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Levels of some heavy metals contamination of street dust in the industrial and high traffic density areas of Jos Metropolis

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Abstract

This study determined the levels of some heavy metals in street dust collected over the industrial and high traffic density areas of Jos Metropolis. The dust samples were collected by direct gravity deposition using high volume air sampler in January, 2010 and analyzed for the levels of nickel, chromium, cobalt, copper, zinc, iron, manganese, lead and tin using UNICAM (969) Atomic Absorption Spectrophotometer. The results revealed wide range of concentrations of the heavy metals; reflecting high level of anthropogenic activities which have significantly contributed to the increasing load of heavy metals in the atmosphere. In the industrial area, iron recorded the highest mean concentration of 21.18ppm while copper recorded the lowest mean level (0.44ppm). Similar results in the high traffic density area showed that iron also recorded the highest mean level (21.66ppm) but nickel recorded the lowest mean concentration of 0.43ppm. The metal contents of the street dust in both the industrial and high traffic density areas showed strong positive correlations. The contamination factors of the heavy metals showed very high environmental contamination with cobalt (122.9 and 90.5) followed by lead (70.0 and 48.4) and chromium (13.6 and 32.4) in the industrial and high traffic density areas respectively. Apart from nickel levels, the concentrations of the heavy metals recorded in this study exceeded the ambient air permissible limits set by United Nations Environment Programme (UNEP). Furthermore, the pollution load indices of the heavy metals showed potential deterioration of site quality in the study areas. Therefore adequate sensitization and control measures should be instituted by the Ministry of Environment to limit the emission of heavy metal pollutants into air.

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Introduction

The presence of heavy metals has been identified as useful indicators for contamination in surface soil, sediment and dust environments. Accumulations of metals on urban surfaces can be attributed to vehicle exhausts, industrial discharges, oil lubricants, automobile parts, corrosion of building materials, atmospheric deposition (Adriano, 2001; Li *et al.*, 2001) and particulate emission (Sutherland and Tolosa, 2000). Dust pollution emanates from the injection of dust particles into the atmosphere and the control of street dust constitutes a significant challenge in urban areas. It was estimated that the annual amount of dust emitted into the air by Nigeria motor vehicle was 612,000 tonnes and 187,000 tonnes for unpaved and paved roads respectively. Also, the total harmattan dust load over Nigeria was estimated to have increased from 160,000 tonnes in 1979 to between 300,000 to 600,000 tonnes in 1995 per annum. It was also reported that, about 584,000 tonnes of smoke particles were estimated to be emitted annually into the atmosphere from the burning of about 80 million cubic meters of fuel wood. The burning of an estimated 18.5 million tones of domestic waste is also said to be capable of throwing about 58,400 tones of dust into the air annually (Egwuatu, 1998).

Recent investigations revealed that the residents of operational areas such as Benue Cement Company are exposed to health hazard and suffer from asbestosis (NIOHH, 1999). Steel plants such as Aladja and Ajaokuta and the steel rolling mills at Jos, Katsina and Oshogbo were major sources of atmospheric pollution. It was also known that mining, smelting and quarrying activities have created local environmental effects throughout the world and in the past have led to acute or chronic intoxication due to the emission of trace metals such as lead (Pb), arsenic (As), cadmium (Cd), and mercury (Hg) (NIOHH, 1999).

According to Yongming *et al.* (2006), components and quantity of street dusts are important environmental pollution indicators. Rapid growth of the industry, population, and transportation system can contribute to increasing pollution levels in nearby surrounding area including heavy metals in dust (Lin *et al.*, 2002). Atmospheric dust did not only affect human health but also constitute a significant source of environmental pollution (Meng and Lu, 2007; Wilkening *et al.*, 2000; Wolterbeek, 2002). Atmospheric dust suspended in the air will eventually deposit on the surface of the water and topsoil, thus introducing toxic substances into the biosphere (Wolterbeek, 2002). Particle size and chemical composition of dust could decide the significant impact of dust on air quality, public health, and climate (Maring *et al.*, 2003). Furthermore, dust ingestion, dermal contact and breathing are common pathway by which toxic metals can easily invade the human body (Abrahams, 2002). Metals such as Cd, Ni and Pb are known examples of elements that exact pronounced negative health effects from inhalation and have been observed from both occupational and ambient air exposure (Vincent, 2005).

