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Seasonal Variation of Indoor Dust Levels of Potential Toxic Heavy Metals in Early Childhood Education Classrooms

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ABSTRACT
The study examines the seasonal variation in potentially toxic heavy metals found in indoor dust in early childhood classrooms, as heavy metal exposure becomes more common in Nigerian childcare settings. Six preschool dust samples from two Nigerian cities were collected during the dry and wet seasons, respectively. After being dried to a consistent weight, the dust samples were ground in a standard pulverizer. The Atomic Absorption Spectroscopy (AAS) method was used to conduct quantitative and qualitative analyses of the samples to determine the heavy metal and elemental composition of the dust in both locations. The dust samples contained seven heavy metals (As, Cd, Co, Cu, Mn, Pb, and Zn), with concentrations varying by season: Co 0.83 μgg^{-1} to Zn 38.43 μgg^{-1} during the rainy season, and 1.82 μgg^{-1} Cu to 80.00 μgg^{-1} Zn during the dry season. The study concluded that seven elements were present in the sample, and it is recommended that the government of the Federal Republic of Nigeria implement the necessary mechanisms to monitor the impact of dust on preschool children.

Keywords:
Dust,
Childhood Classrooms,
Atomic Absorption Spectroscopy,
Rainy and Dry Seasons.

INTRODUCTION

Heavy metals are naturally occurring elements with a fairly high atomic weight and a least density five times that of water Ali et al 2021. The following heavy metals are known to be enduring environmental contaminants: As, Cd, Co, Cr, Cu, Hg, Pb, and Zn. They are available because urbanized areas are contaminated from a variety of sources. According to reports, one of the main sources of heavy metal pollution is air and vehicle pollution (Abdul Rahman et al. 2013; Aweda et al. 2021).

Heavy metal exposure is increasing in Nigerian preschool classrooms, but government decision-makers are not giving it enough attention. Kids spend a large amount of time indoors. Human sensitivity to indoor particulate matter pollution is therefore a serious concern. Indoor air typically contains higher concentrations of chemical pollutants than outdoor air, such as semi-vaporizable organic compounds (SVOCs). Many indoor pollutants are absorbed through materials that begin as airborne particles and then settle as dust (Aweda et al., 2017; Alaiyemola et al., 2024). As reported by Aweda et al. (2023), heavy metal concentration is found in harmattan dust blown across Nigeria.

Preschoolers are susceptible to lead poisoning. If large amounts of lead are exposed uncontrollably, it can lead to serious functional issues such as behaviorally disruptive effects, low IQ, decreased learning capacity, and anaemia over time. Soils and dust are important ecological diagnostic tools that assess human well-being. Soil dust that was blown into homes and may be ingested by occupants without their knowledge through various channels (Bharti et al., 2017; Poggio et al., 2009).

Ingestion, inhalation, and skin contact are the three ways that toxic metals can be exposed unintentionally (Olatunde et al., 2016). Children are more vulnerable to the effects of soil ingestion because of their propensity for excessive consumption (Poggio et al., 2009). The associated health consequences are greater in this age group due to their poor resistance to toxins and preference for oral ingestion (Olatunde et al., 2016; Falaiye et al., 2013). Heavy metals are easily transported through sand and sediment, whereupon they can easily percolate into the surrounding dust and cause heavy metal contamination. Additionally, non-biodegradable metals can undergo bioconversion into compounds that are less noxious or mobile than they were in the beginning. The purpose of this study was to determine the concentration of heavy metals in the indoor dust of preschool children from two Nigerian locations.

MATERIALS AND METHODS

Dust samples were gathered from six significant schools in the densely populated regions of South-West Nigeria, namely Ibadan and Oshogbo as shown in Figure 1.

