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Review Article

# Review on Assessment of Heavy Metal Pollution in Soil Sediments of Industrial Areas

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## Abstract

There are a number of heavy metals which are toxic and potential carcinogens. When they are released into the atmosphere by both natural and artificial sources like industrial waste, automobiles exhaust and mining, they have a tendency to accumulate in living beings resulting in adverse health effects. The issue of soil heavy metal contamination is prevalent worldwide and thus it is essential to study the contamination status of soil at various areas facing extreme anthropogenic pressure. This review article addresses the problem of soil heavy metal pollution in the industrial areas and its impact on the environment as well as human health.

**Keywords**: Heavy Metal Pollution; Ecosystem; Soil Pollution; Health Impact

## Introduction

"Heavy metals [1-25] are elements with a density greater than 4.5 g $m^{-3}$ and have strong capacities to migrate, enrich, and contaminate" (Zhaoyong., *et al*. 2019 [6]). With Urbanization and rapid industrial development across the globe, pollution of natural resources like air, water and soil has increased manifold. These life supporting systems are being continuously dumped with numerous pollutants thereby intensifying environmental health risks especially in developing countries like India. Soil is the major sink for heavy metals released into the environment. Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, sewage sludge, pesticides, wastewater irrigation, paper & pulp units, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Khan., *et al.* 2008 [16], Zhang., *et al.* 2010 [23], Abou El-Anwar, 2019 [16] and Chen., *et al.* 2021 [6]). "Various anthropogenic activities like mining extraction, metal industries, chemical processing, smoke and dust emission, urban transport activities, and agricultural practice greatly promote heavy metal load to the soil day by day" (Chakraborty., *et al*. 2021 [5]).

### Soil contamination analysis

The various papers reviewed conducted the Soil contamination analysis for heavy metals and Human health analysis by applying the following indices.

### Contamination factor (CF)

The contamination Factor (CF) is expressed as:

CF = C metal/C background.

### Pollution load index (PLI)

The extent of pollution load index (PLI) developed by Tomlinson., *et al*. 1980 [5], as follows:

PLI = n √ (CF1 × CF2 × CF3 × ........ CFn).

### Geo-accumulation index (Igeo)

Geo-accumulation index was first applied by Muller[18] (1969). The Igeo equation was proposed by Muller (1969) as follow:

$$Igeo = \log_2 Cn/ 1.5\, Bn$$

Muller classified Igeo values in seven levels as Igeo < 0 (not polluted), Igeo = 0-1 (uncontaminated to moderately polluted), Igeo = 1-2 (moderately polluted), Igeo = 2-3 (moderate to heavy polluted), Igeo = 3- 4 (heavy polluted), Igeo = 4-5 (heavy to extremely polluted), and Igeo>5 (extremely polluted).

### Degree of contamination (DC)

It is the computation of all contamination factors (Hakanson, 1980 [11]):

$$DC = \sum^{n}_{1} CF$$

### Human risk assessment (HRA)

According to the USEPA, the health-risk assessment (HRA) is a model developed to estimate human health risk that is caused by contaminants. The potential risk of exposure to and adverse health effects of the studied metals through dermal and ingestion pathways will be estimated as follows:

$$CDI_{ing}(\text{mg kg}^{-1}\text{ day}^{-1}) = C\ (\text{mgkg}^{-1}) \times IngR \times EF \times ED \times 10^{-6}/BW \times AT$$

$$CDI_{inh}\ (\text{mg kg}^{-1}\text{ day}^{-1}) = C\ (\text{mgkg}^{-1}) \times EF \times ET \times ED/PEF \times 24 \times AT$$

$$CDI_{der}\ (\text{mg kg}^{-1}\text{ day}^{-1}) = C\ (\text{mgkg}^{-1}) \times SA \times AF \times ABS \times EF \times ED \times 10^{-6}/BW \times AT$$

Where,

ABSd (unit less): Dermal absorption factor

AF (mg $cm^{-2}$): Soil to skin adherence factor

AT (d): Averaging time for non-carcinogenic effects

BW (kg): Average body

ED (year): Exposure duration

EF (d $year^{-1}$): Exposure frequency

ET ($hd^{-1}$): Exposure time

IngR (mg $d^{-1}$): Soil ingestion rate receptor

PEF ($m^3 kg^{-1}$): Soil-to-air particulate emission factor

SA ($cm^2 event^{-1}$): Skin surface area available for exposure

Lifetime Average Daily Dose (LADD**)** to estimate the carcinogenic risk

$$LADD= C/PEF \times AT_{can} \times (CR_{child} \times EF_{child} \times ED_{child}/BW_{child} + CR_{adult} \times EF_{adult} \times ED_{adult}/BW_{adult})$$

### Hazardous quotient

The non-carcinogenic effect will be evaluated by calculating hazardous quotient (HQ) which is the ratio of CDI to reference dose (RfD):

$$HQ = CDI/RfD$$

Hazardous index is a cumulative sum of HQ of the three pathways and represent a non-carcinogenic risk hazard.

