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Assessment of Heavy Metal Contamination in Surface and Sub-Surface Soils from Dumpsites In Kano Metropolis, Nigeria

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Abstract

The study aimed to assess the level of metals contamination around municipal solid waste dumpsites in Kano metropolis, Nigeria. Forty-two soil samples were collected from seven municipal solid waste dumpsites (Durumin Zungura, Murtala Muhammad Specialist Hospital, Sharada, Kaura Goje, Tudun wada, Dorayi and Gwale). Analysis for the concentration of these heavy metals; Zn, Pb, Cd, Cr and Ni was conducted by the use of Flame atomic absorption spectrophotometer (FAAS).The mean concentration of heavy metals in the soils sample were Zn (0.009 mg/kg), Pb (1.02 mg/kg), Cd (0.007 mg/kg), Cr (0.15 mg/kg) and Ni (0.15 mg/kg) for surface soils (0-15cm) while the mean values for sub-surface soils (15-30cm) were Zn (0.10 mg/kg), Pb (0.27 mg/kg), Cd(0.008 mg/kg), Cr (0.15 mg/kg) and Ni (0.17 mg/kg). The maximum concentrations of the five heavy metals in both sample and control sites were below WHO (2007) and DPR (2002) standard. Based on the result of soil contamination around the dumpsites in Kano metropolis, it indicated that, all the seven dumpsites were in the class of low contamination. The contamination/Pollution Index values of all the studied heavy metals (Zn, Pb, Cr, Cd and Ni) were in the class of slightly contaminated by heavy metals. It is recommended that the government should consider a basement treatment for dumpsites before use. This will provide sorption surfaces for pollutant and prevent groundwater contamination.

Keywords: Heavy metals, Contamination , FAAS, Kano metropolis

INTRODUCTION
The disposal of domestic, commercial and industrial garbage in the world is a problem that continues to grow with human civilization (Abdul, 2009). Municipal solid wastes, due to insufficient collection and improper disposal, is a major concern for many rapidly growing cities in developing countries (Adamo *et al.*, 2009). Millions of tons of toxic solid wastes from a variety of sources annually find their way into dumpsites. Pollutants from these wastes most often penetrate the lower soil horizons and subsequently polluting the ground water at varying degrees. The presence of heavy metals in the environment beyond acceptable limits calls for concern because of the deleterious effects of toxic metals on humans, animals and plants (Caylak and Tokar, 2012). Disposal of solid wastes in major cities of Nigeria in the last few decades has posed major environmental and public health problems. This has become a source of worry for rural and urban planners in Nigeria because of the explosive population growth and urbanization (Dirisu *et al.*,2019). The views of many researchers is that the

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current trend in the municipal wastes disposal and management practices may increase the heavy metal burden of the soil and underground water (Albores *et al.*, 2000, Okoronko, 2006, Elaigwu *et al.*, 2007). Studies done on soils at dumpsites show that the soils contain different kinds and concentration of heavy metals, depending on the age, contents and location (Udosen *et al.*, 1990; Haluschak *et al.*, 1998; Odukoya *et al.*,2000). Field investigations as well as soil column studies have reported rapid leaching of significant concentrations of zinc, copper, chromium and cadmium (Sukkariyah *et al.*, 2005). Municipal waste contains such heavy metals as As Cd, Co, Cu, Fe, Hg, Mn, Pb, Ni, and Zn which end up in the soil and are leached out from the dump sites (Fatoki, 2000). Several studies have revealed high heavy metals concentration in leachate and soils within the vicinity of dumpsites (Ogundiran and Afolabi, 2008; Oyelola and Babatunde, 2008).Assessing soil pollution with toxic elements has to be done compared to the baseline concentrations in soil. Pollution, in this case, will be measured as the amount of metal enrichment in the sample, above the concentrations present in the background value (Abrahim and Parker, 2008; Rafiei *et al.*, 2010; Razos and Christides, 2010). In order to assess the impact of toxic metals pollution on different environments byusing various enrichment calculation methods, several works have been done (Abrahim and Parker, 2008; Adomako *et al.*, 2008; Aikpokpodion *et al.*, 2010; Ghrefat *et al.*, 2010, Liu *et al.*, 2005; Nasrabadi *et al.*, 2010). Some indicators of contamination in soil and sediment most often applied in these studies are enrichment factor (EF), pollution load index PLI), modified contamination degree (mCd) and geo-accumulation index (Ghorbani et al., 2015Previous studies also have established the presence of some heavy metals in some solid waste dumpsites of Kano Metropolis (Koki and Jimoh (2013), Koki and Jimoh (2013), and Karkarna and Mujahid (2020),).The analysis in present study shows that there is variation in the concentration of the heavy metals among studied sites and all mean concentration values of the heavy metals under investigation were found to be lower below EU and DPR (2002) standard limits. However, the level of soils contamination in the studied areas were investigated, which shows that, the soils were slightly polluted with the target heavy metals (Zn, Pb, Cd, Cr and Ni).

