

ASSESSMENT OF HEAVY METALS CONTAMINATION IN INDOOR AIRBORNE DUST WITHIN SOKOTO METROPOLIS

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Abstract

Indoor airborne dust pollution is a growing environmental and public health concern due to its potential to expose occupants to harmful heavy metals. This paper assesses the concentration of lead (Pb), cadmium (Cd), and chromium (Cr) in indoor airborne dust samples collected from various locations in Sokoto Metropolis, Nigeria. A total of 21 samples were analyzed using Atomic Absorption Spectroscopy (AAS), and the results were compared to permissible limits set by the World Health Organization (WHO). The findings indicate that Pb concentrations were elevated across all study sites, with three locations exceeding 1 ppm, raising serious health concerns. Cadmium concentrations were found to be within permissible limits in some areas, while Cr levels were consistently low throughout the sample locations. The study attributes these variations to anthropogenic activities, including vehicular emissions, industrial discharges, and household sources such as paints, cosmetics, and fossil fuel combustion. The presence of heavy metals in indoor dust poses potential health risks, particularly to children, the elderly, and individuals with respiratory conditions. The paper highlights the need for enhanced indoor air quality management, stricter regulatory policies on industrial emissions, and public awareness campaigns to mitigate exposure.

Keywords: Indoor airborne dust, heavy metal pollution, lead, cadmium, chromium, environmental health.

Introduction

Air pollution has become a critical environmental and public health concern worldwide, particularly in urban areas where industrialization, vehicular emissions, and anthropogenic activities contribute significantly to deteriorating air quality. Heavy metals in airborne dust pose a serious health risk among various air pollutants due to their persistence, bioaccumulation, and potential toxicity (Chen *et al.*, 2019). Heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg) are known to have detrimental effects on human health, especially when inhaled in fine particulate form. Studies indicate that exposure to heavy metals in indoor air can lead to respiratory diseases, neurological disorders, and even carcinogenic effects (Wu *et al.*, 2021). Given the enclosed nature of indoor environments, assessing heavy metal pollution in airborne dust is crucial for understanding its impact on human health, particularly in urban centers such as Sokoto Metropolis.

Indoor environments are often considered safer than outdoor settings; however, several studies have demonstrated that indoor air quality can be more polluted due to limited ventilation and

the accumulation of contaminants from various sources (Zhang *et al.*, 2020). Indoor airborne dust originates from a mix of outdoor particulates, household activities, building materials, and consumer products, many of which contain heavy metals. Urban centers like Sokoto Metropolis, characterized by rapid population growth and reliance on fossil fuels, present a significant risk for heavy metal accumulation in indoor environments. Studies have shown that metals such as Pb, Cd, and chromium (Cr) can be introduced indoors through airborne particulates from vehicle emissions, industrial discharges, and domestic activities such as cooking and smoking (Adewuyi & Opasina, 2018).

The presence of heavy metals in indoor airborne dust raises significant public health concerns, particularly for vulnerable populations such as children, the elderly, and individuals with pre-existing health conditions. Due to their small particle size, heavy metals in dust can be easily inhaled and absorbed into the bloodstream, leading to systemic toxicity (Alghamdi *et al.*, 2022). Prolonged exposure to these contaminants has been linked to various health problems, including cognitive impairments in children, kidney damage, and cardiovascular diseases in adults (Ali *et al.*, 2021). Understanding the concentration and distribution of heavy metals in indoor airborne dust is essential for developing effective mitigation strategies to protect public health.

Sokoto Metropolis, located in northwestern Nigeria, experiences a unique climatic condition characterized by high temperatures, low humidity, and frequent dust storms, particularly during the Harmattan season. These environmental factors can significantly influence the concentration and distribution of airborne particulates, including heavy metals (Ezeh & Chukwu, 2017). Additionally, the region's reliance on traditional biomass fuels, roadside vehicular emissions, and limited waste management infrastructure contribute to poor indoor air quality. Despite the potential health risks, limited studies have been conducted to assess heavy metal pollution in indoor airborne dust within Sokoto Metropolis. This knowledge gap underscores the need for comprehensive research to evaluate the sources, concentration levels, and potential health implications of heavy metals in indoor environments.

