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An Estimation of Daily Intake of Potentially Toxic Elements from Urban Dust of Abakaliki, Nigeria

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ABSTRACT
This study examined the total concentration of eight potentially toxic elements (PTEs) in urban dust of Abakaliki and also calculated the daily intake (DI) of these PTEs. Fifteen samples were investigated and the result revealed that the range of mean total PTE concentrations was found in this order: 3.59 – 15.3 mg/kg (As); 66.8 -172 mg/kg (Cd); 0.288 – 1.36 mg/kg (Cr); 25.4 – 86.6 mg/kg (Cu); 55.5 – 1815 mg/kg (Pb); 397 – 1389 mg/kg (Mn); 22.3 – 52.7 mg/kg (Ni) and 73.3 – 434 mg/kg (Zn). For each element the highest concentration (representing the worst-case scenario was used to calculate the daily intake and it was observed that only Pb with a DI of 4.88 µg kg_{bw}^{-1} day^{-1} exceeded Pb recommended tolerable daily intake (TDI) of 3.6 µg kg_{bw}^{-1} day^{-1}. Based on a soil and dust ingestion rate of 50 mg /day for children between the age of 1 and <6 year, the amount of dust that a child would ingest in order to exceed the recommended tolerable daily intake TDI was also calculated.

Keywords: urban dust, potentially toxic elements (PTEs), oral ingestion, Abakaliki, tolerable daily intake (TDI)

INTRODUCTION
Dust is an environmental component that has been found to house contaminants particularly urban dust. Dust is derived from soil, and represents the small particles that have settled onto humans, outdoor objects and surfaces due to either wet or dry deposition. It consists basically of natural and anthropogenic components (Amato *et al.*, 2009). The natural components include plant residue, fragmented rock and volcanic release while the anthropogenic constituents include vehicular exhausts particles, lubricating oil residues, tyre wears, engine coating wears, brake lining wear particles, heating systems, municipal waste incineration, constructions, renovations, mining and extraction processes, smelting, corrosion of galvanised metal components and building deterioration (Zhao *et al.*, 2006). Dust particles released from contaminated sites travel long distances and could be in constant contact with humans due to outdoor activities. This is because these dust particles have light weight. They are known to be fine solid particles and settle out under their own weight but could also remain suspended for some time in the atmosphere depending on its particle size (Hojai *et al.*, 2012). Thus, urban dust is a repository of environmental contaminants and need to be investigated regularly for total elemental concentrations.

Oral ingestion of dust occurs deliberately or involuntarily. It is common among all the exposed population. Due to the pervasive nature of dust, it is constantly in contact with the skin, clothes and any other objects not specially protected. It has been noted (Abrahams *et al.*, 2002) that every exposed population particularly in the urban environment would possibly ingest a small quantity of dust. This easily happens because dust adhering to our body, especially the fingers, may be unintentionally ingested due to hand-to-mouth activity. Moreover, fruits and vegetables could easily come in contact with dust and if not properly washed could lead to unintentional soil ingestion. Moreover, eating of dropped foods could also lead to soil ingestion (Elom *et al*, 2013). Exposure via the pathways (oral, dermal and inhalation) to these PTEs could cause potentially adverse effects, carcinogenesis and development of numerous health effects including: Skin and internal cancer, DNA damage, neurological effects and alterations to endocrine system (Guito *et al*, 2011). However, the effects depend on the dose and exposure duration. Interaction of dust particles with the eyes and the ears are known to cause irritation (Biasiol *et al* 2007).

MATERIALS AND METHODS
Sample collection and preparation
Abakaliki is the capital of Ebonyi State. Dust samples were collected within the capital territory. All sampled sites were selected randomly but with due regard to high volume of traffic,

populated areas and the location of pedestrians walkways. Figure 1 shows sampled locations. Fifteen urban dust samples (Figure 1) were collected. Dust samples were collected using a plastic dustpan and brush. Different dustpans and brushes were used at each site; gloves were worn to avoid cross contamination. Collected samples were transferred to self-sealing bags (Kraft bag) for transport to the laboratory. The sampling procedure was maintained for all sites to minimise sampling variability and maintain sample integrity. The samples were dried at a temperature of 35 □C for 48 hours. The dust samples were then sieved using a < 125 µm nylon sieve to remove unnecessary matter such as small pieces of building material and other debris. The < 125 µm dust samples collected after sieving were weighed (their mass recorded) and stored in sealed plastic containers. All procedures were carried out without contact with metal objects / utensils to avoid potential cross-contamination of the samples

