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Pollution indexing and health risk assessments of trace elements in indoor dusts from classrooms, living rooms and offices in Ogun State, Nigeria

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ABSTRACT

Heavy metals are known to have a negative impact on human health especially children through oral ingestion. Total metal concentrations were determined in indoor dust from 19 locations consisting of classrooms, living rooms and offices in Ogun State, Nigeria. Digestion and instrumentation reproducibility were validated using certified reference materials (BCR 723 (Road Dust), NIST 2711a (Montana Soil) and NIST SRM 1640e (Trace element in water)). The measured and certified values showed good agreement. Potential threat levels using geo-accumulation (I_{geo}) and human health risk for both children and adult were assessed. The mean I_{geo} levels for the classified and probable carcinogens is in the order Cd (4.84) > Cr (3.28) > Pb (2.61) > Ni (2.48) > As (1.64) while other elements are in the order Zn (5.41) > Ba (4.86) > Sr (4.38) > Zn (4.27) > V (3.24) > Cu (3.14) > Hg (2.61) ≈ Tl (2.61). For human health risk, ingestion was the main route of exposure followed by dermal uptake and inhalation. Hazard index values for all studied metals were lower than the safe level of 1 while Hg vapor exhibited the highest risk value (0.13) in the case of children. The carcinogenic risk for As, Cd, Co, Cr, Ni and Pb were all within the acceptable level (10^{-4}–10^{-6}), but there was potential carcinogenic risk posed by Cr for both adults and children.

1. Introduction

Globally, heavy metals pollution have drawn much attention from the academia, government agencies and pressure groups due to their potential health effects on human living both in rural and urban areas. Metals such as lead, cadmium, mercury, zinc and chromium are known for their persistent behavior in the environment with consequent environmental, human and animal damage (Zheng et al., 2013; Zhu et al., 2013). Some of these metals are known human mutagens and carcinogen and are associated with various human ailments like cardiovascular, nervous system, blood and bone diseases, kidney failure, gingivitis, tremors among others (Rashed, 2008; Sun et al., 2013; Zheng et al., 2013).

Human beings may be exposed to heavy metals through oral ingestion, inhalation and or dermal contacts (Zheng et al., 2010a,b; Zheng et al., 2013; Li et al., 2014). One of the common routes of these metals to children and adults is through indoor dust contact. Indoor environment may be contaminated with metal laden dust in several ways. These might be infiltration from outdoor sources majorly from vehicle emission, transfer of particles by wind, legs or shoes and internally from smoking, incense burning, building and furniture materials, consumer products and occupants' activities (Mielke et al., 2001; Rashed, 2008; Darus et al., 2012). Studies have shown that time spent indoors varies with occupation, age, gender and status. According to Schweizer et al. (2007), people living in urban cities almost spent 90% of their time exposed to the indoor atmosphere. Exposure of children to indoor dust is particularly of interest due to their tendency to play on the floor and their habit to put everything in their mouth (Zheng et al., 2010a,b; Luo et al., 2012; Saeedi et al., 2012).

Unlike the developed countries, developing nations lacks adequate learning environment for children and subsequently, pupils and their teachers are often exposed to various contaminants within the educational facilities. Also, due to lack or poor implementation of environmental sanitation policies, living and working environments are not as hygienic as in the developed countries. Due to the un-hygienic living conditions in many developing countries, children and adults are often exposed to different environmental pollutants and subsequently leading to illnesses and

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eventually death. Past studies in Nigeria had mainly focused on levels of heavy metals in street dusts and soils (Bada and Oyegbami, 2012; Olawoyin et al., 2012; Azeez et al., 2013; Lar et al., 2013) with fewer reported cases of metals contamination in indoor environments (Adekola and Dosumu, 2001; Popoola et al., 2012; Ekwumemgbo and Omoniyi, 2013). In addition, elevated levels of heavy metals had been reported in children and adult blood samples in the Nigeria environment (Nriagu et al., 1997; Babalola and Babajide, 2009). Aside from scanty work carried out on heavy metals in classroom dust, attention is primarily drawn only on Pb, Cd, Zn, and Ni.

In a recent document, International Agency for Research on Cancer (IARC, 2011) categories heavy metals based on their potency to cause cancer. As and inorganic arsenic compounds, nickel compounds, cadmium and cadmium compounds were classified as class I carcinogenic elements. Lead compounds (inorganic) are class 2A while and cobalt and cobalt compounds are class 2B. Based on this classification, cancer risk for these metals could be computed while non-cancer risk for unlisted metals is also feasible.

Till date, no previous work in Nigeria had assessed the potential human health risks posed by heavy metals from classrooms, living rooms and offices dust either to children or adults. Thus, the objectives of this study were to (1) investigate the degrees of contamination of dust by trace elements using geo-accumulation index and (2) to evaluate the potential health risk to children and adults of these metals through various routes of exposure.