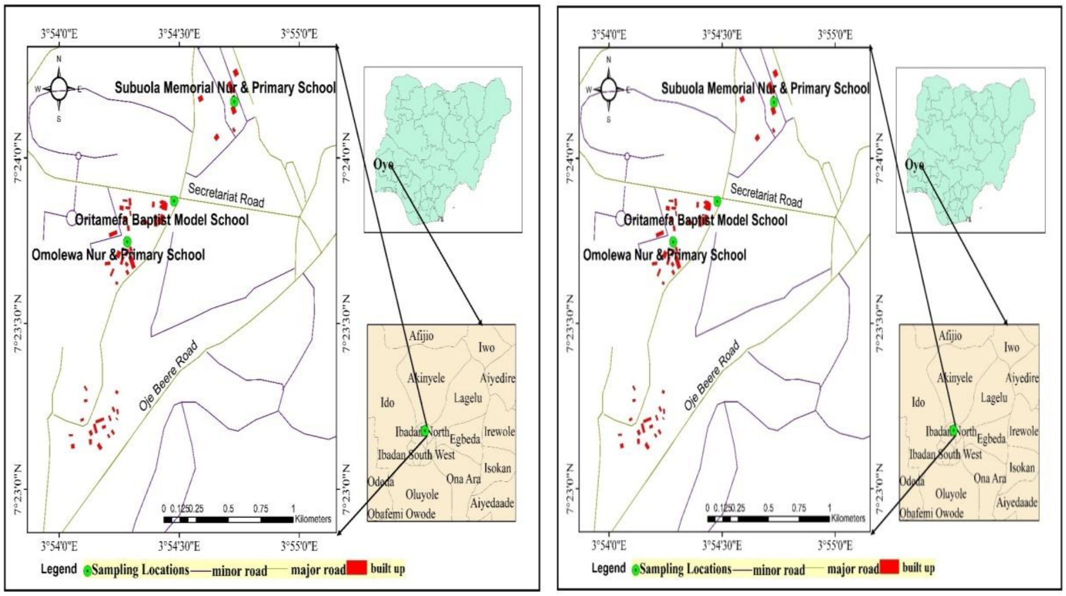

Figure 1: Map of the Sampling Site

Map of the Sampling Site with Sample Location marked as Ibadan and Osogbo; six preschool classes (with children ranging in age from six months to six years) dust samples were collected. The samples were collected for the wet season (May, June, and July 2021) and the dry season (December, January, and February 2020). Using a soft paintbrush, dust samples were collected from the preschool classrooms' furniture, windows, and fans, as well as from the surface soil in the surrounding outdoor ecosystem. The samples (n =6) from the indoor ecosystem were gathered at each sampling location from the children's habitually played areas as well as the areas they regularly occupied.

When the kids were playing outside near the preschool, in the garden or on the playground, the dust was sampled using a ring that was 2 cm deep and had a surface area of 0.04 m^2 (0.02 m x 0.02 m). Following that, these dust samples were placed into separate, appropriate plastic bags. Before being digested, the samples were carefully filtered in the lab using a <63 µm size sieve. Additionally, dust was collected by cleaning 0.09 m^2 (0.03 m×0.03 m) of the interior wall surface. Dust samples were typically placed in sample bottles, allowed to dry by air, and then sieved through a 2 mm stainless steel sieve before being stored in plastic bottles for examination.

RESULTS AND DISCUSSIONS

Table 1: Mean Heavy Metals Content in Indoor Dust Sample for Dry and Wet Seasons (µg/g)

	As	Cd	Co	Cu	Mn	Pb	Zn
			Dry Season				
1	2.48	41.47	19.80	2.20	41.46	2.77	1.78
2	25.42	38.98	3.80	4.17	38.98	21.68	59.00
3	30.48	21.83	37.02	18.92	21.83	20.78	80.00
4	73.22	29.55	3.53	18.68	29.40	4.88	27.08
5	39.15	54.40	3.63	1.82	54.40	20.38	38.63
6	2.51	3.03	2.80	1.57	30.25	37.38	19.55
Overall mean±SD	28.88±4.08	31.54±4.66	11.76±1.80	7.89±1.30	36.10±4.50	17.98±3.30	37.67±5.74
			Wet Season				
1	1.73	5.00	0.83	4.58	21.92	3.38	7.08
2	2.83	18.65	0.87	21.85	20.40	5.18	20.63
3	2.92	2.37	2.92	2.83	21.10	6.52	38.43

4	1.60	19.88	17.30	2.48	20.35	3.80	2.98
5	1.50	4.65	2.21	3.63	1.32	5.88	5.00
6	5.28	3.62	2.22	3.83	19.28	3.32	30.33
Overall mean± SD	2.64±0.83	9.03±1.70	4.39±0.93	6.53±1.08	17.40±3.23	4.68±0.96	17.41±2.50
FAO/WHO,2011	7	3	19	20-100	850	300	300

Table 1 displays the findings from the examination of the dust samples from the classrooms for As, Cd, Co, Cu, Mn, Pb, and Zn. In both seasons, arsenic contents ranged from 1.50 to 5.28 µg/g and 2.48 to 73.22 µg/g (Table 1). Table 1 shows 28.88 and 2.64 µg/g of dry ssample. In comparison to a comparable study carried out in Shah Alam, Malaysia by Nkansah et al. (2015), the mean content of the current study was three times that of the Shah Alam study.

