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## A Review

# Health Risk of Toxic Heavy Metals on the Human Body *via* Contaminated Dust and Their Mitigation in Pakistan

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**Abstract.** Dust contamination is a challenging atmospheric issue that poses a major ecotoxicological risk to both the environment and human health. The presence of toxic heavy metals (HM's) in dust can put human health at risk if inhaled, ingested or *via* dermal contact. They can cause severe health problems, resulting in widespread mortality and morbidity. Therefore, it is crucial to develop eco-friendly ways and the appropriate strategies to minimize HM's in dust to build a healthy environment. The purpose of this systematic review is to present evidence-based information about the sources of HM's-containing dust, its effects on human health and the mitigation strategies that must be implemented in Pakistan, as well as to highlight the research gap in this area. The most illustrious database, Science Direct (SD), was used to conduct the online literature search and the first step involved identifying 109 review papers and 199 research articles from Pakistan that had been published in peer-reviewed journals between 2015 and 2023. According to the literature research, there are numerous sources and health risks of dust-containing HM's that need to be minimized and in a changing environment we found that phytoremediation is a good option for reducing toxic HM's in dust.

**Keywords:** air pollution, ecotoxicological risk, mortality, morbidity, illustrious database, science direct, research gap, sources, strategies, phytoremediation

## Introduction

Heavy metals (HM's) are extremely intoxicating, non-biodegradable and chronic carcinogenic contaminants (Zhao *et al*., 2023; Naimabadi *et al*., 2022). They are mostly generated by natural sources (Mitra *et al*., 2022) and derived from anthropogenic activities such as stone-crushing, coal burning, agriculture, the poultry and animal industries, widespread use of metal-contaminated fertilizers and pesticides and the combustion of industrial and vehicular fuels in the modern age, particularly in Pakistan (Mohmand *et al*., 2015). There are the three most typical methods by which HM's can enter the body; digestion, followed by breathing and then skin contact (Safiur Rahman *et al*., 2019). When biological systems are exposed to heavy metals, oxidative stress may result, which can cause various problems such as DNA damage, protein alteration and lipid peroxidation (Wu *et al*., 2016a). Cellular changes caused by oxidative stress can result in tumor development (Wallace and Buha, 2020).

The health risks associated with HM's exposure *via* dust have received a great deal of attention (Han *et al*., 2023). Dust particles are an essential human health transporter for potentially hazardous substances in metropolitan environments (Asvad *et al*., 2023). HM's in dust can cause skin irritation, chronic viral infections (Alex *et al*., 2023) and neurodegenerative disorders like Alzheimer's and Parkinson's have been shown by metal accumulation in the brain. Chronic exposure to HM's causes encephalopathy, which manifests as sleeplessness, lack of attention, vomiting, convulsions and coma as well as respiratory discomfort, dyspnea, tremors, delusions, amnesia, anxiety and cognition (Caito and Aschner, 2015). They negatively affect normal and human gastric adenocarcinoma cell lines (AGS) and human lung cancer cell lines (A549) by raising the expression of CYP1A1 and inflammatory markers (IL6 and TNF) (Naimabadi *et al*., 2022). Additionally, their

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contact with children raises the possibility of having anemia (Zheng *et al*., 2022). To reduce the adverse effect of HM's on human health there are some mitigating strategies have been developed such as dust suppressants, extraction and distillation, blocking exposure pathways (Alex *et al*., 2023). After evaluating various research from across the world, it has been concluded that in Pakistan exposure to HM's and its adverse effects on human health through dust increasing day by day. There is a need to increase and implement more remediation and techniques to build a safe environment.

The objectives of this paper are as follows:

1. To evaluate the toxicity and health risk of various HM's on the human body through the dust in Pakistan.
2. To determine the strategies for depleting dust containing HM's in Pakistan.

