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Levels, spatial distribution and ecological risk assessment of Cadmium and Lead in surface soil of Nsukka industrial cluster areas, South-East Nigeria

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Surface soil samples collected from four Industrial work sites in Nsukka Urban Industrial cluster areas, South- East Nigeria were investigated for levels, spatial distribution and ecological risk of Cadmium (Cd) and Lead (Pb). A total of 200 samples were analysed using Flame Atomic Absorption Spectrophotometer (AAS) following wet digestion using 65% Nitric acid. The results revealed Cadmium and lead concentration levels in surface soil from the area studied are unevenly distributed spatially showing a range of 1.855-2.798 mg/kg for Cd in Automobile (AM) work sites, 0.068-0.084 mg/kg in Motor Parts (MP) Fabrilation sites, 0.000-0.020 mg/kg in wood work (WW) sites and 0.218- 0.259 mg/kg in Aluminium work (AW) sites. The respective mean concentrations for Pb were 1.913, 1.410, 1.384, 1.114, 0.086, 0.074 and 1.020, 0.099 mg/kg. Apart from WW samples, Cd levels in all the samples were above the maximum allowable unit of 0.07mg/kg set by World Health Organisation (WHO). Pb levels exceeded the maximum allowable unit of 0.05 mg/kg in all the samples suggestive of increased Pb content in soil due to anthropogenic interactions. The RI of AM worksite showed high risk while MP fabrication worksite had moderate ecological risk. The contribution of Cd to the risk potential was much.

Key words: Industry, surface soil, pollution, Cadmium, lead, ecological risk, worksite, Nsukka.

INTRODUCTION

There is several rising global concern on the impact of toxic of heavy metals in the environment (Adekola and Mitchell, 2011; Anthwange et al., 2012; Etim et al., 2016). In 2010, an estimated 400 children were reported to have died in Zamfara State, Northern Nigeria due to lead poisoning from mining activities and many surviving children tested high levels of lead in their blood (Ivan, 2012). Another report in 2015 mentioned at least 65 cases of lead poisoning identified in Niger State, Nigeria and 28 children died from the menace (Winsor, 2015). From the various studies investigating the sources of toxic metals exposures and their effects on human health, soil has been identified as a potential pathway of human exposure to these metals especially Cd and Pb (Orisakwe, 2009; Fsroogi et al., 2009; Sandalio et al., 2001). Apart from direct

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dermal contact with high levels of toxic metals in soils, food incorporated metals via plant uptake is also a major potential threat to human health.

Routine analyses of soils to determine Cd and Pb in populated areas is vital since elevated levels of these toxic metals are primarily found in urban areas due to industrial and human activities. This study establishes base-line data on the concentration of cadmium and lead from industrial areas of Nsukka. The associated ecological risks of these metals were also investigated.

EXPERIMENTAL

Area of study

This study was carried out in Nsukka Industrial Areas of Enugu State, South-East Nigeria. The area is characterized by tropical humid climate and distinct dry and wet (rainy) seasons; usually beginning from November to March and April to October respectively. The geographical co-ordinates of Nsukka are 6°52'N and 7°23'E.

Sampling technique

A total of 200 surface soil samples at 0 - 5.0 cm depth were collected from 20 sample stations. 10 samples were collected from each station worksite based on hexagonal grids mapped out in the area of about 1 km^2. Based on land use, the industrial site was divided into four zones. In each sampling site, four subsamples were collected within an area of 50 m^2 and mixed thoroughly to obtain a representative/composite sample. The collected samples were dried at 60°C, sieved through a 2.0 mm Nylon sieve to remove plant debris, stones, gravels, metal scraps and stored in polythene bags prior to analysis.

Digestion of samples

One gram of each sample was put into 150 mL conical flask, a mixture of concentrated HNO3: HClO4: HF in the ratio 3:1:3 was added according to literature (Nwajei and Gagophein, 2000). Distilled water was added to make up the mark. Blank solutions were prepared and used to zero the instrument used for sample determination and also carried through the digestive process. The concentrations of Cd and Pb were determined using Atomic Absorption Spectrophotometer (ARIAN model AA4). Each sample was determined in triplicates.

Quality control

The precision and accuracy of the method was tested
by spiking the soil samples with standard materials and determining recoveries. The % recovery was determined using the equation.

$$\frac{\%RSY}{Z} \times 100$$

Where S= Concentration of metal in spiked sample
Y = Concentration of metal in unspiked sample
Z= Spiking concentration in mg/L

Potential ecological risk index

The degree of ecological risk of heavy metals in soils is estimated using the Risk index (RI) proposed by Hakanson (1980). RI is calculated by the equations:

$$C_f^i \quad C_D^i / C_R^i \tag{1}$$

$${}^{i}_{n}E_r \; T_r \, C_f^i \tag{2}$$

$$\mathrm{RI} = E_{li}^{i} \quad r \tag{3}$$

Where Cif contamination coefficient
CiE concentration of heavy metal in soils.
CiR background concentration of heavy metal in soil.
Tir toxic-response factor for a given heavy metal.
Er potential risk of individual heavy metal
RI = sum of potential risk of individual heavy metal

Using Hakanson approach, the Tir for Cd and Pb are 30 and 5 respectively (Nwajei and Gagophein, 2000). The CiR used in thiscalculation is the world average elemental concentration value of Cd = 0.30 mg/kg and Pb = 20mg/kg because Nigeria has no reliable background values for these metals (Hakanson, 1980). Hakanson defined five categories of Cir and four categories of RI.