It is clear from Table 1 results that sample 4's content (73.22 µg/g) is roughly five times higher than the study's overall mean. According to Nkansah et al. (2015), naturally occurring As in soil can range from 1.0 to 50 mg/kg, depending on the source from which the sample was taken. It is evident from the results that the highest content of As recorded in sample 4, which is the evaluated content of As, is above the range of expected proportions found in the natural environment.

According to Christoforidis and Stamatis (2009), corrosion and vehicle exhaust are thought to be the sources of As and Cd found in street dust. As a result, the location of auto stores within a 10-meter radius of the school's grounds may be attributed to the content of As at sample 4. The playground is heavily contaminated with emissions from the shops' operations because it appears the pupils and the shop use the same area.

Table 1 lists the amount of CD in the classroom dust. The average levels of Cd in the dust were 31.54 and 9.03 µg/g for both seasons, ranging from 3.03 to 54.40 µg/g and 3.62 to 19.88 µg/g. Comparing this study to a related study conducted in 69 kindergartens in Wuhan, China by Nkansah et al. (2015), the average content of CD in this study is five times higher. Nonetheless, all of the school's evaluated content was higher than the benchmark content of 3 µg/g, with samples 5 and 4 having the highest contents in the dry and wet seasons, respectively, at 54.40 and 19.88 µg/g.

In soil, normal levels range from 3 to 5 µg/g. Typically, the amount of cadmium in soil is between three and five µg/g (FAO/WHO, 2011). Every sampling location recorded contents in the soil that was more than five times what was anticipated. The contents of the CD and human activity near the school were connected, which may have been caused by the mechanic's workshop and the freeway being so close to the school grounds

The overall mean content of Co was less than the benchmark limit for each sample. Samples 3 and 4 had the highest levels of Co in the wet and dry seasons, at 17.30 and 37.02 µg/g, respectively. In addition to samples 3 and 4, Co. was present in all schools. The mean CO content determined from the recorded values is shown in Table 1, and it was found to be 4.39 and 11.76 µg/g of dry soil. This mean content is higher than the values found for all other samples during both seasons, except samples 1, 3, and 4.

The present findings are consistent with the earlier research conducted by Gault et al. (2010) and Nkansah et al. (2015), which suggested that the exposure level to Co is typically low. Additionally, it usually occurs through food or skin contact with materials that have trace levels of cobalt (Gault et al., 2010). The European Food Safety Authority's guideline value for non-carcinogenic effects is kept at 600 µg Co/day by Tvermoes et al. (2013).

Based on the lowest level of adverse effects observed, which was 23 mg Co/kg daily, this value was determined. The maximum lifetime daily Co dose at which all age groups and the majority of potentially sensitive subpopulations would be considered "safe" is represented by this dose. 20 mg/kg is the highest amount of Co that can be found in dust (Abdul Rahman et al., 2013). Thus, it can be concluded that the Co values found in this study may not currently be harmful to the students.

In dry and wet seasons, respectively, copper contents ranged from 1.57 to 18.92 and 2.48 to 21.85 µg/g (Table 1). For each sample in this study, the overall mean copper content was found to be 7.89 and 6.53 µg/g of dry sample for the two seasons (Table 1.1). Comparing the current work's mean content to a related study conducted in Shah Alam, Malaysia by Nkansah et al. (2015), we found that it was lower. It is clear from Table 1.1's results that samples 3 (18.92 µg/g), 4 (18.68 µg/g), and 2 (21.85 µg/g) had contents that were roughly three times higher than the study's overall average for both seasons.

According to FAO/WHO (2011), depending on the parental material, naturally occurring Cu in soil can range from 2 to 100 mg/kg. Based on the results, it can be inferred that the Cu content found in samples 3, 4, and 2, which had the highest recorded Cu content, falls within the range of naturally occurring proportions found in the ecosystem. According to Christoforidis and Stamatis (2009), car emissions are thought to be the source of the nickel and copper found in street dust. Consequently, the placement of open market stores within a 15-meter radius of the school grounds may be the cause of the Cu content at samples 3, 4, and 2.

