TOXIC METALS IN OFFICE DUST AS GEOCHEMICAL INDICATORS OF INDOOR CONTAMINATION

Supported by tetfund TERTIARY EDUCATION TRUST FUND

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Received: November 20, 2016 **Accepted:** March 23, 2017

Abstract: In this study, indoor settled dust samples were collected from twenty one offices within the seven College buildings of the University of Agriculture Makurdi, Nigeria. The dust samples were analysed for the concentrations of Cadmium (Cd), Chromium (Cr) and Lead (Pb). The results of the analyses show toxic metals concentrations in the order of Cd < Cr <Pb. The metal contents (µg/g dry weight) found in all the sample locations during the period of assessment ranges from 0.1223 – 0.3357, 0.9936 – 3.060 and 53.45 – 225.5 for Cd, Cr and Pb, respectively. Indoor settled dust loading within the University of Agriculture Makurdi as well as the concentrations of Cd and Cr were lower than reported values from popular cities around the world and within the threshold limits. However, the concentrations of Pb in all the sample locations were higher than the maximum permissible limits. This is a source of concern since occupants of these offices are exposed to these health threatening pollutants through dust inhalation, ingestion or otherwise for appreciable period of time on daily basis. The results of this study also indicated anthropogenic sources of the metals. Therefore, since dust could be related to human health hazards and as a potential monitoring tool for toxic metal contamination in the indoor environment, frequent studies should be conducted to monitor these pollutants in future so that appropriate measures can be taken to regulate anthropogenic activities to ensure a better environmental quality in the University.

Keywords: Contamination, indoor, Makurdi, office dust, toxic metals

Introduction

Dusts are solid particles ranging in size from below 1 µm up to around 100 µm, which may be or become airborne, depending on their origin, physical characteristics and ambient conditions (WHO, 1999). Dust is present in the indoor environment as a composite of particulate matter derived from interior and exterior sources (Fergusson and Kim, 1991). They function as sinks and reservoirs of hazardous chemical pollutants such as Cadmium, Chromium and Lead which can be accumulated in human body through direct inhalation of dust, ingestion and dermal contact. According to Rasmussen *et al*. (2001), soil and street dust are thought to contribute anywhere from 20 % to 95 % of indoor settled dust. This is as a result of industrial land use, traffic emissions and geological weathering. Metals can also originate from interior sources such as paint chippings, household products, crafts, hobbies and tobacco smoking, and these tends to accumulate in house dust (Rasmussen *et al*., 2001).

While some heavy metals such as Zn, Mn, Fe,and Cu serve as micro nutrients required by the body at low concentrations, others such as Cd, Pb, As and methylated form of Hg have no known biological importance and may be toxic even at low concentrations (Duruibe *et al*., 2007; Shinggu *et al*., 2010). According to Gerstner and Huff (1997), toxic metals cause more problems to man because they tend to accumulate in the brain, kidney and the immune system where they can severely disrupt normal body functions. Although individual metals exhibit specific signs of their toxicity, the following have been reported as general signs associated with Cadmium, Lead, Arsenic, Mercury, Zinc, Copper and Aluminium poisoning: Gastrointestinal (GI) disorder, diarrhea, stomatitis, tremor, heamoglobin urea- causing a rust-red colour to stool, paralysis, vomiting and convulsion, depression and pneumonia (McCluggage, 1991). The nature of effects can be toxic (acute, chronic or sub-chronic), neurotoxic, carcinogenic, mutagenic or teratogenic.

Several researchers (Fergusson and Kim, 1991; Al-Rajhi and Seaward, 1996; Shi *et al*., 2008; Yap *et al*., 2011) have focused on the elemental composition of dust and results revealed that these metals easily get embedded in dust particles from industries, agricultural farmlands, construction sites, roadside dusts and other anthropogenic sources. These have shown increasing evidences on the impact of indoor settled dust on human health and environment. Thus, it becomes essential to study the concentrations of these pollutants in the micro-environment so as to relate it to the exposure level and possible health risks to the occupant. Therefore, if dust-laden with toxic metals provide a critical link in the exposure pathway for indoor occupants, contaminated office dust can undoubtedly pose a potential hazard to the health of workers in such offices.