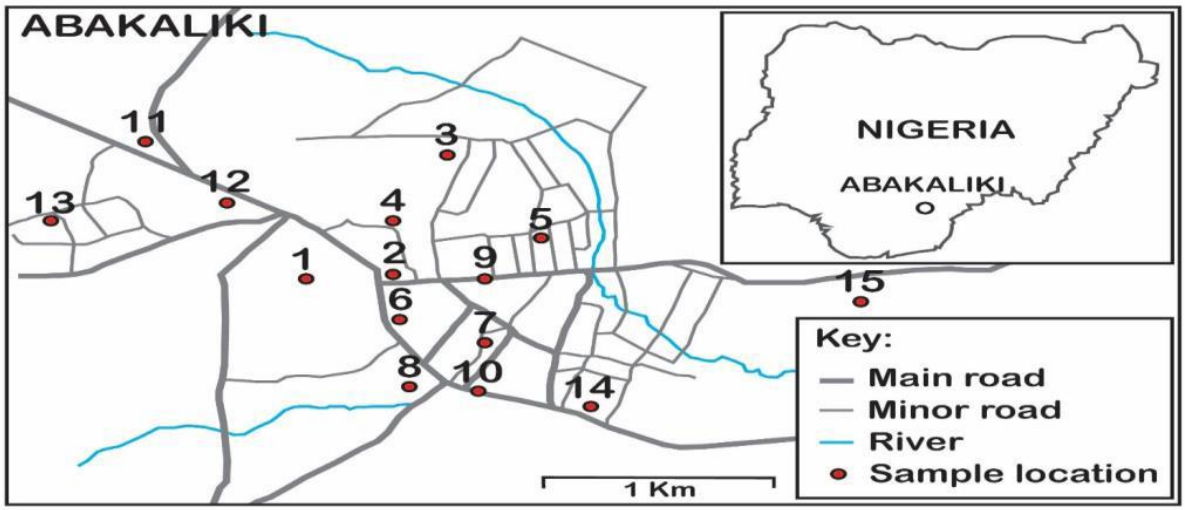

Figure 1: Map of Abakaliki showing the sampling locations (officer's mess (1), opposite Ebonyi Hotel (2), Outside of the Federal Medical Centre (3), Outside of the INEC (4), Awolowo Street (5), Outside of the Abakpa Main Market (6), Abakpa Motor Park (7), Vanco roundabout (8), Ukwansi Street (9), Ogoja Road (opposite United Bank of Africa, UBA (10), 0utside of Old Kpirikpiri Market (11), Obodo Park (12) , Unity Square (13), Outside of St. Theresa's Catholic Church (14), Okpara street (15).

Instrument and Reagents

All chemicals used were certified analytical grade. Concentrated hydrochloric acid (HCl) and concentrated nitric acid (HNO3) were supplied by Fisher Scientific Ltd. (Loughborough, UK). A multi-element standard for As, Cd, Cr, Cu, Pb, Mn, Ni and Zn and internal standard solution containing Indium (In), scandium (Sc) and terbium (Tb) were obtained from SPEXCerPrep (Middlesex, UK). Ultra-pure water of conductivity 18.2MΩ-cm was produced by a direct QTM Millipore system (Molsheim, France). Sample digestions were carried out using a start D multiprep 42 high throughput rotor microwave system (Milestone Microwave Laboratory Systems) supplied by Analityx Ltd. (Peterlee, UK) while sample measurement was carried out using an ICP-MS X series II (Thermo Electron Corporation, Cheshire, UK).

Microwave digestion protocol

0.5 g of each sample was accurately weighed into a 65 ml PFA (a perfluoralkoxy resin) microwave vessel pre-cleaned with concentrated nitric acid. An acid mixture (aqua regia) of 13 ml (HCl: HNO3, 3: 1 v/v) was carefully added into the PFA vessels and sealed with a TFM cover. The solution was gently swirled to homogenize the sample with the reagents; the vessels were then introduced into the safety shield of the rotor body and then placed in the polypropylene rotor of the microwave oven. All the vessels containing samples were properly arranged prior to starting the microwave digestion process. The microwave oven was operated at a temperature of 1600C, power of 750 watts, extraction time of 40 mins and a ventilation (cooling time) of 30 mins. After cooling, the digested samples were filtered using a whatman filter paper (grade 41, pore size 20 µm) into 50 ml volumetric flask. The filtrate was diluted to the mark with ultrapure water of resistivity 18.2 MΩ-cm at 250C. It was then transferred into a 50 ml Sarstedt tube and stored in the refrigerator (< 4 0C) prior to PTE content determination using Inductively coupled plasma mass spectrometry (ICP-MS).

