa Central, North-Eastern Nigeria. The area lies between latitude 9° 15' N 12° 25' E and longitude 9° 20'N 12° 30E, covering a total area of 1,213.30 sq.km^2 (Figure 1 and Figure 2). The coordinates for the respective dumpsites is shown in table 1. The area has a tropical climate, marked by dry and rainy seasons. The rainy season commences around May and ends in the middle or late October. The rainfall is characterized by a single maximum with a mean total rainfall of 1,113.3mm.The dry season starts in late October and ends in late April (Adebayo and Tukur, 1999). Maximum temperatures in Yola can reach 40°C, around April, while minimum temperature could be as low as 18.30 °C between December and early January, which marks the harmattan season characterized by northeast westerly winds that blows across the Sahara desert carrying with it dust particles. Relative humidity in the area is about 26% in the months of January, while February is the lowest; with high relative humidity values of 58, 69, 79, 79, 77 and 66, respectively which could be recorded during the months of May to October, particularly during the months of July and August as the peak, with about 80% relative humidity (Adebayo and Tukur, 1999). Most inhabitants in the area are civil servants, traders, fishermen, farmers and cattle rearing.

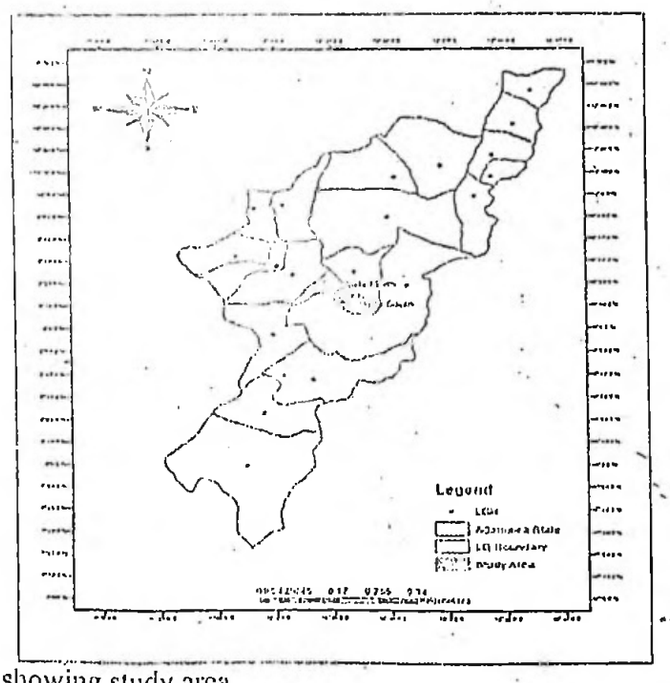


Fig. 1: Map of Adamawa showing study area.

Collection of samples

Soil samples were collected from six (6) sites each within the dumpsite vicinity of Jimeta and Ngurore areas. One (1) soil sample was collected from six (6) sites making a total of twelve (12) soil samples, six for each study area mentioned. Soil samples were collected at depth between 0 –20 cm, to serve as future surveillance points, coordinates of these points were recorded using global positioning system (Garmin, GPS72H).

Table 1: Sampling coordinates at the study area

S/N	LGA	Dumpsite	Ward	Latitude (N)	Longitude(E)
1	Yola-North	Jimeta	Dobeli	9.287804^{0}N	12.458260^{0}E
				9.287644^{0}N	12.458201^{0}E
				9.288050^{0}N	12.457797^{0}E
				9.287317^{0}N	12.457571^{0}E
				9.287517^{0}N	12.456770^{0}E
				9.287451^{0}N	12.455511^{0}E
2	Yola-South	Ngurore	Ngurore	9.287485^{0}N	12.233566^{0}E
				9.287175^{0}N	12.233432^{0}E
				9.287721^{0}N	12.233568^{0}E
				9.287335^{0}N	12.233653^{0}E
				9.287359^{0}N	12.233500^{0}E
				9.286963^{0}N	12.233211^{0}E