To provide a healthy University environment and protect the lives of workers from toxic metal contamination, it is important to have a thorough understanding of the levels of these pollutants. However, in spite of the numerous data available on toxic metal contamination of outdoor and residential indoor dust, not much attention has been paid to this subject as it relates to academic institutions in Nigeria, particularly the University of Agriculture Makurdi, which on daily basis experience high traffic inflow, construction infrastructure, agricultural activities and laboratory reagent emissions etc.

The purpose of this study therefore, was to determine the levels of toxic metals (Cadmium, Chromium and Lead) in dust samples collected from selected offices within the University of Agriculture Makurdi, Nigeria, with the aim of establishing background levels for occupant exposure. A study such as the one described in this work is highly desirable particularly because of the link between the indoor environment and the health of occupants. The information obtained from this study therefore will form the basis for planning as well as management strategies to achieve a better environmental quality in the institution.

Materials and Methods

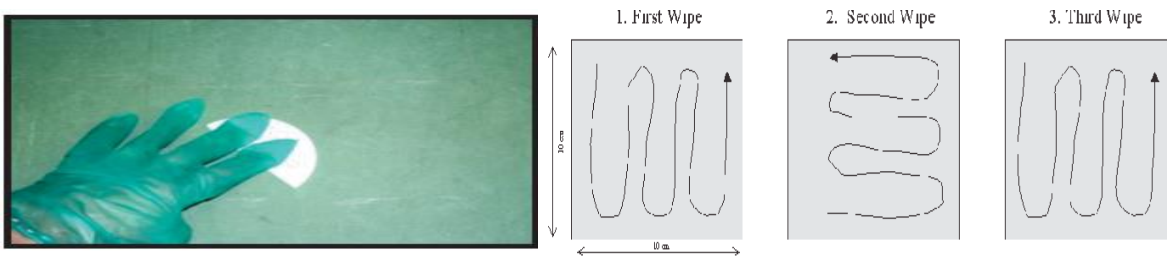
Study area

University of Agriculture, Makurdi (UAM) is located in Makurdi town, the capital of Benue State, Nigeria between latitude 7°38'N - 7°50'N, and longitude 8°24'E and 8°38'E, situated in the Benue valley in the North Central region of Nigeria. The town has a total estimated population of 500,791 people (as at 2007) with a total land area of about 200 km^2 and is traversed by the second largest river in the country, the river Benue. University of Agriculture Makurdi occupies an arable land area of 8,048 hectares thus making it the largest holder of agricultural land mass amongst institutions of its kind. The University is made up of nine Colleges and several

Departments spread throughout its North Core and South core campuses. As a University of Agriculture, a lot of agricultural activities take place within the institution with the application of modern technologies such as the use of tractors, fertilizers, herbicides and pesticides of different sorts. This as well as the heavy traffic witnessed on daily basis contributes to the presence of substantial amount of heavy metals within the indoor environments of the institution.

Sampling

Twenty one offices were selected at random for this study. Sampling of office dust was conducted between November, 2014 and March, 2015, representing the dry harmattan season when there is high level of dust in the study area. Settled dust samples were collected from offices using the wipe sampling methodology according to the guidelines provided by the National Institute for Occupational Safety and Health, NIOSH 9100 method (1994) and American Society for Testing and Materials, ASTM E1728 protocol (2002) (Fig. 1). This procedure prescribes a vertical and horizontal overlapping S-shape movement, applying even pressure to the wipe surface to ensure that every space in the demarcated area is wiped thrice.