The research questions of this paper are as follows:

1. What are the main sources of toxic HM's in the dust?
2. How will dust containing toxic HM's affect human health?
3. What will be the accessible method to mitigate toxic HM's in the dust?

This SLR adhered to the fundamental steps outlined and carried out by (McMeekin *et al*., 2020; Moher *et al*., 2015). The purpose of the literature review was to compile a number of essential papers that would address the study's research questions. SD was the platform for the literature search to identify and choose the literature review. The following steps were modified for the research methodology: (i) Topic selection, (ii) Identify research questions, (iii) recognition of research statement, (iv) source determination, (v) set inclusion and exclusion criteria, (vi) data filtering and sorting related to the topic. The last phase entailed data synthesis following the research objectives and questions.

The research questions were linked to the issue of the health risk of toxic HM's on humans *via* dust in this harmonized strategy. A minimum number of articles related to "Health risk of toxic HM's on the humans *via* contaminated dust and their mitigation in Pakistan" were discovered, including research papers, reviews, observational studies and case studies. First, the titles and abstracts were reviewed. Second, the whole article of those in English was obtained. In the end, only original research papers and review articles that had been published in peer-reviewed Journals between 2015 and 2023 were considered to continue the discussion Table 1. The study was expanded to identify by including all studies cited in key review papers Table 2. HM's in dust, Health risk on the human body and mitigation of HM's in the dust. This strategy can help to present thorough, dependable and diverse data by identifying new patterns in the study topic. Since it is a thorough evaluation of already published information, ethical clearance was not necessary. Information from papers that have previously been published was cited in this SLR with the appropriate publications.

The online literature search was carried out using the most well-known database SD for scientific peer-reviewed literature. To compile a significant number of literature data, nominated and screened related publications that is, journal articles, conference papers and book chapter were reviewed. Keywords that are pertinent to the topic and terms that are commonly used in research articles were selected. Therefore, the designated database SD was used to find the literature: Heavy metals in dust or toxic metals in dust or toxic metal(oid)s in dust and (Health risk assessment or potential risk estimation or potential human health risk) and (mitigation of dust heavy metals), Table 2.

Moreover, an assessment of published review papers relevant to toxic HM's in dust, their health impact on the human body and their mitigation (Saikat *et al*., 2022; Khan *et al*., 2021; Rehman *et al*., 2021; Qadeer *et al*., 2020; Rehman *et al*., 2020; Khalid *et al*., 2019; Eqani *et al*., 2016b; Mohmand *et al*., 2015; Subhani *et al*., 2015), their keywords and search strings were carried out. SD database was designed as a consequence of many publication kinds, including review papers (109), research papers (199), encyclopedias (16), book chapters (85), conference abstracts (86), case reports (1) and other (18) in total since 2015 to 2023. Publications in this area need to be increased every year Fig. 1.

Selection and grouping of pertinent data were done. For further investigation, identified studies whose whole texts were not available were omitted. After conducting a literature review, an exclusion criteria were used to frame the review. The exclusion and inclusion criteria are summarized in Table 3. Finally, after reviewing the information obtained from the database, a preliminary search was carried out, resulting in a large reduction in the sample size. This search produced a large number