Heavy metal contamination in indoor airborne dust represents a growing environmental and health challenge, particularly in urban areas with high industrial and vehicular activities. Sokoto Metropolis, with its unique climatic conditions and urban development trends, presents a compelling case for investigating indoor air pollution. This study seeks to assess the levels of heavy metal pollution in indoor dust, identify potential sources, and evaluate the associated health risks. The findings will be instrumental in guiding policymakers, health professionals, and environmental scientists in designing effective mitigation strategies to safeguard public health and improve indoor air quality.

Materials and Methods

Study Area

This study was conducted in Sokoto Metropolis, a rapidly growing urban centre in north-western Nigeria. Sokoto experiences a hot semi-arid climate characterized by high temperatures, low humidity, and seasonal dust storms, particularly during the Harmattan period. It is located between latitudes 12° 55' N and 13° 10' N, and longitudes 5° 09' E and 5° 17' E. The city's urbanization, vehicular traffic, industrial activities, and reliance on biomass fuel contribute significantly to air pollution, making it a suitable location for assessing heavy metal contamination in indoor airborne dust.

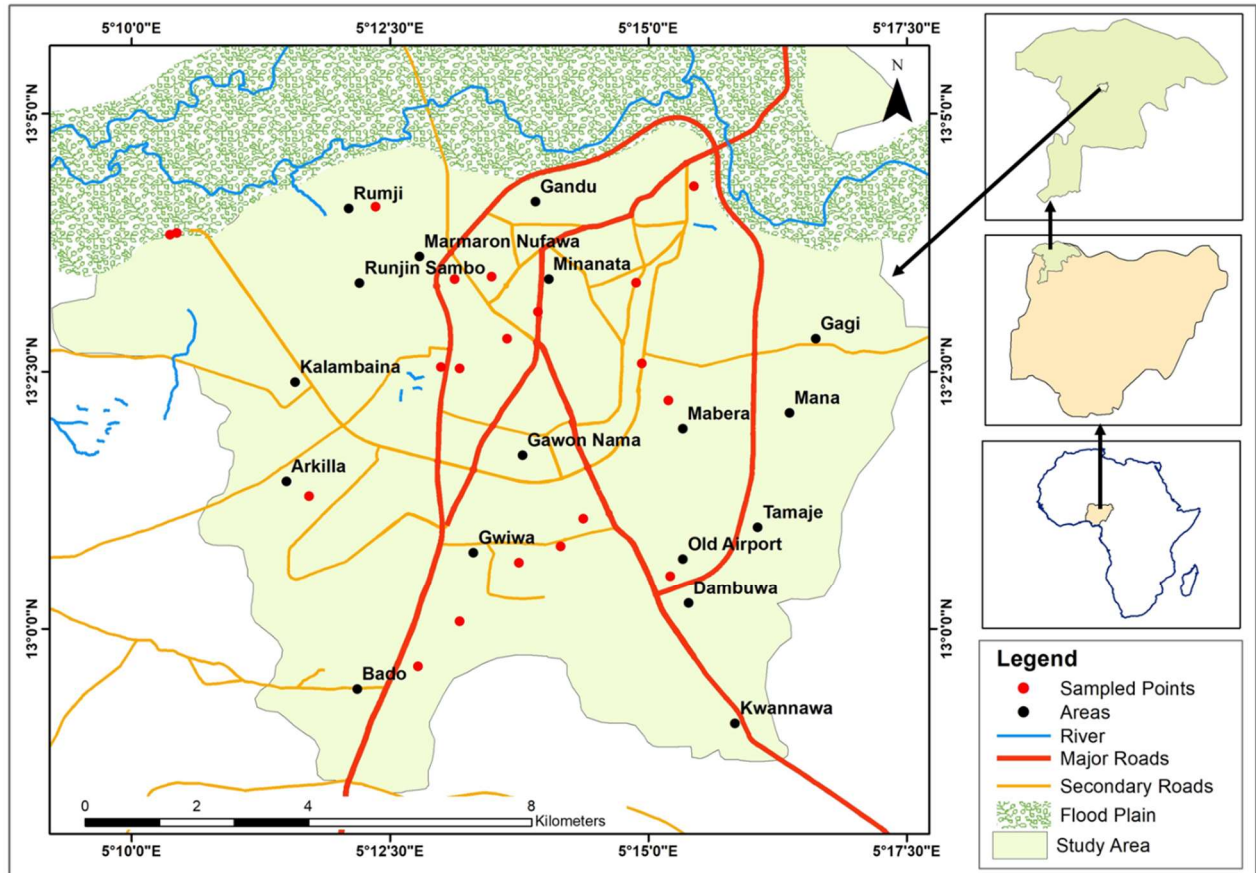


Figure 1: The Study Area

Justification of Analysis Method

Several methodologies have been employed globally to assess heavy metal contamination in airborne dust, including inductively coupled plasma mass spectrometry (ICP-MS) and atomic absorption spectrometry (AAS) (Kumar *et al.*, 2021). These techniques enable accurate quantification of heavy metal concentrations and facilitate risk assessment studies. By adopting AAS analytical approach, this study aims to provide baseline data on heavy metal pollution in indoor airborne dust in Sokoto Metropolis, thereby contributing to the body of knowledge on indoor air quality in developing urban centers. The findings of this study could inform policy decisions, public health interventions, and environmental management strategies to mitigate heavy metal exposure and its associated risks.

Sampling Strategy

A stratified random sampling approach was employed to ensure representative dust collection across different indoor environments. Samples were collected from residential homes, schools, offices, and commercial buildings in various parts of the metropolis. The selected sites were categorized based on:

Dust Sample Collection

Pre-cleaned glass slides and petri dishes were placed at elevated surfaces (1.5 m above ground) in each indoor environment for 14 days to allow dust deposition. After collection, samples were carefully transferred to sterile, airtight polyethylene bags to prevent contamination.

Sample Preparation and Digestion

To extract heavy metals from the dust samples, a wet digestion method was employed using a mixture of concentrated acids (Jain *et al.*, 2024). The procedure involved:

- i. Weighing 0.5 g of dust sample using an analytical balance: Placing the sample in a Teflon digestion vessel and adding 10 mL of nitric acid (HNO₃) and 5 mL of hydrochloric acid (HCl) (Aqua Regia mixture).
- ii. Digesting the mixture using a microwave digestion system at 180°C for 30 minutes.
- iii. Cooling the digested solution and filtering it through a Whatman No. 42 filter paper.
- iv. Diluting the filtrate to 50 mL using deionized water before analysis.

Heavy Metal Analysis

The concentrations of heavy metals in the digested dust samples were determined using Atomic Absorption Spectroscopy (AAS) (Chakraborty *et al.*, 2024). The target heavy metals included lead (Pb), cadmium (Cd), and chromium (Cr). The procedures were as follows:

AAS Analysis: Used for Pb, Cd and Cr using a PerkinElmer AAnalyst 800 spectrometer. Calibration was performed using certified standard reference materials (SRM 2583), and blank samples were analyzed to ensure accuracy (Chakraborty *et al.*, 2024).

The heavy metal concentrations were statistically analyzed using a line graph for data visualization and one-sample t-test, which was used to compare the heavy metal concentrations with the permissible standards.

Results and Discussion

The concentrations of selected heavy metals (Lead (Pb), Cadmium (Cd), and Chromium (Cr)) in indoor airborne dust samples from various locations in Sokoto Metropolis revealed varying levels of contamination (Figure 2, 3 and 4). While some areas recorded concentrations within or below the permissible standards set by National Environmental Standards and Regulations Enforcement Agency of Nigeria (Table 1). The variations in concentrations reflect the influence of anthropogenic activities, environmental conditions, and building characteristics in different sampling sites.