Environmental challenges posed by the proliferation of human activities such as industrial effluent discharge, vehicular emissions, bush burning, wastes incineration and mining operations have become evident in the industrial and high traffic density areas of Jos metropolis but there is dearth of baseline data on the levels of heavy metal pollutants in dust over the areas. It was also observed that very little interest has been developed on metal contaminations of street dust despite its direct contact with greater part of every population (Alhassan *et al.*, 2012). Thus, this study sought to provide preliminary information on the levels of some heavy metals in street dust over the industrial and high traffic density areas of Jos metropolis. The study will form a baseline data for future environmental impact assessment of the street dust over the study area.

Materials and methods

The study area

The study areas consist of the high traffic density area and industrial area of Jos, Plateau State capital (latitude 9°55'N and longitude 8°54'E). Jos has an elevation of 300ft above sea level and is characterized by highlands and steep valleys (JMDB, 2008). It has an estimated population of about 3.5million people according to the 2006 consensus, a situation that has contributed to its chaotic dust generation. The city has a conducive weather which tends to attract people from various places for economic transactions and this has contributed to the high population growth of the metropolis. Several small scale industries such as quarries, steel rolling mills, flour mills, blacksmithing and timber works are common activities in the industrial area while the high traffic density area is characterized by high traffic volume (transportation), panel beating, battery charging, welding and fabrication, auto-mechanic workshops, petrol stations and motor parks. These activities contributed immensely to the dust generation in the study areas.

Sampling points

Four sampling points were chosen in each of the study locations and samples were collected in January 2010, which is the peak month of dry season activities in the areas. At the industrial area, dust samples were collected at Lamingo, Sabon Fobur, Zarazon and Nubatong while at the high traffic density area, samples were collected at Polo, Flyover bridge (Kabon), Joseph Gomwalk way and Rukuba road. These points encompass areas of high industrial, commercial and domestic activities.

Sample collection and pretreatment

Five random samples were collected within each point by gravimetric method using a high volume air sampler (Deitz, 1975). The dust sampler was fitted with pre-weighed whatman membrane filter paper (3.0μm) through which ambient air was pulled using a blower motor. Dust samples were collected for 8hours (9:00am-5pm) over 10days at an interval of three days throughout the month of January, 2010. A total of forty (40) samples were collected from the two areas.

The samples were conveyed in a sealed and labelled polythene bag to the analytical laboratory of Nigerian Institute of Mining and Geosciences, Jos and dried in the oven at 105°C. Then, they were screened using 150μm sieve and stored in a clean and labelled polythene bag prior to analysis (Deitz, 1975).

Preparation of samples for the determination of heavy metals (exception of tin)

The samples were prepared following the methodology of the analysis of heavy metals in dust described by Yap *et al.* (2002). The dust samples were dried to constant dry weights in an oven at 105°C. A measured amount (1g) of the dust sample was weighed and placed in digestion tube. The dust was digested with HNO_3 and $HClO_3$ in the ratio of 4:1. The digestion tube was placed on the digestion block and heated at 40°C for 1hr and heated further at 140°C for 2hrs (Yap *et al.*, 2002). Then, the volume of the solution was increased to 40ml by adding distilled water after which it was filtered with Whatman No.1 filter paper and stored in an acid-washed polyethylene bottle (Yap *et al.*, 2002, 2007). All the equipment and glassware were first acid-washed to avoid external contamination.