**Table 1.** Heavy metals in dust, their sources and their mitigation in Pakistan

| S. No. | Sample | Heavy metals | Dominant metals | Mitigation | References |
|---|---|---|---|---|---|
| 1. | Dust from schools in Lahore, Pakistan | As, Cd, Cr, Cu, Ni, Pb, and Zn | Cd contamination in school dust was extremely high, whereas Pb and Zn contamination was modest. Cu and Cr contamination is mild to moderate. | Preventive, sanitary, and hygienic procedures must be learned. | (Rehman *et al*., 2021) |
| 2. | Dust from eight important junctions of Lahore and Faisalabad, Pakistan. | Cu, Ni, Cd, Pb, and Zn | Zn and Pb were the most abundant metals in both cities, whereas Cd was the least abundant. | To create environmentally safe cities, remediation, cleaning, and constant monitoring are required. | (Qadeer *et al*., 2020) |
| 3. | Dust from an industrial area, roadsides, and residential areas of Lahore Pakistan. | Cd, Cr, Cu, Ni, Pb, and Zn | The dust had high levels of Cd, Pb, and Zn contamination and low levels of Cr and Cu contamination. | To safeguard children's vulnerability, indoor school buildings must be ultra-clean, and outdoor ones must have green infrastructure. | (Rehman *et al*., 2020) |
| 4. | Dust from different site locations of Islamabad and Swat of Pakistan. | Lead | Pb levels from Islamabad were much greater than those from the Swat district in dust samples from all types of land use (industrial, urban, and rural). | - | (Eqani *et al*., 2016b) |
| 5. | Dust were collected from the Lahore and Sargodha (rural, urban, and industrial areas) of Pakistan | Zn, Pb, Mn, Cu, Ni, Cr, Co, Cd | In urban areas (Zn, Ni, Cr, Co, Mn, and Cd) and in the industrial area, Pb and Cu were dominant metals | - | (Mohmand *et al*., 2015) |
| 6. | Dust was collected from hair & nail in Lahore and Sargodha, Pakistan | Arsenic (As) | Industrial land use locations have the highest levels of As dust, which are followed by urban and rural sites. | - | (Subhani *et al*., 2015) |

**Table 2.** Keywords in articles related to toxic heavy metals, dust, health risk and their mitigation in Pakistan

| Authors | Searching by words |
|---|---|
| (Rehman *et al*., 2021) | Heavy metals, dust, potential ecological risk, Lahore, Pakistan |
| (Qadeer *et al*., 2020) | Heavy metals, dust, health risk assessment, Faisalabad, Lahore developing country |
| (Rehman *et al*., 2020) | Heavy metals, dust, health risk assessment, Lahore, Pakistan |
| (Eqani *et al*., 2016b) | Heavy metal (Lead), risk estimation, dust, hazard index (HI), Islamabad, Swat, Pakistan |
| (Mohmand *et al*., 2015) | Toxic metals, dust, potential risk estimation, Lahore and Sargodha, Pakistan |
| (Subhani *et al*., 2015) | Heavy metals, dust, human health risk, Lahore and Sargodha, Pakistan |
| (Khalid *et al*., 2019) | Air pollution, heavy metals, phytoremediation, Pakistan |
| (Khan *et al*., 2021) | Ornamental plants, phytoremediation, horticulture, heavy metals, Pakistan |
| (Saikat *et al*., 2022) | Heavy metals, environmental health, toxicity |
| This SLR | Heavy metals, health risk , dust, mitigation |

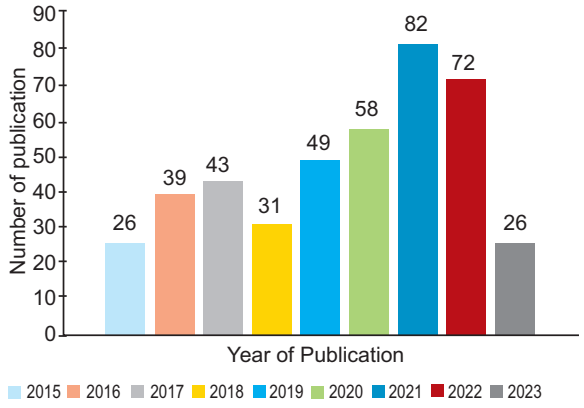


**Fig. 1.** Published articles in SD during 2015-2023.

**Table 3.** Inclusion and exclusion criteria for SLR adapted from Adro and Leitão (Adro and Leitão, 2020)

| Inclusion criteria | Exclusion criteria |
|---|---|
| SD database from the start of indexation from 2015 until March 2023; (Heavy metals in dust or toxic metals in dust or toxic metal(oid)s in dust) and (Health risk assessment or potential risk estimation or potential human health risk) and (Phytoremediation) in the title, abstracts and also keywords in the database of SD; research papers, conference abstracts and book chapters. | Inaccessible full-text and repeated papers; Grey literature; contents not directly linked to "Health risk of toxic heavy metals on the human body via contaminated dust and their mitigation in Pakistan" |