Inductively coupled plasma mass spectrometry (ICP-MS) protocol

Samples to be analysed by ICP-MS were prepared in triplicate by measuring 1 ml of either the filtrate, or blank into a 10 ml Sarstedt tube; this was followed by addition of 30 µl of mixed internal standard (In, Sc and Tb) and 9 ml of water (1%

HNO3). Eight calibration standards over the range 0-400 ppb were prepared from a 100 ppm multi-element standard with mixed internal standard; this was used to calibrate the instrument and also to construct the calibration curves. The instrument was tuned to verify mass resolution and maximise sensitivity. This was done in both standard mode and Collision Cell Technology (CCT) mode. On that basis 75As, 52Cr, 63Cu, 55Mn, 60Ni and 66Zn were determined using CCT mode whereas 111Cd and 208Pb were determined using standard mode. During sample analysis, calibration standards were determined after every tenth sample to check for instrument consistency. Calibration curves for PTEs based on a concentration range of 0-400 ppb with 8 calibration data points were done on ICP-MS and the regression coefficient (R2) obtained for both modes was 0.999 (linear graph).

RESULTS AND DISCUSSION

The total concentrations of As, Cd, Cr, Cu, Mn, Ni, Pb and Zn were determined from the < 125 µm particle size fraction. The results indicate that the total concentration of PTEs in the urban dusts varied from location to location with Pb having the highest concentration (1815 mg/kg) and Cr the least concentration (0.288 mg/kg). Cadmium was not detected in two locations. The range of mean total PTE concentrations was found in this order: 3.59 – 15.3 mg/kg (As); 66.8 -172 mg/kg (Cd); 0.288 – 1.36 mg/kg (Cr); 25.4 – 86.6 mg/kg (Cu); 55.5 – 1815 mg/kg (Pb); 397 – 1389 mg/kg (Mn); 22.3 – 52.7 mg/kg (Ni) and 73.3 – 434 5 mg/kg (Zn). A box plot (Figure 2) showing median, mean, box boundary (25th and 75th percentile) and whiskers (10th and 95th percentile) has been used to show the distribution of these PTEs in the urban dust. For every element so determined, the highest concentration (representing the worst-case scenario was used to calculate the daily intake as well as the amount of dust that could be consumed by a child in order to exceed recommended tolerable daily intake(TDIoral).

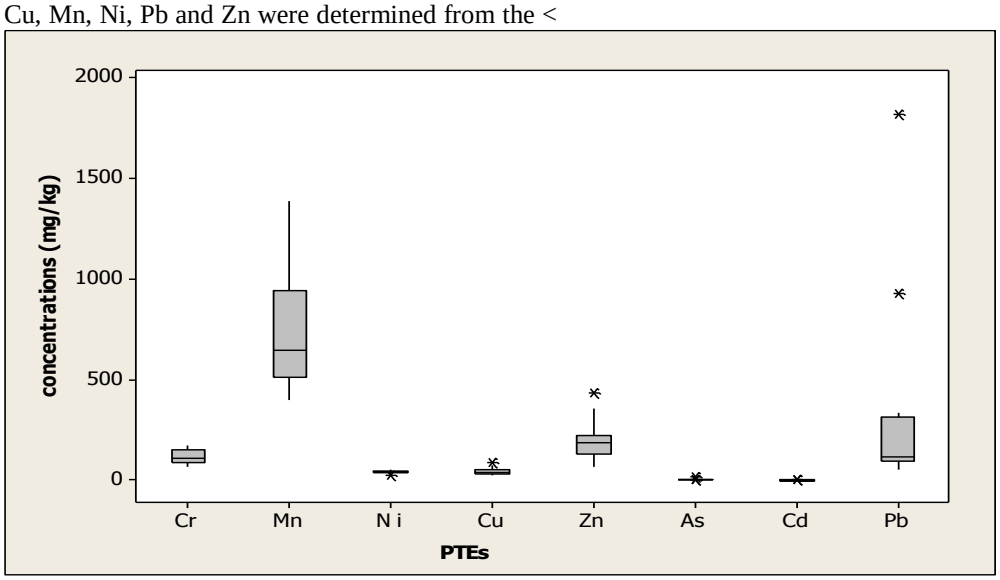

Figure 1: Box plot of PTEs in urban dusts of Abakaliki showing: median, mean, box boundary (25th and 75th) percentile and whiskers (10th and 90th) percentile