Source: Field Survey 2018

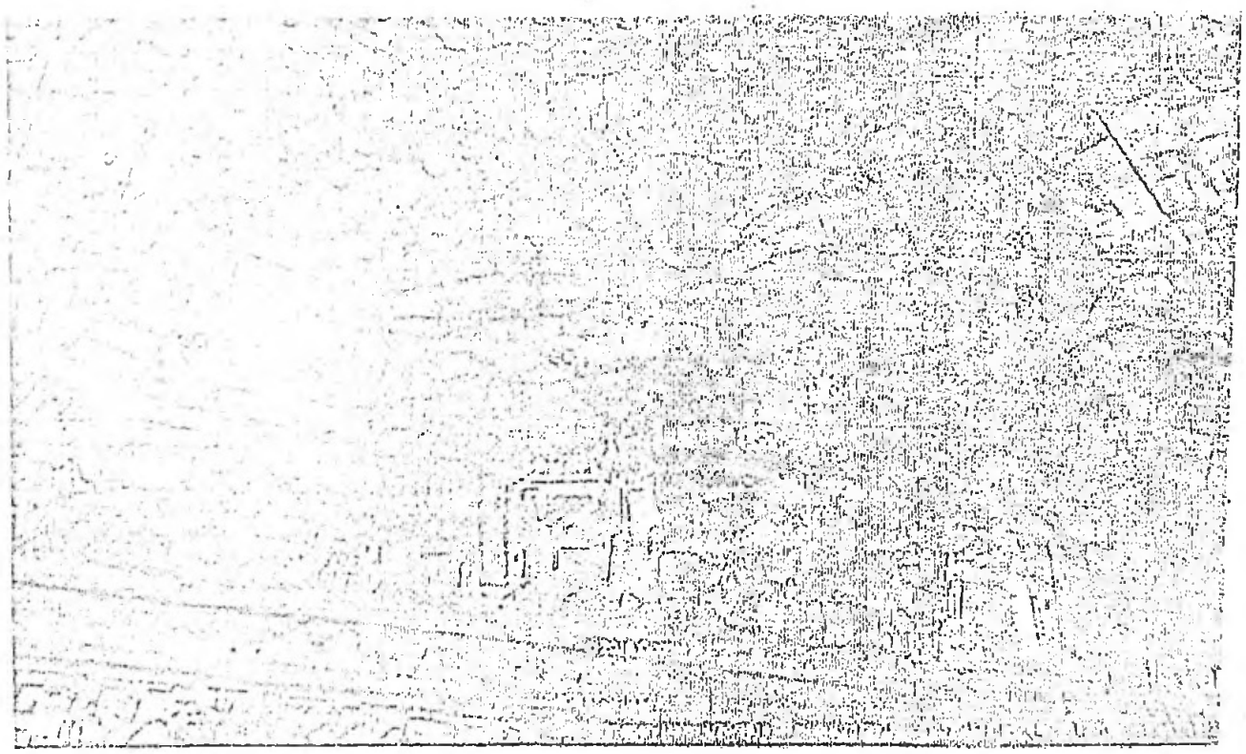


Fig. 2: Soil sampling locations near Jimeta city solid waste dumpsite, 2018.

Soil samples were dried at room temperature and then kept in an oven at 65°C for 24hrs before being grinded using an electric grinder. The soil samples were further sieved to 1 mm size. About 6.00 g of the powder from each soil sample was mixed with 1.35 g of starch binder and placed into a polished lapped thrust piece with smooth surface and fixed into hydraulic press machine. The pellets in pressed tablets were obtained by applying an average pressure of 20 bars. (FAO/WHO 2 Chailapakul*et al.*, 2007; Wuana and Okie 2011).Determination of the heavy metals su Cu, Cr, Fe, Cd and Pb in the filtrate of soi achieved by Atomic Absorp Spectrophotometer (Air Acetylene I intergraded mode, Buck 210VGP) afte digestion with a mixture of HCl and HNO_3 Laboratory. The pH value was also determin

using glass electrode method with a standard calibrated pH meter (Gupta *et al.*, 2008; Khan *et al.*, 2008).