of publications that were evaluated for relevance through a review of the abstracts. Subsequently conducting an extensive literature analysis and establishing exclusion criteria, the structure of the review was formed Table 1 using specified research and review papers (Ahmed *et al*., 2023). Research gaps were identified for future studies were made.

**Trends of review articles.** Science of The Total Environment, *Renewable and Sustainable Energy Reviews*, *Environment International*, *Chemosphere*, *Atmospheric Environment*, *Environmental Pollution*, *Resources, Conservation and Recycling*, *Environmental Research*, *Journal of Environmental Management*, *Journal of Hazardous Materials*, *Journal of Cleaner Production*, *Advances in Agronomy*, *Environmental Technology and Innovation*, *The Lancet*, *Construction and Building Materials*, *Applied Geochemistry*, *Waste Management*, *Process Safety and Environmental Protection*, *Journal of Environmental Chemical Engineering*, *Heliyon*, *Cleaner Engineering and Technology*, *Mutation Research - Reviews in Mutation Research*, *Food Research International, Chemico-Biological Interactions*, *Analytica Chimica Acta*, *Progress in Energy and Combustion Science*, *Ceramics International*, *CATENA*, *Safety Science*, *Water Research*, *World Development*.

**Trends of research articles.** *Science of The Total Environment*, *Chemosphere*, *Environmental Pollution*, *Atmospheric Environment*, *Ecotoxicology and Environmental Safety*, *Journal of Hazardous Materials*, *Journal of Cleaner Production*, *Atmospheric Pollution Research*, *Environment International*, *Environmental Research*, *Pedosphere*, *Journal of Environmental Sciences*, *Environmental Technology and Innovation*, *Journal of Geochemical Exploration*, *Applied Energy*, *Waste Management*, *Ecological Indicators*, *Microchemical Journal*, *Journal of Environmental Management*, *Saudi Journal of Biological Sciences*, *Urban Climate*, *Environmental Nanotechnology*, *Monitoring and Management*, *Atmósfera*, *Heliyon*, *Journal of King Saud University – Science*, *Sustainable Cities and Society*, *Energy Policy*, *Agricultural Water Management*. Maximum published papers related to the keywords are found in above mentioned Journals and most cited papers among them are shown in Table 4.

## Results and Discussion

A study of toxic heavy metals in dust and their source identification give information relevant to the implementation of risk management methods. Therefore, this SLR is structured into three research questions. "What are the main sources of toxic HM's in the dust?" "How will dust containing toxic HM's affect human health?" and "What will be the accessible method to mitigate toxic HM's in the dust?" Some research was undertaken in various cities around Pakistan to emphasize the origins, health effects and mitigation methods of hazardous heavy metal dust. According to a study done in Pakistan, reported that the source of toxic HM's in the dust can be both anthropogenic and natural sources, such as vehicle emissions, agricultural