Study Area

The study area, Kano Metropolis lies between latitude 11° 55′ 0″ N to 12° 0′ 0″ N and longitude and 8° 25′ 0″ E to 8° 35′ 0″ E (Figure 1). Kano Metropolis is made up of six Local Government Areas (Dala, Fage, Gwale, Municipal, Nasarawa, and Tarauni) and some parts of Kumbotso, Ungogo, and Tofa Local Government Areas. Kano metropolis has an estimated population of over 4 million people with a male – female ratio of about 1 to 1.32 (Maigari, 2014). Kano is in the dry-sub-humid agro-ecological zone of Nigeria (Ojanuga, 2006). It is typically characterizedby tropical wet and dry climate classified as Aw by W.Koppen (Olofin, 1987). The dominant geology is basement complex (Olofin, 1985; KNARDA, 1998).Ahmad (2008) has placed the dominant soil class ofthe area to be Alfisol according to the USDA soiltaxonomy.

MATERIALS AND METHODS

Instrumentation

The research instruments used include Global Positioning System for recording the coordinate, soil auger used for taking the soil sample, measuring tape used for measuring the soil depth, Kjiedal digestion set and Atomic absorption spectrophotometer to analyses the concentration of heavy metals under investigation

Soil Samples Collection and Sampling point

Forty-two soil samples were collected from seven municipal solid waste dumpsites of Kano metropolis using circular plot method. In each dumpsite, three point's soil samples were collected from the depth (S1, S2 and S3). At each point two soil samples were from the depth of 0-15cm and 15-30cm. These two depth were selected because anthropogenic pollutants are normally found in the upper layer of the soil (Parth *et al*., 2011). A hand-held Global Positioning System(76 Garmin) was used to obtain the geographic coordinates of each sampling location. Samples collected were placed in a cooler and taken to the laboratory for analysis. Each soil sample was composed of 2 sub-samples collected around the corresponding sampling point, and all the sampling coordinates were recorded by portable Global Positioning System(figure 1). The samples were carefully handled right from the field to the end of the laboratory analysis to avoid contamination.