RESULTS AND DISCUSSION

Arecovery range of 99.8- 101.1% for Cd and 98.3-99.9% for Pb obtained in the analysis gave an indication that the analytical technique would sufficiently estimate the metals in the matrix. The results of the metallic concentrations in the surface soils expressed as range and mean plus standard deviation (MeanS.D) are presented in Table 1.

Cadmium and lead concentration levels in surface soil from the area studied are unevenly distributed spatially. In AM, the mean value of Cd is higher than the World Health Organisation (WHO) accepted limit of 0.07 mg/kg Cd in soil (European Parliament, 2013). The high level of Cd can be attributed to the wide use of Cd – Ni batteries to power tools in spite of the ban in most countries . In MP, the concentration of Cd ranged from 0.068 to 0.084 mg/kg with a mean value of 0.077±0.006 mg/kg, slightly above WHO acceptable limit. WW showed a Cd concentration range of 0.00 to 0.020 mg/kg with a mean value of 0.006±0.009 mg/kg. This was the least mean concentration of Cd in all the industrial work sites studied. AW had a mean Cd content of 0.231±1.19 kg/mg and ranged from 0.218 to 0.259 mg/kg all higher than the recommended WHO limit of Cd concentration in soils (Trekin and Wedepohi, 1961). The sequence of mean Cd concentration with respect to the industrial work sites is as follows: AM>AW>MP> WW. A Cd concentration of 0.5 mg/kg in soil is said to reflect human influence (Trekin and Wedepohi, 1961). Cadmium adsorption and distribution in soils is principally influenced by competition from

Table 1. Result of Cd and Pb analysis in the surface soil samples (mg/kg)

Sample	Cd range	Mean S.D	Pb range	Mean S.D
Automobile Worksite (AM)	1.855-2.798	2.269 0.933	0.00-3.361	1.913 1.410
Motro parts fabrication sites (MP)	0.068-0.084	0.077 0.006	0.176-2.864	1.384 1.114
Wood work sites (MP)	0.00-0.020	0.006 0.009	0.004-0.178	0.086 0.074
Aluminum work site (AW)	0.218-0.259	0.231 0.019	0.901-1.145	1.020 0099
Blank	< 0.001	< 0.001	< 0.001	<0.001
WHO Acceptable Limit	0.07		0.05	
LOD	0.001		0.001	
LOQ	0.003		0.003	

LOD= Limit of detection ; LOQ= Limit of quantification.

Table 2. Potential ecological risk of Heavy metals index of soil samples.

Sample station	Element	C^i_f	C^i_n	RI	Grade of soil
Automobile (AM)	Cd	7.56	226.0 (High Risk)	226.50	High risk
	Pb	0.10	0.50 (Low Risk)		
Motor parts Cd Fabrication (MP)	Cd	2.57	77.10 (moderate risk)	77.45	Moderate risk
	Pb	0.07	0.35 (low risk)		
Wood work site (WW)	Cd	0.20	6.00 (low Risk)	6.02	Low risk
	Pb	0.004	(0.02 (low risk)		
Aluminum Worksite (AW)	Cd	0.77	23.1 (low risk)	23.125	Low risk
	Pb	0.05	0.25 (low risk)		

other metals, hydrous metal oxides content, presence of organic and inorganic ligands, soluble organic matter content, clay content and pH (Mico et al., 2006). As shown in Table 2 the mean concentrations of Pb in AM, MP, WW and AW were 1.913±1.410, 1.384± 1.114, 0.086±0.074, 1.020±0.099 respectively. The values were above WHO acceptable limit of lead in soil (0.05 mg/kg) (Mico et al., 2006). The trend of mean concentrations of Pb in the industrial worksites is viz: AM > MP> AW > WW.

The result is comparable to those from studies of road side soils in Jos metropolis [14] and soils of Nasarawa metropolis (Abechi et al., 2010). The use of leaded fuels in automobile engines, lubricants, etc. may account for high value of Pb observed in AM. Several studies have recorded high lead concentrations in soil dust due to vehicular emissions, lubricating oil/fuel spillage or some other factors due to industrial activities (Mico et al., 2006; Opaluwa et al., 2012; Olajide et al., 2016).

Both Cd and Pb are categorized as class – 1 elemental impurity and thus require high consideration during risk assessment across all potential sources of elemental contaminants (Keith and Neil, 2016).

Ecological risk assessment

The calculated value of risk index of the metals contamination is shown in Table 2. The RI of automobile worksite (AM) showed high risk while motor parts fabrication worksite (MP) had moderate ecological risk. The contribution of Cd to the risk potential was much and would be of concern contributing up to 99.8% to total RI. The other two sites had low potential ecological risk. Due to high toxic response factor of Cd, the contamination of the surface soil by Cd ought to be given urgent remediation. The result of this work is consistent with the finding of several earlier works which reported high ecological risks mainly due to high Cd load in the soils (Keith and Neil, 2016; Zhu et al., 2012; Wu et al., 2010).

Conclusion

The concentration values obtained for both Cd and Pb exceeded the maximum permissible limits recommended by World Health Organization most of sites studied. This is of concern since inhalation of Cd and Pb results in the accumulation of the toxic metals in body organs with chronic effects and probable carcinogenic effects as well as suppression of reproduction.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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