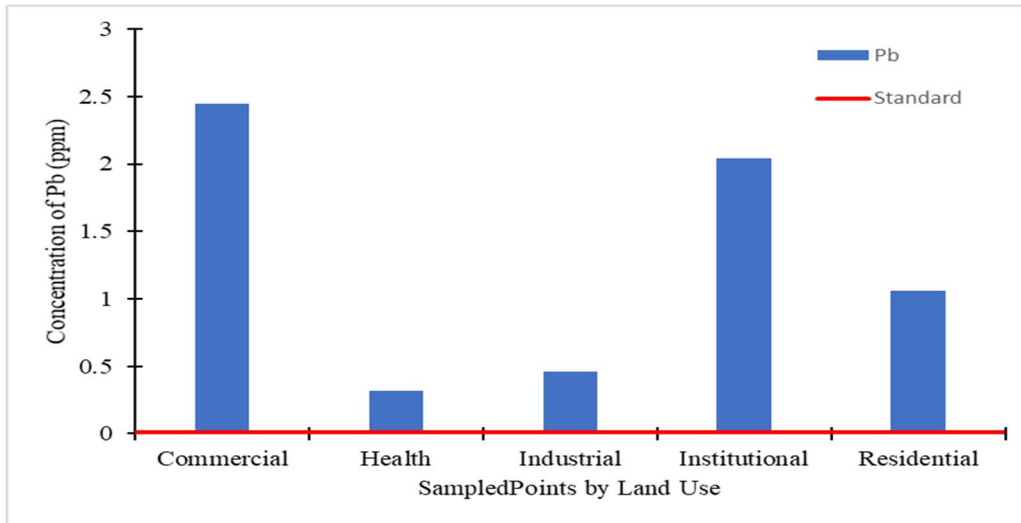


Figure 2: Concentration of Pb

The results revealed that Pb concentrations were high throughout the sample areas, with three locations exceeding 1 ppm and surpassing the recommended safety limits (Figure 2). These elevated Pb levels could be attributed to vehicular emissions, industrial activities, lead-based paints, and other domestic sources. Studies have shown that Pb contamination in indoor dust is often linked to resuspended road dust, deteriorating lead-based paints, and emissions from industrial products (Li *et al.*, 2021). The presence of high Pb levels in residential and commercial buildings suggests long-term exposure risks, particularly for children and individuals with pre-existing respiratory conditions (Kumar *et al.*, 2022). Lead exposure is known to cause neurological impairments, reduced cognitive function, and cardiovascular disorders (USEPA, 2021). The findings underscore the need for urgent mitigation strategies, such as improved ventilation, dust control measures, and restrictions on Pb-containing products in indoor environments.