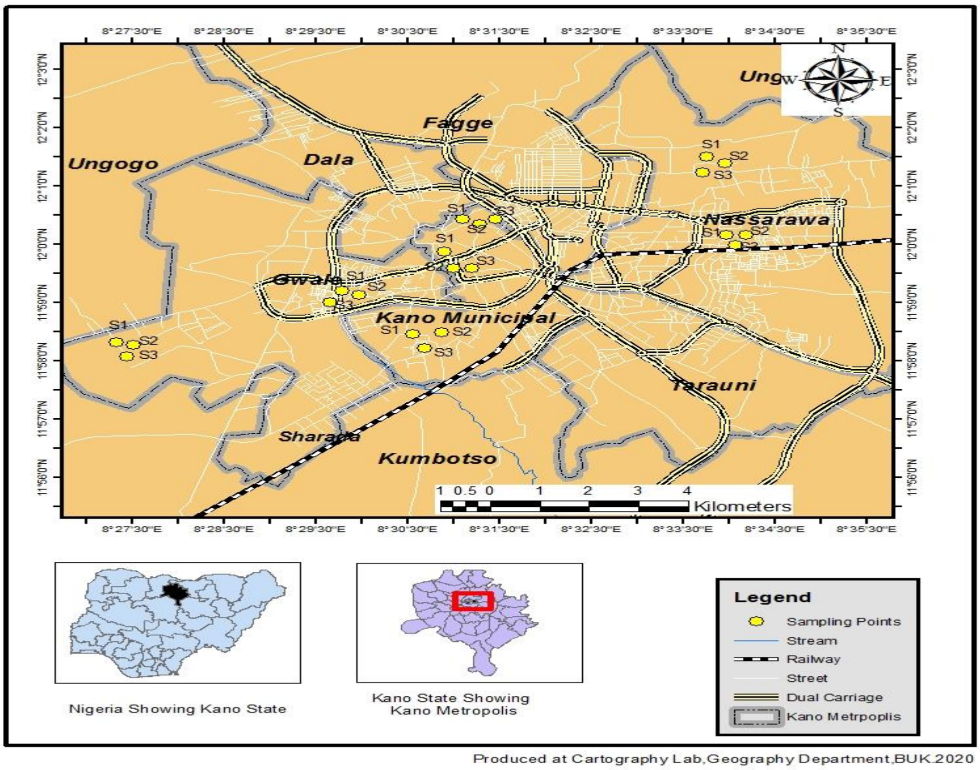

Figure 1 Map showing the distribution of Sampling points

Laboratory Analysis

Double acid digestion technique was used in sample extraction for total heavy metal determination. The fractions of heavy metals that are exchangeable and soluble were determined through the modified Tessier sequential extraction technique of Kashem *et al*., (2007) in which 10g of each sample was mixed with 100cm^2 of de-ionized water. The resultant mixture was shaken for eight hours, left to stand overnight and then centrifuged for 15 minutes at 10.000 rpm. The supernatant liquid was decanted and used in the determination of the concentration of soluble metals in the soil. The residue from the soluble metal fraction was mixed with 100cm^{2}of ammonium oxalate and shaken for eight hours at 10,000 rpm and left to stand overnight, centrifuged for 15 minutes and decanted. The solution was used to determine the fraction of metals in exchangeable form.

The heavy metals analyze include; Zn, Pb, Cd, Cr and Ni and were investigated in the soil and water Unit of Geography Department, Bayero University Kano, Kano state. Heavy metals analysis was done using Atomic Absorption Spectrophotometer (AAS Bulk Scientific 210 VGP). The equipment was first calibrated using buck certified atomic absorption standards for the respective heavy metals to obtain calibration curve. Reagent blank was first run at intervals of every ten sample analysis to eliminate equipment drift. All samples were analyzed in duplicates for reproducibility, accurate check and precision. All analyses were run in triplicates and the concentrations of the metals were determined using Atomic Absorption Spectrophotometer.

Statistical Data Analysis

Data were analyzed using SPSS software (version 23) and Microsoft Excel 2007. Descriptive data (minimum, maximum, mean, standard deviation) werepresented for the result of the five studied heavy metals concentration(Zn, Pb, Ni,Cr and Cd) in surface (0-15cm) and sub-surface (15-30cm) soils. The contamination factor was analyze using descriptive statistics in which the data presented in means and tables form. The Pearson's correlation was determined to examine the relationship between studied heavy metals in the dumpsites.