Preparation of samples for the determination of tin

A known weight (0.2g) each of the samples was measured into platinum crucibles and 4.0ml aliquot of anhydrous sodium carbonate was added as a fusing medium. Then, 4.0ml of sodium peroxide was added to the contents and mixed thoroughly (JMDB, 2008). The crucibles were heated on air-acetylene flame at a temperature of 140°C for 7mins to completely ash the samples.

Then, they were cooled and poured into beakers containing 50% HCl and covered with watch glasses (Deitz, 1975). In each beaker, a yellow solution was obtained. The solutions were further heated on a hot plate to completely dissolve the residue and 10ml of deionised water was added to each and shaken gently. Then, each solution was filtered into a 50ml volumetric flask and the filtrate made up to mark with deionised water.

Five serial calibration standards were prepared for all the metals by diluting aliquots of the working metal solutions with 0.25M HNO_3 and the calibration standards were made to cover the optimum absorbance range for the standard calibration curves of each metal (Deitz, 1975).

Analyses of the samples extracts

The samples extracts were analyzed for their levels of iron (Fe), cobalt (Co), lead (Pb), tin (Sn), zinc (Zn), manganese (Mn), copper (Cu), chromium (Cr) and nickel (Ni), using UNICAM (969) Atomic Absorption Spectrophotometer equipped with air – acetylene burner.

Assessment of metals contamination

The levels of contamination of the heavy metals in the street dust were assessed by determining the contamination factors (Cf) of each metal according to the method developed by Håkanson as reported by Yekeen and Onifade (2012).

$$Cf = \frac{Cm}{Cref} \text{ -----------1}$$

Where, Cm is the measured concentration of the heavy metal in the dust and *Cref* is the reference value of heavy metal used; in this study, UNEPA ambient air quality standard (Appendix 1). Furthermore, each area was evaluated for the extent of metal pollution by employing the method based on the Pollution Load Index (PLI) developed by (Thomilson *et al.*, (1980), as follows:

$$PLI = (Cf_1 \times Cf_2 \times Cf_3 \times Cf_4 \ldots . Cf_n)^{1/n} \text{ ------------ 2}$$

Where n is the number of metals studied and Cf is the contamination factor calculated for each metal as described in equation 1. The PLI provides simple but comparative means for assessing a site quality (Thomilson *et al.*, 1980). The categories of pollution level indices developed for the description of soil contamination include PLI < 1 represents perfection, PLI = 1 represents base line level of pollution and PLI > 1 denotes deterioration of site quality (Thomilson *et al.*, 1980).

Results and discussion

Concentrations of some heavy metals of street dust in the industrial and high traffic density areas of Jos metropolis. The results in Fig. 1 showed variable concentrations (ppm) of iron, cobalt, lead, tin, zinc, manganese, copper, chromium and nickel in the street dust collected from five random positions (100m apart) within each of Lamigo, Sabon Fobur, Zarazon and Nubatong in the industrial area of Jos metropolis. Iron recorded the highest concentration with mean level of 21.18ppm while copper recorded the lowest level with mean concentration of 0.44ppm (Fig. 2). Although, copper is essential to human life, at high dose however, it has been associated with anaemia, liver and kidney damage, stomach and intestinal irritation in humans (Lenntech, 2005).

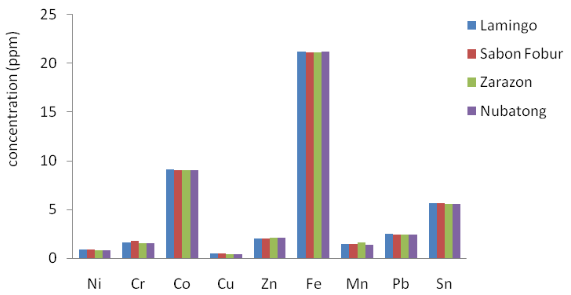

Fig. 1. Mean concentrations (ppm) of the heavy metals in street dust in the industrial area of Jos metropolis.