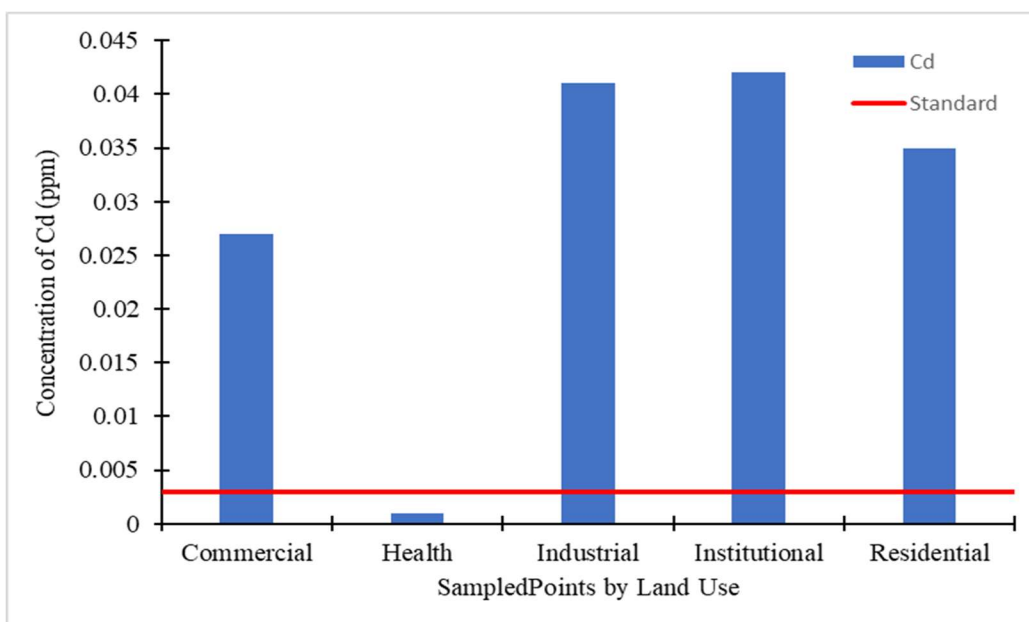


Figure 3: Concentration of Cd

The results of the study reveal consistently high concentrations of cadmium (Cd) across the study area (Figure 3), emphasizing a widespread environmental concern. Interestingly, only areas surrounding health facilities recorded Cd levels below the permissible limits, suggesting that such zones may benefit from better environmental management practices or stricter monitoring protocols (Fu *et al.*,2022). In contrast, Cd concentrations at sample points located within industrial, institutional, commercial, and residential areas were significantly elevated, often exceeding NESREA safety thresholds. This trend points to the strong influence of anthropogenic activities, particularly industrial operations, vehicular emissions, and improper waste disposal, as major contributors to Cd contamination (Zhao *et al.*,2023; Zhang *et al.*,2020).

The elevated Cd levels in industrial and commercial zones could be attributed to emissions from manufacturing processes, metal plating, battery production, and fuel combustion, which are known sources of cadmium in urban environments (Zhang *et al.*,2020; Li *et al.*,2022). In residential areas, the improper disposal of electronic waste, use of phosphate fertilizers in nearby gardens, and household waste mismanagement may also contribute to elevated Cd levels. Similarly, institutional areas, though typically less associated with heavy industrial activities, may experience contamination from maintenance operations and localized pollution sources. These findings are consistent with recent studies showing that urban land uses significantly influence the spatial distribution of heavy metals in the environment (Wang *et al.*,2023). Recording high concentrations of Cd has been associated with kidney damage, bone demineralization, and increased cancer risk (Järup & Akesson, 2022).

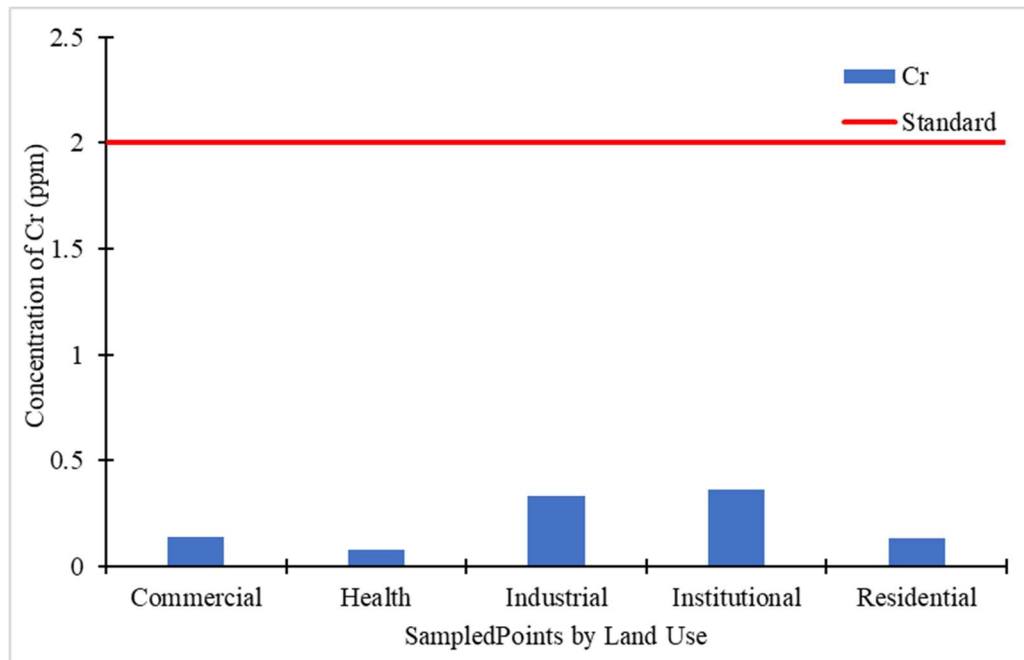


Figure 4: Concentration of Cr

The results also revealed that Cr concentrations were consistently low throughout the sample areas, with values well below the NESREA safety thresholds (Figure 4). The lower Cr concentrations may be linked to the absence of major Cr-emitting sources in the surveyed locations. Chromium contamination in indoor dust is often associated with industrial emissions, cement production, and corrosion of metal fixtures (Wu *et al.*,2021). The low Cr levels indicate

that indoor sources in Sokoto Metropolis may not be significant contributors to Cr pollution. However, continuous monitoring is essential since Cr (VI), a toxic form of chromium, has been classified as a carcinogen, and prolonged exposure can lead to respiratory complications and skin disorders (Ali *et al.*, 2023).