Soil Contamination Assessment

The Contamination/Pollution Index (C/P) of the metals in the soils was calculated using the scheme formulated by Lacatusu (2000). The equation is as follows:

Contamination factor (Cf) == Ci / Si…………………Equation (1)

where Cf mean contamination factor for a special heavy metal, Ci is the heavy metal content in a soil sample (mg kg-1);and Si is the target values of the same metal (mg kg-1). The target value was obtained by using the standard formulated by the Department of Petroleum Resources of Nigeria (DPR)/cluster abundant values for maximum allowed concentrations of heavy metals in soil in mg/kg-11 (Zn=140 mg/kg, Pb=85 mg/kg, Cr=100 mg/kg, Nickel =35 mg/kg,Cd=0.8).The significance of interval of contamination/ pollution index was given in table 1 below.

Table 1 terminologies used to describe the significance of soil Contamination

S/NO	Class	Significance
1	<.1	Very slight contamination
2	0.10-0.25	slightly contamination
3	0.26-0.5	Moderate contamination
4	0.51-0.75	Severe contamination
5	0.76-1.00	Very severe contamination

Adopted by Lacatusu, (2000).

RESULTS AND DISCUSSION

The statistical analysis results are summarized as minimum, maximum, mean and standard deviation of (Zn, Pb, Cr, Ni and Cd) in surface (0-15cm) and sub-surface soils (15-30cm)concentration (in mg/kg) in Table 3.

Table 2 shows the means levels of Zn ranged from 0.003 to 0.30 mg/kg in the surface soils (0-15cm)from the dumpsite and 0.013 to 0.55 mg/kg in the sub-surface soils (15-30).The results of this study were also slightly lower as compared to a study by Lawan *et al*., (2012) on vertical migration of heavy metals in dumpsite soil at Maiduguri Metropolis dumpsite, Nigeria that reported mean zinc concentration at 1.80 ± 0.01mg/kg. The Large concentrations of Zn in the soil have adverse effects on crops, livestock and human (Parth *et al.,* 2011).The chief pollution sources of Zn in soils are metalliferous mining activities, agricultural use of sewage sludge and the use of agro-chemicals such as fertilizers and pesticides. Large concentrations of Zn in the soil have adverse effects on crops, livestock and human (Parth *et al.,* 2011).

Based on the result presented in the table 2, the soil lead contents vary from (0.001-17.33mg/kg in surface soils (0-15cm) while in sub-surface soils (15-30cm) lead concentration ranged between (0.01-1.77mg/kg). The result obtained in this study was also far lower than 24.70-54.20 mg kg-1 reported by Akinbile, (2012) for land fill site at Akure, Nigeria. The concentration of Pb in this study was far lower than DPR (2002) and WHO (2007) standard with Maximum allowable limit of 85 mg/kg and 100mg/kg respectively. The implication of Lead poisoning can cause a number of adverse human health effects. It is particularly detrimental to the neurological development of children (Tokar *et al*., 2011; Jomova and Valko, 2011; Castro-González and Méndez Armenta, 2008).

The mean levels of Cd ranged from 0.002 to 0.025 mg/kg in the surface soils (0-15cm)and 0.004 to 0.02 mg/kg in the sub-surface soils (15-30cm).The result is in agreement with the findings of Asawalam and Eke (2006) and Njoku and Ayoka (2007) who investigated the trace metal concentrations and heavy metal pollutants from dump soils in Owerri, Nigeria. The finding is in agreement with Al-Turki and Helal (2004) and Ren *et al.* (2005) who reported that lead and cadmium are anthropogenic metals, and without external interference, are normally not abundant in upper layer soils. The implication of this Cadmium in soil and water can be taken up by certain crops and aquatic organisms and accumulate in the food-chain (WHO, 2007). Cadmium metals on human health could be devastating. It was found, for instance, that long-term exposure to Cd causes renal dis-function and lung cancer in humans. The health effect of this metal can also be linked to increased blood pressure and negative effects on the myocardium in animals.

As per results from Table 2 the mean concentration of Cr ranged between 0.004 to 0.27 mg/kg which was slightly higher than 0.07 to 0.31 in the sub-surface soils (15-30cm). Similarly, the result is consistent with the finding of Amos-Tautua *et al.* who reported mean concentration of Cr in the dump soil varied between 0.05±0.01 and 0.06±0.01 mg/kg for similar study at Yenagoa in Nigeria. Anthropogenic input of Cr comes from solid wastes, where approximately 30% of Cr originates from plastics packaging materials and lead-chromium batteries (Jung *et al*., 2006).The result of the present study was far below the MAL (maximum allowable limit) of Cr for Nigeria (100.0 mk kg-1), (DPR, 2002).