**Table 4.** Most cited papers

| Rank | Author, year | Title | Journal | Citations |
|---|---|---|---|---|
| 1 | (Moher *et al*., 2015) | Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement | *Systematic reviews* | 17341 |
| 2 | (Mohmand *et al*., 2015) | Human exposure to toxic metals *via* contaminated dust: bio-accumulation trends and their potential risk estimation | *Chemosphere* | 255 |
| 3 | (Khan *et al*., 2021) | Ornamental plants for the phytoremediation of heavy metals: present knowledge and future perspectives | *Environmental Research* | 66 |
| 4 | (Qadeer *et al*., 2020) | Concentrations, pollution indices and health risk assessment of heavy metals in road dust from two urbanized cities of Pakistan: comparing two sampling methods for heavy metals concentration | *Sustainable Cities and Societies* | 60 |
| 5 | (Eqani *et al*., 2016 b) | Human lead exposure *via* dust from different land use settings of Pakistan: a case study from two urban mountainous cities | *Chemosphere* | 60 |
| 6 | (Rehman *et al*., 2020) | Characterizing pollution indices and children health risk assessment of potentially toxic metal(oid)s in school dust of Lahore, Pakistan | *Ecotoxicology and Environmental Safety* | 56 |
| 7 | (Khalid *et al*., 2019) | Study of the responses of two biomonitor plant species (*Datura alba* and *Ricinus communis*) to roadside air pollution | *Chemosphere* | 38 |

and industrial activities (Rehman *et al*., 2021). Another study in Pakistan showed that the origins of certain trace metals in dust were zone specific, pointing to both geological impacts and anthropogenic activity (Eqani *et al*., 2016a). One of the study conducted in Pakistan and found that, the rural areas were mostly unpolluted and where they were moderately polluted with Lead, this was mainly due to geological factors and short and/or long-distance atmospheric deposition from nearby polluted areas. The industrial and urban areas of both sites were highly polluted due to severe anthropogenic influence (Eqani *et al*., 2016b).

Other than Pakistan, studies reported that the principal sources of HM's in urban dust are exhaust emissions from heavy vehicles, (47.5%) (Alharbi *et al*., 2019) natural sources (29.3%), mixed sources (including waste from the vehicle repair sector and paints and pigments) (23.2%) of the total HM's concentration (Fan *et al*., 2021) and increasing number of industrial organizations, factories, infrastructure and road vehicles. Another study found five major probable sources: coal combustion, traffic and industrial, natural, construction and furniture sources and unidentified sources, with contributions of 34.09%, 20.72%, 18.72%, 7.597% and 18.87%, respectively (Ma *et al*., 2021). According to one research, the majority of metal sources for dust are anthropogenic, except for As and Fe, which have geochemical origins (Sultan *et al*., 2022). When the presence of heavy metals in dust in Pakistan is compared to that of other international cities, it is found to be in the median place (Qadeer *et al*., 2020).

HM's exposure *via* dust can cause adverse effects on human health like carcinogenicity, neurotoxicity, nephrotoxicity, immunological toxicity, cardiovascular toxicity, skin toxicity, reproductive and developmental toxicity and genotoxicity (Mitra *et al*., 2022). The pathway of toxicity of heavy metal in humans has been described in Fig. 2

There are preventive and mitigating techniques have been developed to lessen the exposure and adverse effect of toxic metals through dust. There isn't much relevant research available about toxic metals containing dust mitigation in Pakistan, thus we utilize only dust background in our study to assess mitigation strategies. There are some major methods which can be grouped into technical and non-technical. The suggested non-