$$HI = \sum HQ_i = HQ_{ingestion} + HQ_{inhalation} + HQ_{dermal}$$

### Environmental and health impacts of heavy metals

As, Cr and Pb are considered to be potential carcinogens and are associated with the occurrence of many diseases (Zhong., *et al.* 2018 [23]). The assessment of soil heavy metal pollution in and around industrial locations is of prime importance to researchers worldwide as soils are the most important sink for heavy metal accumulation. Various anthropogenic activities are adding toxic metals to the soil regularly. Therefore, their concentrations in the soils reflects the health of the ecology and environment of the area. Moreover, they serve as an important indicator of human exposure to such metals. Human beings are exposed to the risks of heavy metal pollution via, direct ingestion, inhalation, dermal contact, indirectly through the food chain, etc. Heavy metals exhibit long term persistence in urban soils and have much lower mobility. Govil., *et al.* 2001 [10] investigated the environmental and geochemical environment around Patancheru industrial development area of Andhra Pradesh, India to determine the extent of chemical pollution in the soil and the results revealed that soils in the area are significantly contaminated with many heavy metals, such as Cr, V, Fe, As, Cd, Se, Ba, Zn, Sr, Mo and Cu, present above the normal distribution in the soil. Similar kind of study was carried out by Pradhan[20] and Kumar 2014 evaluate the pollution risk of heavy metals by recycling e waste in an industrial area in Delhi and reported higher concentrations of heavy metals like As (17.08 mg/

kg), Cd (1.29 mg/kg), Cu (115.50 mg/kg), Pb (2,645.31 mg/kg), Se (12.67 mg/kg) and Zn (776.84 mg/kg ecological and health risk assessment) in surface soils of e-waste recycling areas compared to those in reference site. Chakraborty., *et al.* 2021 [5] observed that the developmental projects and economic actions such as mining, industries, urban expansion, and agricultural activities contribute toxic heavy metals into the soils and it adversely affects human health and broadly the environment.

Gastrointestinal, nervous system disorders, immune system damage, birth defects and cancer are the result of the complications of heavy metals toxic effects" (Mood-Balali., *et al.* 2021 [17]) According EPA and the International Agency for Research on Cancer (IARC), these metals are also classified as either "known" or "probable" human carcinogens based on epidemiological and experimental studies showing an association between exposure and cancer incidence in humans and animals (Tchounwou., *et al.* 2012 [21]). Jaishanker., *et al.* 2014 [15] reviewed the effects of some heavy metals *i.e.* arsenic, lead, mercury, cadmium, chromium and iron, on the environment and living organisms, mainly human beings. Fei., *et al.* 2018 [8] studied association between heavy metal soil pollution and stomach cancer. Devi and Yadav 2018 [7] carried out the health risk assessment of heavy metal pollution in Patna, India and observed that the primary pathway of heavy metal exposure to both adults and children population was ingestion via soil. In their study, the estimated hazard index was highest for Pb, suggesting significant non-carcinogenic effect to both adults and children population.

Zhaoyong., *et al.* 2019 [24] conducted health risks evaluation of 10 heavy metals in the urban dust of Chinese cities which showed that of the three exposure ways, the $HQ_{ing}$ from hand-mouth intake was the most common exposure route. Briffa., *et al.* 2020 [4] have reviewed the toxicological effects of heavy metal pollution on human beings and reported that some of the metals effects the biological functioning and growth while a few other bioaccumulate in organs causing serious diseases such as cancer. Jahromi., *et al.* 2020 [14] while studying human health risk assessment for exposure to heavy metals (Cu, Zn, Cd, Pb) present in surface soil of zinc-lead mine(Iran) obtained considerable values of ecological risk (RI = 497.95) and high contamination degree (mCd = 11.83) thereby implicating the potential of high health risk in the mining area. Anguilera., *et al.* 2021 [3] while working on the heavy metal contamination levels, main emission sources, and human health risks in samples of street dust in Mexico City found that the high levels of Cr and Pb in urban dust represent a health risk for children. Agyemang., *et al.* 2022 [2] studied the heavy metal pollution in surface soils of automobile workshops in Ghana and reported that the accumulated toxic levels in soils can threaten human health through possible routes of exposure.

Many of the researchers have conducted studies to evaluate the carcinogenic as well as non-carcinogenic effects of heavy metals on human beings. Gao and Wang 2018 [9] studied the of heavy metal pollution in soils of industrial area of Shanghai, China and reported that the non-carcinogenic risk was mainly due to Cr with an HI value of 6.48 for adults and 39.01 for children thus indicating a higher risk to children from heavy metal pollution. Similarly, Musa., *et al.* 2019 [19] investigated the carcinogenic and non-carcinogenic health risks of the heavy metal concentrations in street dust of North Cyprus and observed that for non-carcinogenic human health risk, the heavy metals on the street dust for all ages (children and adults) were below 1 with exception of Cr, signifying that Cr might cause non-carcinogenic health risk. Further, the values for carcinogenic health risk were lower than the threshold limit. While conducting studies on distribution, toxicity and health risk assessment of few metals in surface dust in Bhiwadi Industrial area, India, Verma., *et al.* 2019 [22] reported that the Non-carcinogenic health risk due to metals in surface dust was high. Hui., *et al*. 2021 [12] quantified the risks of heavy metal pollutants in soil to human health and reported that the total carcinogenic risk indexes of the two different groups of people (Adults and children) are between $10^{-4}$ and $10^{-6}$, which are higher than the human health recommended by the US EPA Recommended level ($10^{-6}$). Their study revealed that the soil in the study area is exposed to severe heavy metal pollution and thus creates a risk of cancer. Jadoon., *et al*. 2021 [14] evaluated the heavy metals in the urban dust samples in Alexandria for its implications on human health and reported that the cancerous risk of Pb ($1.4 \times 10^{-4}$) for children exceeded the guideline values and was considered unacceptable, whereas the cancerous risks of other studied metals were acceptable for both subpopulations (adults and children).

## Conclusion

Due to urbanization and industrial expansion over the years, the soils are degrading with high loads of pollution and has become a challenge. These industrial areas are rapidly spreading and developing all over the world comprising huge number of small scale and large-scale industries, ongoing major infrastructure projects including other commercial activities. It is essential to carry out research studies regarding heavy metal pollution in and around industrial area so as to provide a valuable data that can be used for policy framing, management of environment, safeguarding human health, and for town planning of the regions undergoing fast industrial transformation.

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