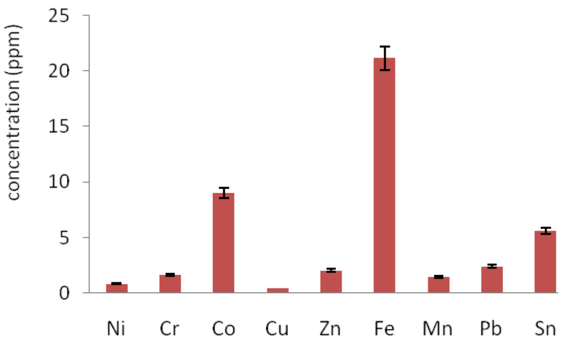

Fig. 2. Overall mean concentrations (ppm) of the heavy metals across the industrial area.

The trend of the concentrations of these heavy metals in the dust revealed that Fe > Co > Sn > Pb > Zn > Cr > Mn > Ni > Cu. The level of iron obtained in this study exceeded UNEP's permissible limit of 5mg/m^3 (NESREA, 2009). The high iron contents of the particulate matter in the industrial area could be due to high incidence of wear off from car bodies, incineration of iron-rich wastes, mining activities as well as welding and blacksmithing that existed in the area. Cobalt also recorded high level and this may be favoured by the disposal of cobalt-rich items such as car parts, rubber tyres, and kitchen utensils. The cobalt concentration of the street dust also exceeded UNEP's permissible limits of 0.01mg/m^3 (NESREA, 2009), although, research reports showed that cobalt has low toxicity to humans (Saxena, 1989). The mean concentrations of tin (5.60ppm) also exceeded the UNEP's tolerance limit of 1mg/m^3 (NESREA, 2009) and it may be due to the release of tin dust into the environment via the high mining activities of this metal that existed in the study area. It could be recalled that Jos is the richest naturally endowed tin ore in Nigeria. Mean lead (Pb) contents (2.42ppm) of the street dust within the industrial area was also high. Apart from vehicle exhausts; several industrial operations powered by the use of gasoline engine may emit significant amount of lead into the environment in which case, the continuous emission could result to excess accumulation of lead in the atmospheric dust.

The concentrations (ppm) of the heavy metals in street dust collected at Polo, Kabon, Joseph Gomwalk way and Rukuba road in the high traffic density area of Jos metropolis were as presented in Fig. 3. The trend of concentrations of the heavy metals revealed that Fe > Co > Pb > Sn > Zn > Mn > Cu > Cr > Ni. Iron still recorded the highest mean level of 21.66ppm but nickel recorded the lowest concentration of 0.43ppm (Fig. 4).

Contamination factors of the heavy metals in the street dust

The contamination factors of the heavy metals in both the industrial area (Fig. 5) and high traffic density area (Fig. 6) showed very high environmental contamination by Co followed by Pb and then Cr. In the industrial area, Fe, Sn and Zn recorded considerable contamination levels while Sn and Fe showed considerable contamination levels in the high traffic density area. Generally, the degree of concentration and accumulation of heavy metals in environmental indices depend on the type of heavy metals and the activities taking place in a particular area. According to Yekeen and Onifade (2012), the Håkanson's classification of contamination factor (Cf) of heavy metals indicated that a Cf > 6 represents very high contamination, 3 < Cf < 6 represents considerable contamination while 1 < Cf < 3 and Cf < 1 represent moderate and low contaminations respectively. In view of the several human health effects which have been reported following prolonged exposure to Co, Pb and Cr; the level of contaminations of the street dust by these metals may constitute health hazards to residents of the study areas following prolong dust inhalation.

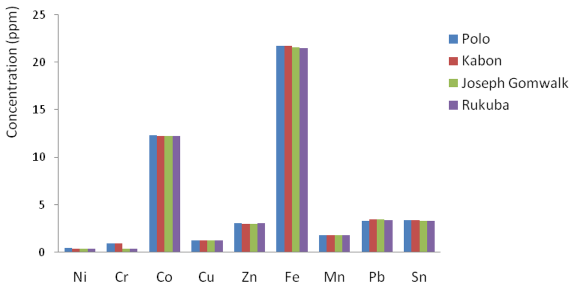

Fig. 3. Mean concentrations (ppm) of the heavy metals in street dust in the high trafic density area of Jos.