Sources: NIOSH, (1994) and ASTM, (2002);

Fig. 1: Dust wipe sampling technique

Using quantitative ashless filter paper (Whatman No 42) as the wipe material, a total of 210 wipe samples of office dust were collected from desks (900 cm^2 each) and ceiling fan blades (100 cm^2 each). To serve as control, 30 samples of outdoor settled dust were also collected from three locations within the College buildings sampled. The various sample locations and their codes are shown in Table 1. After sampling the area, the wipe material was folded with the contaminated side on the interior and placed into a pre-labeled sealable bag. The number of wipe material used per sampling depended on the visual observation of surface load. In each of the college building sampled, one field blank filter paper was exposed to all handling procedures used for the analytical samples with the exception that no surface was wiped (ASTM, 2002) as adopted by McDonald *et al*. (2010). This quality control measure was aimed at reducing gravimetric bias and also to account for any contamination of the wipe samples prior to analysis. The amount (g) of dust in each office was found by subtracting the initial mass of filter paper before sampling from the final mass of filter paper after sampling using electronic analytical balance. Following completion of sampling, all samples were transported to the laboratory for digestion and analysis.

Table 1: Sample Locations

College Building	Sample Code	Control
Science	SC_1, SC_2, SC_3	**A**
Veterinary Medicine	VM_1, VM_2, VM_3	**A**
Food Technology	FT_1, FT_2, FT_3,	**B**
Engineering	EN_1, EN_2, EN_3	**B**
Agronomy	AG_1, AG_2, AG_3	**B**
Agric Econ & Ext	AE_1, AE_2, AE_3	**B**
Animal Science	AS_1, AS_2, AS_3	**C**

Reagents/glassware

All reagents used in this study were of analytical grade, supplied by Sigma Aldrich, USA. They were utilized without undergoing any further treatments. Glassware and plastic wares were first washed with detergent, rinsed with deionized water and soaked overnight in 5 % nitric acid, then rinsed again with deionized water. This was to prevent adsorption of metals on them.

Digestion of dust wipe samples

Samples of office dust collected on filter papers were digested to extract metals following the method described in detail by ASTM E1644 protocol (2004), as adopted by McDonald *et al.* (2010). Dust wipe filter papers from each container were digested in concentrated analytical grade HNO_3 on hot plate. After digestion, the contents in the beaker, upon cooling was then transferred quantitatively into a 50 mL volumetric flask and brought to volume with de-ionized water, filtered through ashless filter paper (Whattman no 42) and stored in polypropylene bottles, ready for heavy metals analysis. Following similar procedure, 0.5 g of dust samples from each of the control sites was also digested.

The digests were then analysed for the concentrations of Cd, Cr and Pb using Shimadzu AA-6300 Atomic Absorption Spectrophotometer, fitted with an Auto sampler and equipped with Cd, Cr and Pb Hollow Cathode Lamps.

Results and Discussion

Toxic metals concentrations

Tables and bar charts were used to present the experimental data obtained in this study. Table 2 shows the mean concentrations of toxic metals in each sample location within the study area, while the graphical plots are presented in Figs. 2 – 4. Similarly, Table 3 shows the comparison of the concentrations of toxic metals in the present study with those of existing literature.

Cadmium: The level of Cd in office dust in all the sampling stations within the period of this study varied from 0.1223 – 0.3357 µg/g. The concentration of Cd was highest at the College of Science (SC) while the College of Engineering (EN) recorded the lowest concentration as depicted in Fig 2. The elevated concentration of Cd within the College of Science may be due to laboratory reagent emissions. The disposal of chemical wastes containing Cd compounds which may be released into the atmosphere as dust contains substantial amount of Cd. The high level of Cd at the College of Science may also be traceable to the burning of wastes containing discarded Ni-Cd batteries and plastics containing Cd pigments, vehicle emission, tyre abrasion as well as Agricultural activities such as the application of fertilizers and herbicides in the nearby farms (Lazor*et al*., 2012; Mgbemena and Onwukeme, 2012). Cd inhibits enzymes and has affinity for important ligands/nutrients in living cells. Its interaction with Cu, Fe and Zn in the body induces deficiency symptoms such as hypertension, respiratory disorder, damage to kidney and liver, pneumonities and broncho-pneumonia (WHO, 1999).