Calculation of daily intake (DI)

In order to estimate the human health risk associated with exposure to urban dust, the concentration of PTE from a particular sample that a child (as the most sensitive receptor) could possibly ingest to reach the estimated tolerable daily intake (TDI, for oral ingestion) was calculated using the equation: DI= [EC x SDIR] / BW (Elom *et al*, 2013)), where DI = daily intake (µg kg_{bw}^{-1} day^{-1}) as determined in <125 µm fraction of the dust sample with the highest concentration; EC = Exposure concentration of the PTEs in <125 µm (µg/g); SDIR = soil + dust ingestion rate (0.05 g day^{-1}) ; and BW = body weight (18.6 kg for a 3-6 year old child). The results are shown in Table 1. Due to the carcinogenic nature of As, a TDI would be inappropriate therefore an oral index dose (ID_{oral}) has been proposed of 0.3 µg kg^{-1} bw day^{-1} for As.

It can be seen from Table 1 that of all the PTEs, only Pb (4.88 µg kg_{bw}^{-1} day^{-1}) exceeded the recommended TDI for Pb (3.6 µg kg_{bw}^{-1} day^{-1}) whereas other PTEs were below recommended TDI showing that low risk exist in these locations. However, it is to be noted that constant exposure of children to urban dust could lead to accumulation of these PTEs in their bodies.

Table 1: Calculated daily intake from urban dust and recommended TDI (ID_{oral})

PTEs	Calculated daily intake (DI) (µg kg_{bw}^{-1} day^{-1}) based on 50 mg/day ingestion	Amount of dust that could be ingested by a child in order to exceed recommended TDI (mg/day)	Recommended Tolerable daily Intake (TDI_{oral}) µg kg_{bw}^{-1} day^{-1}
Cr	0.46	16304	150[a]
Mn	3.73	ND	N/D
Ni	0.14	4235	12[b]
Cu	0.23	34782	160[a]
Zn	1.17	25641	600[a]
As	0.04	375	0.3[c]
Cd	0.01	1,800	0.36[d]
Pb	4.88	36.9	3.6[e]

TDI_{oral} for Cr = 150 µg kg^{-1} bw day^{-1} (Nathanail *et al.*, 2009);
TDI_{oral} for Mn = Not Detected (N/D)
TDI_{oral} for Ni = 12 µg kg^{-1} bw day^{-1} (Environment Agency, 2009c);
TDI_{oral} for Cu = 160 µg kg^{-1} bw day^{-1} (Nathanail *et al.*, 2009);
TDI_{oral} for Zn = 600 µg kg^{-1} bw day^{-1} (Nathanail *et al.*, 2009);
ID_{oral} for As = 0.3 µg kg^{-1} bw day^{-1} (Environmental Agency.2010a);
TDI_{oral} for Pb = 3.6 µg kg^{-1} bw day^{-1} (Baars *et al*., 2001)

It was also considered necessary in this work to calculate the amount of dust that could be ingested by a child in order to exceed the recommended TDI (mg/day). Therefore, based on a soil and dust ingestion rate of 50 mg /day for children between the age of 1 and <6 years, to exceed the guidelines (TDIoral or IDoral for As) a child would need to consume, per day, the following amounts of dust per PTE: 375 mg (As); 1800 mg (Cd); 16304mg (Cr); 4235 mg (Cu); 36.9 mg (Pb); 4235 mg (Ni) and 25641 mg (Zn).

CONCLUSION

The research has proven that PTEs are ubiquitous in Abakaliki urban dusts. The findings demonstrated that the concentration of these PTEs do not represent risk to humans and animals. However, over exposure to urban dust could lead to the accumulation of these PTEs in our bodies via exposure pathways and chronic exposure could lead to ill health. Hence, unnecessary exposure should be avoided while personal hygiene particularly for children is recommended. There is also the need for constant Street sweeping to prevent the accumulation of these PTEs in dust particles.

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