The mean concentrations of Ni in the dump soil varied between ND to 0.49 in the surface soils (0-15cm) and 0.002 to 0.45 mg/kg in the sub-surface soils (0-15cm). Ni concentrations in soils at both waste dumping sites were also lower compared to similar study at Kenya, Kadhodeki municipal solid waste dumping sites (17.44 mg/kg) (Murugi, 2009).The major causes of the absence of Nickel in these dumpsites could be attributed to the lack of waste containing household appliances tools, combustion of fossil fuels, nickel mining and electroplating. Nickel is also released into the air by power plants and trash incinerators and settles to the ground after undergoing precipitation reactions (Raymond and Okieimen, 2011).

Table 2 Heavy Metals Concentrations in the Soil Sample (mgkg-1).ND-Not detected

	Surface soil (0-15)					Sub-surface (15-30)				
DUMPSITE	**Zn**	**Pb**	**Cd**	**Cr**	**Ni**	**Zn**	**Pb**	**Cd**	**Cr**	**Ni**
D/ZUNGURA										
MIN	0.002	0.001	0.001	0.005	0.128	0.014	0.001	0.001	0.004	0.004
MAX	0.015	0.004	0.009	0.045	0.330	0.021	0.005	0.007	0.005	0.120
MEAN	0.009	0.002	0.007	0.021	0.303	0.001	0.003	0.005	0.07 0	0.046
SD	0.006	0.001	0.006	0.020	0.051	0.013	0.001	0.003	0.303	0.173
MMSH										
MIN	0.004	ND	0.003	0.002	ND	0.004	ND	0.006	ND	0.002
MAX	0.256	17.33	0.012	0.578	0.034	0.850	0.533	0.023	0.678	0.003
MEAN	0.252	7.11	0.006	0.234	ND	0.097	1.770	0.012	0.114	0.002
SD	0.139	9.158	0.004	0.365	0.00	0.128	3.100	0.009	0.199	0.007
SHARADA										
MIN	0.23	0.002	0.0078	0.0043	ND	0.15	0.002	0.0015	ND	0.004
MAX	0.43	0.045	0.012	0.067	0.285	0.85	0.054	0.056	0.287	0.076
MEAN	0.30	0.022	0.025	0.274	0.061	0.55	0.051	0.020	0.104	0.179
SD	0.107	0.215	0.027	0.354	0.352	0.360	0.015	0.030	0.145	0.244
K/GOJE										
MIN	0.01	0.01	0.001	0.0015	ND	0.005	0.005	0.007	0.008	0.111
MAX	0.07	0.07	0.005	0.008	0.234	0.06	0.009	0.012	0.657	0.333
MEAN	0.003	0.035	0.003	0.004	ND	0.026	0.114	0.009	0.281	0.250
SD	0.031	0.031	0.002	0.003	0.431	0.029	0.029	0.002	0.335	0.128
T/WADA										
MIN	0.006	0.005	0.001	ND	0.0045	0.005	0.005	0.002	0.345	0.004
MAX	0.071	0.071	0.009	0.812	0.234	0.018	0.018	0.009	0.654	0.333
MEAN	0.028	0.046	0.002	0.246	0.149	0.013	0.033	0.004	0.319	0.117
SD	0.036	0.036	0.003	0.645	0.114	0.007	0.010	0.003	0.165	0.193
DORAYI										
MIN	0.01	0.002	0.002	0.004	0.0045	0.004	0.003	0.002	0.0023	0.004
MAX	0.071	0.071	0.009	0.812	0.234	0.03	0.005	0.009	0.528	0.340
MEAN	0.014	0.002	0.003	0.144	0.493	0.017	0.003	0.005	0.177	0.190
SD	0.007	0.007	0.003	165	16.5	.0105	0.013	0.003	0.303	0.170
GWALE										
MIN	0.005	0.0018	0.003	0.001	0.004	0.008	0.002	0.0067	0.001	0.004
MAX	0.170	0.004	0.008	0.487	0.345	0.170	0.004	0.014	0.234	1.111
MEAN	0.063	0.002	0.005	0.163	0.190	0.063	0.002	0.006	0.070	0.450
SD	0.092	.01374	.0025	.28019	.1722	.09268	.01403	0.133	.13395	0.570