Statistical Analysis

SPSS Version 22.0 was used for analysis. The data obtained were subjected to descriptive and inferential statistics. Descriptive statistics mainly mean and standard deviation was used to describe the concentration levels of heavy metals in soil near Jimeta and Ngurore dumpsites. The recorded data was also subjected to Paired T-Test to assess the difference in heavy metals concentration in soil near the two dumpsites. The level of significance was set at P 0.05.

Results

The results pertaining Cadmium (Cd) was omitted because Cd concentration was below the instrumental detection limit in all the soil samples. The maximum permissible concentrations (MPC) of Fe, Cu, Cr, Pb and Cd in dry soil vary in comparison to standard values set up by (FAO/WHO, 2007). Levels of heavy metals Concentrations in soil near Jimeta dumpsite show that in Site 1: Fe with (27.54mg/kg) recorded the highest metal concentration, followed by Cu (0.44mg/kg), Pb (0.28mg/kg), Cr (0.1mg/kg) while Cd was not detected in the sample. In site 2: Fe with (35.68mg/kg) recorded the highest metal concentration, Followed by Pb (1.19mg/kg), Cu (0.13mg/kg), Cr (0.1mg/kg), Cd (ND) was beyond the detection limit. Site 3: Fe (33.39mg/kg) indicated the highest metal concentration in soil, followed by Pb (1.35mg/kg) and Cu (0.58mg/kg), Cr (0.01mg/kg) and Cd was beyond the limit of detection. Site 4: Fe (24.34mg/kg) recorded the highest metal concentration in soil, followed by Cu (0.32mg/kg), Pb (0.23mg/kg), Cr (0.2mg/kg), and Cd was not detected (ND). Site 5: Fe with (36.22mg/kg) showed the highest metal concentration in soil, followed by Pb (1.2mg/kg), Cr (0.2mg/kg), Pb (0.14mg/kg) and the least was Cd (ND). Site 6: Indicated that Fe with (31.28mg/kg) recorded the highest concentration of metals, followed by Pb (1.29mg/kg), Cu (0.44mg/kg), Cr (0.02mg/kg), and Cd was beyond the detection of limit (Table 2).

Heavy metals Concentrations in soil at Ngurrore dumpsite indicated that in Site 1: Fe with (34.484mg/kg) recorded the highest metal concentration, followed by Cu (0.31mg/kg), Pb (0.22mg/kg), Cr (0.1mg/kg) and Cd was beyond the detection limit. In site 2: Fe with (31.23mg/kg) recorded the highest metal concentration, Followed by Pb (1.04mg/kg), Cu (0.283mg/kg). Cr (0.1mg/kg) and Cd (ND) were not detected. Site 3: Fe (29.71mg/kg) indicated the highest metal concentration in soil, followed by Pb (1.24mg/kg) and Cu (0.28mg/kg), Cr (0.1mg/kg) and Cd was beyond the limit of detection. Site 4: Fe (35.33mg/kg) recorded the highest metal concentration in soil, followed by Cu (0.31mg/kg), Pb (0.3mg/kg), Cr (0.09mg/kg), and Cd was not detected (ND). Site 5: Fe with (28.43mg/kg) showed the highest metal concentration in soil, followed by Pb (1.03mg/kg), Cu (0.27mg/kg), Cr (0.1mg/kg) and the least was Cd (ND). Site 6: Indicated that Fe with (33.31mg/kg) recorded the highest concentration of metals, followed by Pb (1.2mg/kg), Cu (0.27mg/kg), Cr (0.01mg/kg), and Cd was beyond the detection of limit (Table 3). The paired T-test analysis for concentration of Cr, Fe, and Pb in soil near the two dumpsites show that there were statistically significant differences in concentration levels of Cr, Fe, and Pb while Cu Show no statistically significant difference between the two dumpsites (Table 3).