The playground is heavily contaminated with emissions from the activities of nearby shops, as it appears that the students and the general public use the same space. The average Mn content for both seasons was 17.40 µg/g and ranged from 29.40 to 54.40 µg/g and 1.32 to 21.92 µg/g, respectively, in the classroom dust. In comparison to a related study conducted in 69 kindergartens in Wuhan, China by Sun et al. (2014), the mean content of Mn in this study is two times lower.

Though all the schools in the sample measured content below the 850 µg/g background limit, schools 5 and 1 had the highest content for both seasons, measuring 54.40 and 21.92 µg/g, respectively. In soil, normal limits fall between 20 and 3000 µg/g. Typically, soil contains no more than 850 µg/g of manganese (FAO/WHO, 2011). All of the sample locations recorded dust values were lower than anticipated. The human activity near the school and the Mn levels did not appear to be related.

In accordance with the findings of this investigation for both dry and wet seasons, the mean lead content varied between 2.77 and 37.38 µg/g and 3.32 to 6.52 µg/g in dry soil (Table 1.1). For both seasons, the mean Pb content of dry soil samples were determined to be 17.98 and 4.68 µg/g, respectively. The study found that the Pb recorded content in all the sampling schools was below the background value, with the exception of the sixth school, which recorded the highest value of 37.38 µg/g, more than seven times higher than the metropolitan average.

Table 1.1 also shows that the remaining 2 samples recorded values below 7 µg/g in both dry and wet seasons, indicating that content of 37.38 µg/g is a deviation. In addition, schools 2, 3, 5, and 6 in the dry season had Pb contents of 21.68, 20.78, 20.38, and 37.38 µg/g. This extremely high content in comparison to the amounts found in the other schools might indicate that Pb release into the school's surroundings has been improved. According to Latif et al. (2013), engine wear, exhausts from burning fuel, and Pb emissions into the environment are mostly caused by tire wear, associated moving parts, battery leaks, and radiator spills.

As a result, the activities of auto-mechanic shops, which are located approximately 15 meters from school and appear to share the school grounds with the students, may be partially to blame for the high lead content found at school 6. Students in school 6 are susceptible to the effects of lead (Pb) in the environment because the amount of Pb found in dust exceeds by more than 1.5 times the allowable limits of 20 mg/kg (Latif et al., 2013)

For both the dry and wet samples, the mean Zn content ranged from 1.78 to 80.00 and 2.98 to 38.43 µg/g. However, for sample 3 in both seasons, the highest Zn content was 80.00 and 38.43 µg/g. Except for sample 3, Zn was found below allowable limits at every sampling site. When the overall mean Zn content over the recorded values was calculated, the results showed that the content was 37.67 and 17.41 µg/g dry soil (Table 1.1). Except of school 2, 3, and 5, the overall mean content is higher than the values found for all other samples during the dry season. This finding is in line with earlier research by Latif et al. (2013), which indicated that exposure levels to zinc are typically very moderate.

The usual ways are through food or skin contact with materials that have moderate concentrations of zinc (Latif et al., 2013). Regarding Tvermoes et al. (2013), the 300 µg Zn/day guideline limit for non-carcinogenic effects is still in place according to the European Food Safety Authority. This figure was based on the lowest level of adverse effects that were recorded, which was 23 mg Zn/kg per day. This would be the highest amount of zinc that could be consumed in a lifetime and be considered "safe" for all age groups and the majority of potentially sensitive subpopulations. According to research, the highest amount of zinc that can be found in dust is 300 mg/kg (FAO/WHO, 2011). Thus, it could be concluded that the Zn values found in this study don't currently pose a risk.

CONCLUSION

This research shows the concentrations of heavy metals in dust from the chosen locations, that is the indoor classrooms. Heavy metal concentrations are within the range of the WHO standard. The research shows that there are seven element presents in the sample collected. However, during the dry season, Zn>Mn>Cd>Cu>Pb>Co>, and Zn>Mn>Cd>As > Pb>Co>Cu are the mean metal contents, respectively. The analysis of the data showed that surface soil naturally contains more heavy metals during the dry seasons than the wet ones.

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