Table 2: Concentrations of toxic metals in office dust in the sample locations

Sample Locations	Toxic Metal Concentrations (μg/g dry weight) Cd	Cr	Pb
SC	0.3357	1.227	172.5
VM	0.1763	0.993	148.2
Ctrl A	0.4000	2.680	260.5
FT	0.2075	1.278	160.9
EN	0.1223	1.950	194.2
AG	0.1616	3.060	53.45
AE	0.1463	1.835	156.7
Ctrl B	0.3800	1.370	234.4
AS	0.1607	1.304	225.5
Ctrl C	0.2000	2.610	399.4

Chromium: Cr exist in nature mainly as chromites ($FeCr_2O_4$) and cryolite ($PbCrO_4$) and is essential for the insulin molecule to bring glucose into the cell for glycolysis. Cr in air settles in less than ten (10) days and sticks strongly to soil particles (Mafuyai *et al*., 2014). The concentration of Cr determined in office dust in all the sampling sites during the period of assessment ranges from 0.9936 – 3.060 μg/g. The highest value was recorded at the College of Agronomy (AG) while the lowest concentration of Cr was recorded at the College of Veterinary Medicine (VM) as shown in Fig. 3. Heavy metal pollution of air can arise from many sources, but Cr arises mainly from fossil fuel burning, preparation of nuclear fuels, electroplating such as chrome – steel or chrome – Nickel and other alloys, brick in furnances, dye and pigments. According to Mafuyai *et al.* (2014), all forms of Cr can be toxic at high levels, but Cr^{6+} is more toxic than Cr^{3+}. This is because exposure to Cr^{6+} in air can damage and irritate the nose, lungs, stomach and intestines. Skin contact with Cr^{6+} may lead to ulcers.

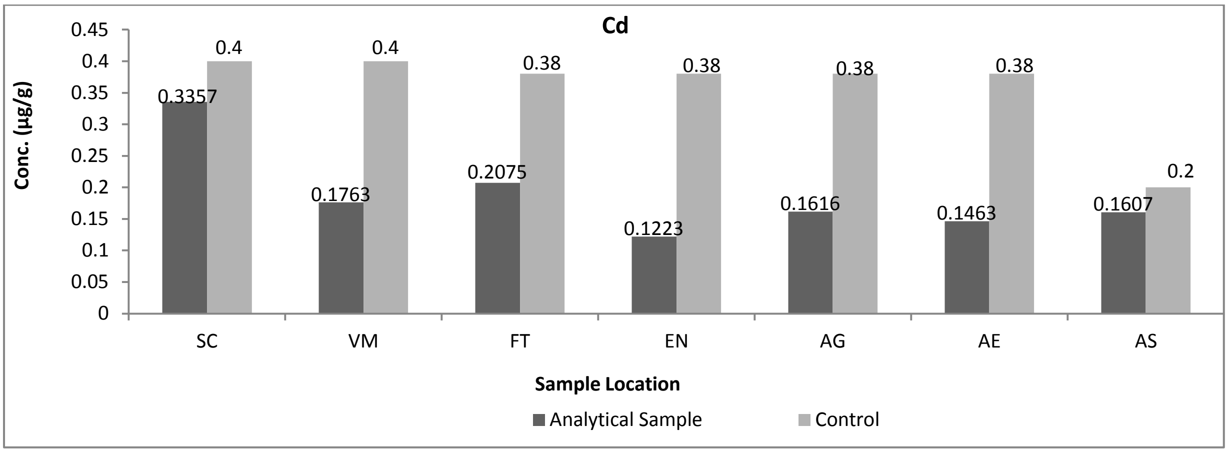


Fig. 2: Concentration of Cd in office dust

Table 3: Comparison of toxic metal concentrations (μg/g dry weight) in office dust from the University of Agriculture Makurdi with those reported in literature