Min-Minimum Concentration, Max- Maximum concentration, SD-Standard deviation
Sources; Laboratory Analysis, 2019

Mean values of metals concentration of soils in the Studied Dumpsites.

The figure 2shows the mean values of the five studied heavy metals (Zn, Pb, Cd, Cr and Ni) across the seven municipal solid wastes dumpsites. The result shows that the mean concentration of the all heavy metals in the sample site was comparatively lower than the control site. The result indicated that Pb recorded the highest concentration (1.02 mg/kg), while Zinc, cadmium, chromium and Nickel recorded lesser concentration, but still all the concentration were found to be far below the European Union (2002) maximum permissible limits, as well as Department of Petroleum Resources DPR(2002) standard limit.

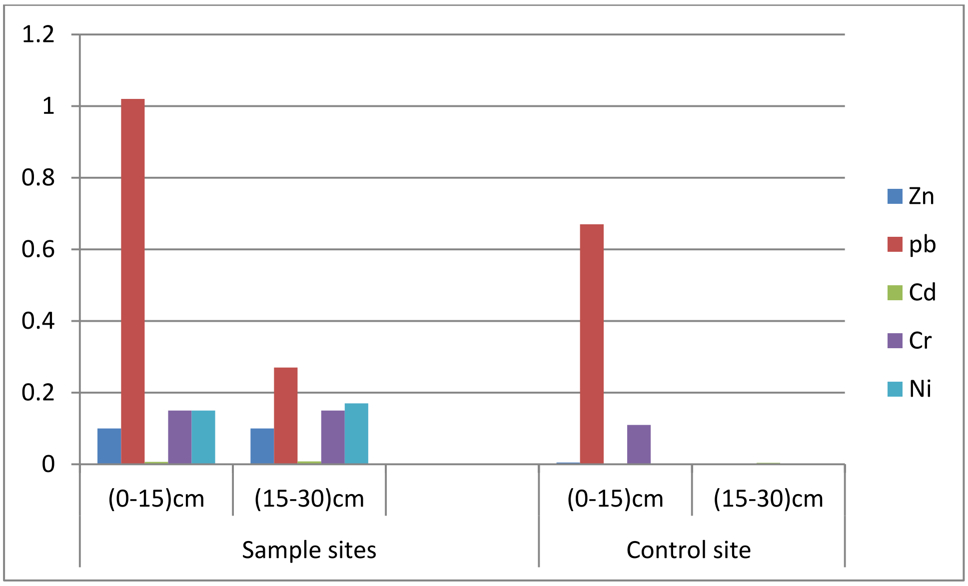

Figure 2 Heavy Metals Concentration at Sample and Control sites in the studied area

The finding of this study is in disagreement with work of Agber *et al*. (2013)who reported the Zn concentration value ranged from(0.5883-1.351 mg/kg) for soils sample close to municipal refuse dumpsite in Makurdi, Nigeria. However, Umoh and Etim (2013) reported similar concentration of 0.0034-1.54 mg/kg from dumpsite within Ikot Ekpene, Akwa Ibom State, Nigeria. The Nickel concentration in the present study was comparatively lower than 17.44 mg/kg reported by Murugi (2009) for soils at Kenya, Kadhodeki dumpsite and also Adie and Osinbajo (2009) reported highest Cr concentration (131-249 mg/kg) which was far lower than the values obtained in the present studies. The result of Cd concentration obtained in this studies is in full agreement of work reported by Amos-Tautau *et al*.,(2013) for similar in Yenagoe, Nigeria.