Table 2: Soil pH and heavy metal concentrations in soil (mg/kg) near Jimeta dumpsite

Site	Cr	Fe	Cd	Pb	Cu	pH
1	0.1	27.54	ND	0.28	0.44	6.46
2	0.1	35.68	ND	1.19	0.13	6.54
3	0.01	33.39	ND	1.35	0.58	6.98
4	0.2	24.34	ND	0.23	0.32	5.76
5	0.2	36.22	ND	1.2	0.14	5.99
6	0.02	31.28	ND	1.29	0.44	6.45
Total	**0.63**	**188.45**		**5.54**	**2.05**	**38.18**
Mean	**0.11**	**31.40**		**0.92**	**0.34**	**6.36**

ND =Not Detected

Table 3: Soil pH and heavy metal concentrations in soil (mg/kg) at Ngurore dumpsite

Site	Cr	Fe	Cd	Pb	Cu	pH
1	0.1	34.48	ND	0.22	0.31	8.32
2	0.1	31.23	ND	1.04	0.28	8.26
3	0.01	29.71	ND	1.24	0.22	8.03
4	0.09	35.33	ND	0.3	0.31	8.12
5	0.1	28.43	ND	1.03	0.27	7.65
6	0.01	33.31	ND	1.2	0.29	8.45
Total	0.41	192.49		5.03	1.68	48.83
Mean	0.06	32.08		0.84	0.28	8.14

Discussion

Results obtained in table 2 and 3 show that the pH values of soil samples at the two dumpsites were slightly alkaline. Ngurore dumpsite had a mean pH value of 8.14 compared to 6.36 mean soil pH value obtained at Jimeta site, which was slightly acidic. The soil pH values obtained in this study were slightly similar to the report of Hunachew and Sandip, (2011), who observed pH values of a disposal site in Addis Ababa area to be slightly basic (pH 8.17± 0.95) in the dumpsite and (pH 7.37± 0.37) in grazing land, but lower than the findings of a similar study in Cameroon (8.55-9.40) (Adjia *et al.*, 2008). This might be as a result of the sorption of metals in the soil (Lee and Saunders, 2003). Result of pH values obtained in our study may be attributed to the buffering effect of soil organic matter against pH changes in addition to the release of basic cation during organic matter decomposition. This result was also supported by Obasi *et al.* (2012), who stated that the pH levels that are acidic tend to have an increased micronutrient solubility and mobility as well as increased heavy metal concentration in the soil.

The mean concentration of the exchangeable cation in soil for the Jimeta site was: Fe (31.4 mg/kg) >Pb (0.92 mg/kg) > Cu (0.34 mg/kg) > Cr (0.11 mg/kg) >Cd (below limit of detection), while the mean concentration of the heavy metals in soil for Ngurore site was: Fe (32 mg/kg) >Pb (0.83 mg/kg) > Cu (0.28 mg/kg) > Cr (0.07 mg/kg) >Cd (below limit of detection). The concentration of Fe in Ngurore site was higher than that of Jimeta site. However, the concentration of heavy metals at Jimeta dumpsite was higher than that obtained at Ngurore dumpsite indicating that the mean concentration of exchangeable cation is directly related to the capacity of absorption of heavy metals since this depend on the combination of the soil properties and the specific characteristics of the element (Nanven *et al.*, 2015). The results of Cu from the dumpsites in the present study is low when compared to the report of Nanven *et al.* (2015), who showed that the mean concentrations of copper (Cu) in the dumpsite and farm soil samples in KuruJantar were 130.19 and 63.23 mg/kg, respectively. The concentration of Cu in this study was lower than the values reported by Adewuyi and Opasina (2010), at Lagos metropolis, Nigeria who carried out an assessment of the physicochemical properties and heavy metal concentration of leachates from Aperin abandoned dumpsite in Lagos City.

The results reported here confirm that the soil obtained nearJimeta and Ngurore dumpsites contained substantial amounts of metals with exception of Cd which was found to be below the limit of detection by the machine. The concentrations of these metals were found to be within the safe limits prescribed by the FAO/WHO, except for lead which was above the safe limit. However cultivation of crops on this soilmay lead to accumulation of heavy metals in the plants.

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