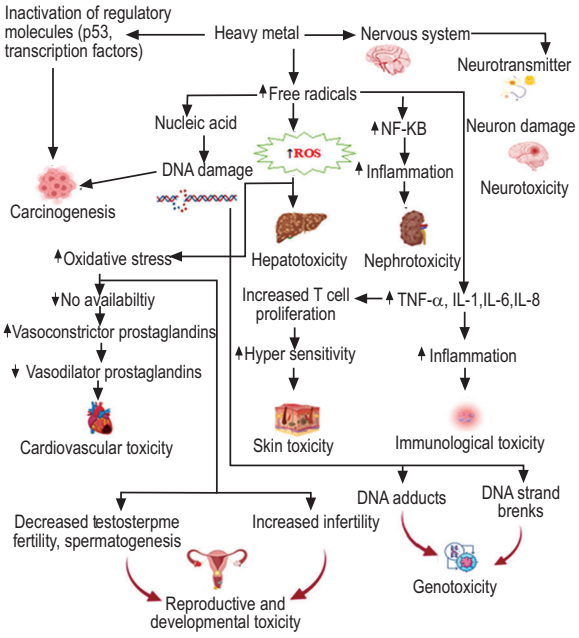


**Fig. 2.** Pathway of toxicity of heavy metal in humans. Modified from: (Mitra *et al*., 2022).

technical preventive and mitigation methods include, restrict exposure pathway, regulate anthropogenic sources (Alex *et al*., 2023), raise awareness among relevant stakeholders, including through creation of a constant monitoring of dust (Wu *et al*., 2016b). To maintain adequate monitoring of dust-HM´s, a local government must also promote awareness (El-Zeiny and Abd El-Hamid, 2022). Other strategies that might be implemented: sweeping and maintaining pavements and roads (Behrooz *et al*., 2021), use of dust suppressants (Zhang *et al*., 2023) in transportation, switching from using fossil fuels to cleaner energy electrical vehicles (Suvetha *et al*., 2022) to reduce dust-HM's.

The technical method, phytoremediation (use of plants) have also been identified to mitigate dust pollution (Kumar *et al*., 2021). According to a study, these trees can aid in phytoremediation based on site-specific individual metal pollution. *Ficus aurea*, a Cd hyper-accumulator and As accumulator; *Ficus benghalensis* a good Pb, Ni and Zn accumulator; *Polyalthia longifolia* Cu and Cr accumulator and *Ficus rubiginosa*, a good Mn accumulator (Sultan *et al*., 2022). Another plant *Datura alba* (*D. alba*) has been investigated and reported that it would be an excellent candidate as a phytoremediator of traffic-borne contaminants (Khalid *et al*., 2019). According to research, *Platycladus orientalis* (*P. orientalis*), another plant, may be used to reduce heavy metals because of its high antioxidant enzyme activity and strong resistance to ROS (Cui, 2022). One study found that using attractive plants in phytoremediation can remove heavy metals while simultaneously enhancing the environment attractiveness (Khan *et al*., 2021). Another study conducted in Faisalabad and indicated that *M. alba*, *E. camaldulensis* and *A. indica* are suggested for industrial and residential areas due to their phytoremediation potential for heavy metals from air (Rahman *et al*., 2022).

## Conclusion

This research presents a systematic review of the literature particularly focusing on Pakistan to identify sources of toxic HM's in dust and their impact on human health and techniques to mitigate their exposure to dust. As far as the sources, possible impacts of dust metals on human health and their mitigation are concerned, Pakistan reportedly has less relevant research accessible than other nations. According to the findings of studies in Pakistan, the sources of HM's are anthropogenic and natural sources, such as vehicle emissions, agricultural and industrial activities. These sources will cause adverse effects on human health such as neurotoxicity, nephrotoxicity, carcinogenicity, immunological toxicity, cardiovascular toxicity, skin toxicity, reproductive and developmental toxicity and genotoxicity. Regarding preventive and mitigating strategies, different studies show that there are technical and non-technical methods that need to implement to build a safe environment from toxic HM's. Phytoremediation is one of the good option for reducing HM's in dust and it has gained popularity over other physical and chemical approaches due to its low cost and ease of implementation while simultaneously enhancing the environment attractiveness. As far as the possible impacts of dust metals on human health and its mitigation are concerned, there is little information available in Pakistan. In the future, more research needs in Pakistan for identifying the toxic HM's in dust, their health impact on the human body and methods for their reduction should be considered. This SLR maintains restrictions on the limited use of a single database and its elimination of grey literature. Additionally, the concentration of this paper was limited to three major topics. (i) sources of toxic HM's in the dust (ii) toxic HM's impact on human health (iii)

mitigation of toxic HM's in the dust. This study provides a comprehensive review of the literature on toxic HM's in dust, including an illustrative analysis of the article's distribution, the maximum cited publications and research trends and issues.

**Conflict of Interest.** The authors declare that they have no conflict of interest.

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