The varying levels of Pb, Cd, and Cr in indoor airborne dust can be largely attributed to anthropogenic activities, which significantly impact indoor air quality. Major sources of heavy metal contamination identified in this study align with previous findings that human activities, industrial emissions, and domestic habits contribute significantly to indoor dust pollution (Guo *et al.*, 2022). The key anthropogenic contributors in Sokoto Metropolis include:

- Vehicular emissions: Roadside buildings exhibited higher Pb concentrations, confirming the role of traffic emissions in indoor dust pollution. Leaded gasoline (though phased out in many countries) and brake pad wear are still recognized as major Pb sources (Manousakas *et al.*, 2021).
- Industrial and artisanal activities: Small-scale industries, including welding, metal processing, and battery recycling, release airborne metals that eventually infiltrate indoor spaces.
- Domestic sources: The use of cosmetics, paints, and beauty care products that contain metallic compounds has been reported as a growing concern in indoor environments (Yang *et al.*, 2021).
- Fossil fuel combustion: The burning of kerosene, charcoal, and wood for cooking generates particulates containing heavy metals that settle as dust within enclosed spaces.

The elevated Pb levels in some areas, coupled with the presence of Cd and Cr, pose significant public health concerns, particularly for children, pregnant women, and individuals with compromised immune systems. Studies have shown that Pb exposure can lead to neurodevelopmental disorders in children, while Cd and Cr exposure are linked to lung, kidney, and bone diseases (WHO, 2022). The fine particle size of indoor dust allows for easy inhalation, increasing the risk of systemic toxicity. Additionally, heavy metal contamination in indoor environments may contribute to long-term indoor air pollution, exacerbating respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD) (Zhang *et al.*, 2021).

The findings of this study align with similar research conducted in urban centers worldwide. For instance, studies in Lagos, Nigeria, and Beijing, China, have reported elevated Pb levels in indoor dust due to vehicular emissions and industrial activities (Adewuyi & Opasina, 2020; Chen *et al.*, 2019). Additionally, a study by Kumar *et al.* (2021) in Delhi, India, found that Cd levels in indoor dust were influenced by cigarette smoke and industrial discharge, similar to the findings in this study. The relatively low Cr levels observed in this study are also consistent with reports from other non-industrialized urban settings, where Cr exposure is mainly limited to metal-based industries (Ali *et al.*, 2023).

Conclusion

The results of this study underscore the significant presence of heavy metals in indoor airborne dust, particularly elevated Pb levels in some areas, while Cd remained within permissible limits and Cr levels were low. The findings point to anthropogenic sources, including vehicular emissions, industrial activities, and domestic product usage, as key contributors to indoor metal contamination. The health risks associated with these contaminants highlight the urgent need for policy interventions, improved air quality regulations, and public health awareness campaigns. Future studies should focus on indoor air quality and health, and long-term monitoring and the

potential interactions between heavy metals and other indoor air pollutants to develop comprehensive mitigation strategies.

Recommendations

Given the health risks associated with heavy metal contamination in indoor dust, the study highlights the need for preventive and control measures to minimize exposure. Recommended strategies include:

- i. Regulating indoor sources: Encouraging the use of lead-free paints, non-toxic cosmetics, and metal-free consumer products to limit indoor heavy metal contamination.
- ii. Improving ventilation and dust management: Frequent cleaning, use of air purifiers, and proper ventilation can help reduce the accumulation of heavy metals in indoor dust.
- iii. Stronger industrial and traffic emissions control: Implementing stricter emission standards for industries and automobiles in Sokoto Metropolis to minimize outdoor-to-indoor pollution transfer.
- iv. Public awareness and health monitoring: Conducting awareness campaigns on indoor air pollution and encourage regular biomonitoring of heavy metal exposure, especially in children and workers exposed to industrial pollutants.

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