Contamination factor of the Heavy Metals in the Soil Samples at the seven studied area

The result presented in figure3 shows that contamination factor (*Cf*) values recorded for the studied heavy metals (Zn, Pb, Cd, Cr and Ni) were in the range less than 0.1. Based on Lactusa (2000) grade index, the contamination/pollution index of all the metals were in the range that showed very slight contamination (<0.1).The finding of this study deviated from the work of Ojodomo(2016) who recorded high level of contamination in soils collected fromdumpsite soils in Wukari, North-Eastern Nigeria.

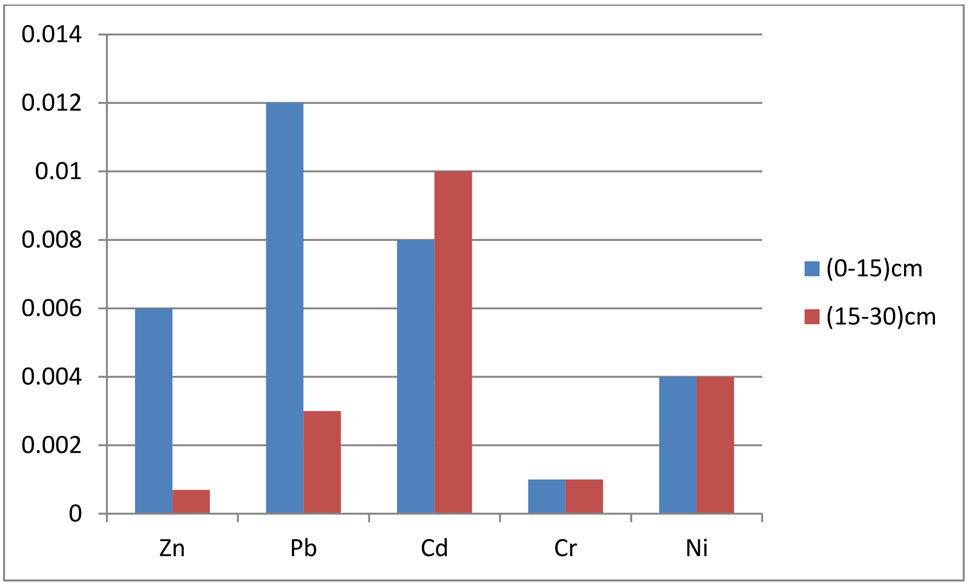

Figure 3 Contamination factors of (Zn, Pb,Cd, Cr and Ni) at (0-15)cm and (15-30)cm

The result in figure3 indicated that all of the heavy metals in the surface and surface soils were in the class of very slightly contamination. The CF values recorded for surface soils (0-15cm) ranged between 0.001-0.012 while for sub-surface soils the CF values ranged from (0.007-0.01). The result in this study deviated with the work of Ogunmodede *et al*., (2016) who reported higher contamination of heavy metals and pollution load index at Ikere Ekiti dumpsite, Nigeria and asFonge *et al*, (2017) who reported high contamination for cadmium (Cd), copper (Cu), zinc (Zn) and mercury (Hg) in soils of a municipal landfill surrounded by banana plantation in the Eastern flank of mount Cameroon.

Conclusion

This paper aimed to evaluate the level of heavy metals contamination in soils around waste dumpsites in Metropolitan Kano. The result revealed that the concentration of the five studied heavy metals (Zn, Pb, Cd, Cr and Ni) in both soils and control sites were found to be far below EU and DPR (2002) standard limits. Furthermore, the results from this study also showed that soils sample within the study area were not contaminated with the studied heavy metals. This study, therefore, recommends that periodic monitoring of soils contamination for heavy metals in the study area is recommended and in future, further study should be done to investigate the levels of different heavy metals, common and other soil physicochemical parameters of the soils in the study area.

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