Study area	Toxic metals concentrations Cd	Cr	Pb	References
Riyadh, Saudi Arabia	8.100	NA	3151	Al-Rajhi and Seaward (1996)
New Zealand	NA	103.0	1223	Fergusson and Kim (1991)
Ottawa, Canada	4.400	NA	233.0	Rasmussen *et al*. (1991)
Shanghai, China	NA	159.3	294.9	Shi *et al*. (2008)
Selangor, Malaysia	7.740	NA	734.0	Yap *et al*. (2011)
University of Agriculture Makurdi	0.3357	3.060	225.5	Current Study

NA = Not Applicable

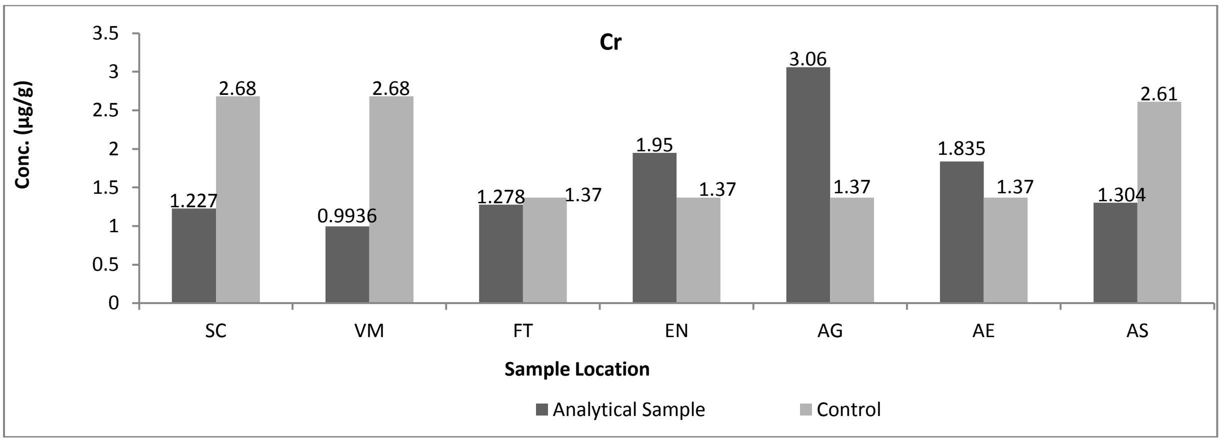


Fig. 3: Concentration of Cr in office dust

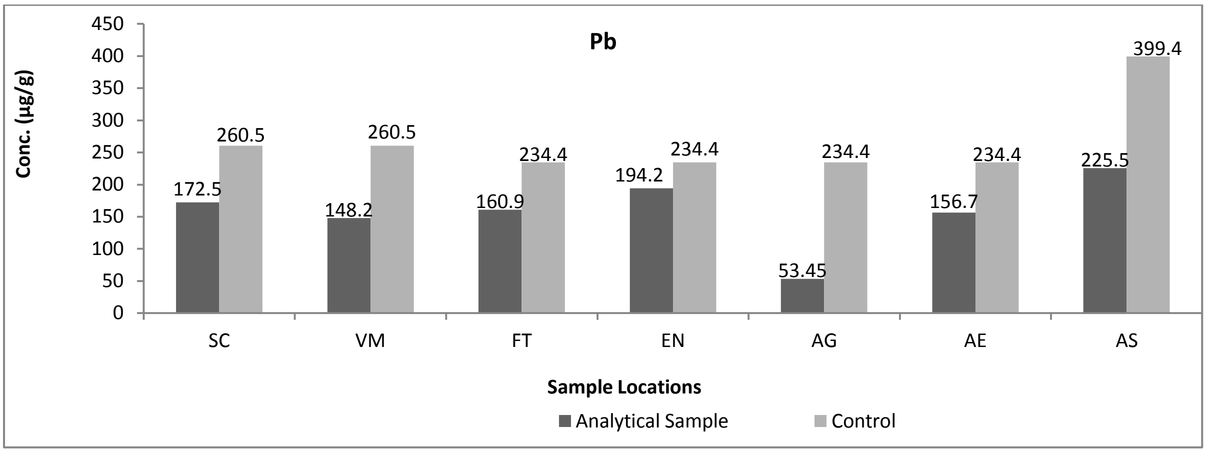


Fig 4: Concentration of Pb in office dust

Lead: The concentration of Pb recorded during the period of this study was fairly high in all the sampling sites. The level of Pb in office dust was in the range of 53.45 – 225.5 µg/g. The highest concentration was recorded at the College of Animal Science (AS) with a mean value of 225.5 µg/g as shown in Fig. 4. The elevated level of Pb in this site and other areas such as the College of Engineering (EN) and College of Science (SC) which recorded a total Pb concentration of 194.2 µg/g and 172.5 µg/g, respectively may be as a result of house age. This is because older buildings usually have more deteriorated interior surfaces, warped windows, doors and crevices in floors which can trap the heavy metal particulates. The study of heavy metal contamination of dust samples in Jaejon area, Korea by Kim *et al.* (1998) revealed that the age of building influences the level of heavy metals in house dust, with older houses (>15 years), significantly of higher concentrations than newer ones (< 15 years). The enrichment of Pb in these sites may be linked to a longer history of contamination from the use of leaded paints, lead solder and lead pipes (Tong and Lam, 2000). Paint chippings from old and deteriorated interior may settle as dust which poses serious threats to the health of occupants. Adegbamowo *et al.* (2006) reported that emulsion and gloss types of paints manufactured and sold in Nigeria contained substantial levels of Pb. Similarly, different human activities such as the application of organic and inorganic fertilizers as well as the use of herbicides at the nearby University commercial farm may also contribute to the high concentration of Pb at the College of Animal Science (AS). In addition to paint chippings and Agricultural activities, the elevated levels of Pb in these sites may be as a result of automobile emissions since most of the sites are close to roads and College car parks. The high concentration of Pb at the College of Science (SC) may be partly due to laboratory reagent emissions which may be linked to the disposal of Pb containing chemical wastes.