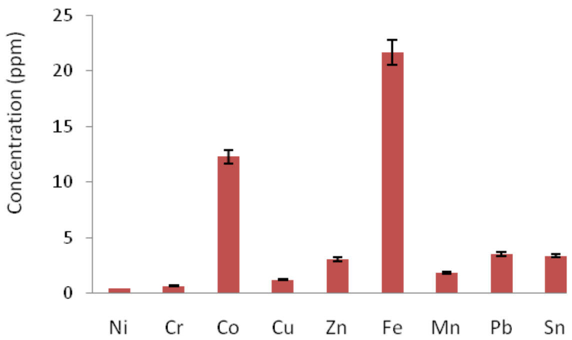

Fig. 4. Overall mean concentrations (ppm) of the heavy metals across the high trafic density area.

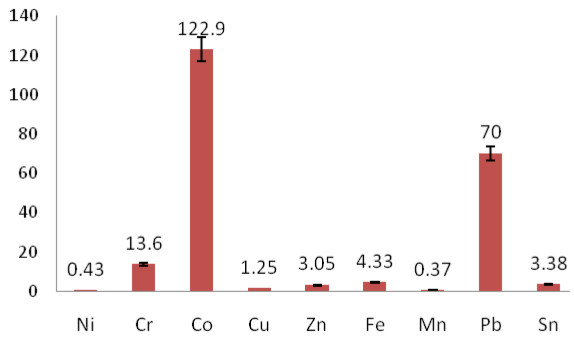

Fig. 5. Contamination factors of the heavy metals in the industrial area.

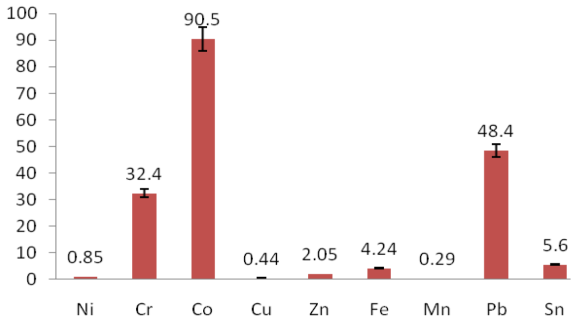

Fig. 6. Contamination factors of the heavy metals in the high traffic density area.

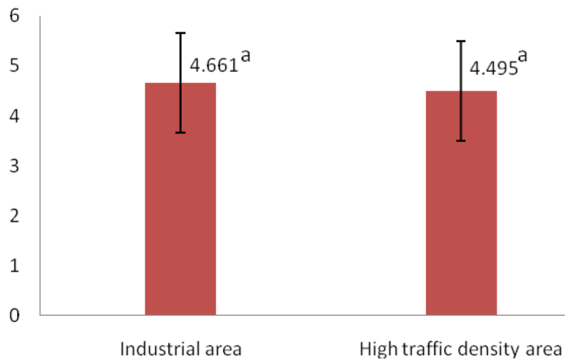

Fig. 7. Pollution load indices of the heavy metals in the study area.