2. Materials and methods

2.1. Reagents and chemicals

Milli-Q water (18.2 MΩ cm, Millipore, Bedford, USA) was used throughout all experiments. All other reagents used were of analytical reagent grade. Nitric acid (65%, Merck, Darmstadt, Germany) was submitted to quartz sub-boiling distillation apparatus (MLS, Leutkirch, Germany). Trace elements mixed standard was obtained from Merck, Germany. Rare earth elements mix standard and Sn were purchased from CPI, USA, while Na, Ca, Sb, Hg, K, P and Mg were purchased from Roth, Germany. Working and calibration standards were prepared daily by proper dilution from 10 mg L^{-1} mix trace and rare earth elements; 10,000 mg L^{-1} of Ca, Mg and P and 1000 mg L^{-1} of Na and K in 10% nitric acid. The calibration curves were constructed in the range of 0.010–100 μg L^{-1} for rare earth and trace metals while the curves for Na, Ca, Mg, K and P are in the range of 0.100–10.0 mg L^{-1}.

2.2. Instrumentation

Digestions for metals determinations were performed with a microwave heated autoclave digestion system (UltraCLAVE III™, EMLS, Leutkirch, Germany). Metal determinations were carried out with an Agilent 7500ce ICPMS (Agilent Technologies, Waldbronn, Germany).

2.3. Sampling and sample preparation

Dust samples were collected from 19 locations consisting of classrooms, living rooms, and offices. Primary (3) and secondary schools (8) samples were collected from semi-urban city of Ilaro in Ogun State and higher institutions (8). Living rooms samples were collected from (45 rooms) pooled to 3 combined samples based on geographical locations at Ilaro, Abeokuta South and Abeokuta North Local Governments. The sampling locations are presented in Fig. 1. Classroom and office dust samples from the same location were collected from 10 to 15 classroom or office and pooled together (office samples separated from classroom samples) to have a representative samples. The samples were collected by sweeping with brooms in classrooms and living rooms and vacuum cleaners in the higher Institutions. Samples were collected between January and April, 2013. All samples were stored in sealed polyethylene bags, labeled, and then transported to the laboratory. Samples were air-dried for at least 1 week and then sieved through a 1 mm mesh sieve to remove refuse and small stones. This mesh size ensured that all ranges of dust particles passed through and small stones and refuse were removed. The samples were grinded using mortar and pestle and transferred into a zip-lock bag for further analysis.

2.4. Samples digestion

For the digestion with the autoclave system, approximately 250 mg (weighed to 0.1 mg) of the dried and sieved dust sample or the reference materials (Road Dust (BCR 723) purchased from European Commission Geel, Belgium and Montana Soil (NIST 2711a) from NIST, Gaithersburg, USA) were weighed into 12 mL quartz vessels and 5 mL concentrated nitric acid (65%) was added. The quartz vessels were then closed with Teflon® caps and placed in the sample rack. The samples were digested according to following program. The digestion program including the cooling time ran for 2 h 30 min with a temperature ramped from 25 °C to 80 °C in 5 min, 80 °C to 150 °C in 15 min, 150 °C to 250 °C in 20 min and a holding time of 30 min at 250 °C. After the digestion, the digests were quantitatively transferred to polypropylene tubes and filled up to 50 mL with Milli-Q water. Total element determination was carried out using ICPMS (Agilent 7500ce) with an external calibration and Ge at m/z 74, In at m/z 115 and Re at m/z 185 as internal standards.

2.5. Contamination assessment methods

A number of estimation methods have been reported in literatures for estimating the degree of pollution in soils, sediments and dusts. In this study, the degree of heavy metals contamination in the dust were characterized by geoaccumulation index (I_{geo}),

$$I_{geo} = \log 2(C_n|1.5B_n) \quad (1)$$

where C_n is the measured concentration (μg g^{-1}) of element n, and B_n is the geochemical background concentration (μg g^{-1}) of the element in fossil argillaceous sediment (average shale). Here, B_n is the background content of element n in the continental crust (Taylor and McLennan, 1995; Hawkesworth and Kemp, 2006; Ozkan, 2012). The following classification is given for geoaccumulation index: <0 = practically unpolluted, 0–1 = unpolluted to moderately polluted, 1–2 = moderately polluted, 2–3 = moderately to strongly polluted, 3–4 = strongly polluted, 4–5 = strongly to extremely polluted and >5 = extremely polluted.

2.6. Health risk assessment model

2.6.1. Daily exposure dose and exposure point concentration

The health risk assessment equations used for estimating human exposure to metals in this study is based on reviewing works reported in literatures and method developed by United State Environmental Protection Agency (USEPA, 1989, 1996; Zheng et al., 2010a,b; Shi et al., 2011; Hu et al., 2012; Li et al., 2013, 2014; Sun et al., 2013; Zheng et al., 2013). The subjects considered were divided into two groups: children and adults. As widely reported in literatures, exposure to metals laden air can occur via three main paths: (a) direct inhalation of atmospheric particulates through mouth and nose; (b) dermal absorption of