The concentrations of toxic metals in dust samples from offices within the University of Agriculture Makurdi as found in the present study are compared with those reported for other popular cities around the world and presented in Table 3. The levels of these toxic metallic pollutants in the present study were found to be lower than other reported values. The maximum concentrations of Cd and Pb in indoor dust samples reported by Al-Rajhi and Seaward (1996) and Rasmussen *et al.* (2001) for Saudi Arabia and Ottawa respectively are higher than the maximum values reported for the same metals in the present study. Fergusson and Kim (1991) as well as Shi *et al*. (2008) also reported higher levels of Cr and Pb in indoor dust samples from New Zealand and Shanghai, China, respectively. Similarly, the maximum concentrations of all the metals reported for Schools in Selangor of Malaysia by Yap *et al*. (2011) are found to be higher when compared with those reported for the same metals in the present study. Factors such as traffic density, agricultural activities, levels of industrial activities and indoor concentrations of these metals as well as population density may be responsible for these differences.

Conclusion

Analysis of office dust from the University of Agriculture Makurdi, Nigeria revealed the concentrations of the investigated metals in the order of Cd < Cr <Pb within the period of assessment. The levels of these pollutants in the present study were generally lower than those reported for other popular cities around the world and were also found to be within the threshold limits (except Pb which showed elevated levels). This suggests a likely common source for these toxic elements which may be traceable to anthropogenic activities within and outside the study area. However, the levels of these pollutants may be drastically reduced within the indoor environment by frequent wet mopping, vacuuming and renovation of deteriorated interiors as well as restricting the use of windows during the harmattan season when there is high prevalence of dust.

Acknowledgements

Our profound appreciation goes foremost to the Management of the Federal University of Agriculture Makurdi for granting us permission to carry out this study in the institution. We also thank the National Research Institute for Chemical Technology (NARICT) for technical assistance during the analysis.

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