Pollution load indices of the heavy metals in the street dust

The result of the pollution load indices of the heavy metals in street dust within both the industrial and high traffic density areas of Jos metropolis (Fig. 7) showed that there is potential deterioration of the site quality. According to the model of Thomilson *et al.* (1980), a Pollution Load Index (PLI) > 1 denotes deterioration of site quality. Apart from Ni level, the concentrations of the other heavy metals recorded in this study exceeded the ambient air permissible limits set by UNEP presented in Appendix 1 (NESREA, 2009). There was no significant difference ($p < 0.05$) between the pollution load indices of the heavy metals in street dust of the study areas. The similar trend of the contamination of street dust observed in the study areas may be due to the fact that several natural and anthropogenic sources introduced varying degree of trace metals into the atmosphere which may be transported over long distance within an area. A variety of ancillary activities such as vehicle repairs, vulcanizing, welding, auto-electrical works, battery charging, combustion of fossil fuels, wastes incineration, and other facilitators of motor transportation have high presence in the high traffic density area. These activities are significant sources of heavy metals emission into the air which are transported via dust. Trans-boundary air pollution is a major source of exposure to heavy metals and because of their persistence and potential for global atmospheric transfer, atmospheric emissions could affect even the most remote areas.

Table 1. Correlation cofficients between the mean concentrations of the heavy metals in industrial area and high traffic density area of Jos.

	Ni	*Cr*	*Co*	*Cu*	*Zn*	*Fe*	*Mn*	*Pb*	*Sn*
Ni	1.0000								
Cr	0.9960	1.0000							
Co	0.7985	0.7414	1.0000						
Cu	0.5147*	0.4359*	0.9271	1.0000					
Zn	0.7616	0.7006	0.9983	0.9476	1.0000				
Fe	0.9003	0.8578	0.9809	0.8366	0.9678	1.0000			
Mn	0.8323	0.7793	0.9983	0.9036	0.9931	0.9906	1.0000		
Pb	0.7732	0.7133	0.9992	0.9417	0.9998	0.9721	0.9951	1.0000	
Sn	0.9952	0.9824	0.8536	0.5962*	0.8215	0.9386	0.8826	0.8316	1.0000

Peared metals with asteriks (*) showed less correlations.

Correlation analysis between the mean concentrations of the heavy metals

The correlation analysis of the mean concentrations of the heavy metals (Table 1) revealed that apart from Cu and Ni, Cu and Cr, Sn and Cu which showed less correlation, the metal contents of the street dust in both the industrial and high traffic density areas showed strong positive correlation. This suggests common anthropogenic source of emission. Heavy metals in soil can also generate airborne particles and dust which may affect the quality of air (Gray *et al.*, 2003). Rapid growth of industry, population, and transportation system have been reported to contribute to the increasing pollution levels in nearby surrounding area including heavy metals in dust (Lin *et al.* 2002). Among the numerous environmental pollutants, heavy metals plays an important role as their concentrations in soil, water and air are continuously increasing due to anthropogenic activities (Gray *et al.*, 2003).

Conclusion

The results of this study revealed variable concentrations of the heavy metals in street dust collected at the industrial and high traffic density areas of Jos metropolis. Apart from the high vehicular emission, wear and tear of automobile parts, there are also high presence of ancillary activities such as mining, welding and blacksmithing, vehicle repairs, vulcanizing, welding, auto-electrical works, battery charging, car parks, petro stations, combustion of fossil fuels and wastes incinerations in the study areas. These have been variously reported to account for high heavy metals emission into the atmosphere and consequently, contamination of atmospheric dust. The contamination factors of the heavy metals showed very high environmental contamination with Co followed by Pb and then Cr. In the industrial area, Fe, Sn and Zn recorded considerable contamination levels while Sn and Fe showed considerable contamination levels in the high traffic density area. Apart from Ni level, the concentrations of the other heavy metals recorded in this study exceeded the ambient air permissible limits set by United Nation's Environment Programme (UNEP). Furthermore, the pollution load indices of the heavy metals showed potential deterioration of site quality in the study areas. Therefore adequate sensitization and control measures become necessary to limit the emission of heavy metal pollutants into air.

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Appendix 1. UNEP's standards for ambient air quality (NESREA, 2009)

Heavy metal	Cu	Co	Cr	Ni	Fe	Mn	Zn	Pb	Sn
Permissible limit (mg/kg)	1	0.1	0.05	1	5	5	1	0.05	1