

Heavy Metal Contamination in Industrial Areas - Suggestions, Recommendations and Future Perspectives: A Review

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Abstract: *Environmental pollution of heavy metals pollution is one of the major problems in the world. It is increasingly becoming an alarming problem and has become of great concern around the world due to the adverse effects. These heavy metal pollutants are widely distributed in the environment through water, soil and also into the atmosphere. Due to the rapidly growing agricultural, metal and pharmaceutical industries, through improper waste disposal, oil and gas, fertilizers, chemical and pesticides raising concerns over their potential effects on human health and the environment. It is also affecting to agricultural farm land to growth, and yield of crop. There are few suggestions, recommendations and future prospects has recommended.*

Keywords: Contamination, Environmental Pollution, Heavy metals, Heavy metal contamination and Pollution

1. Introduction

The term 'Industrial Waste' can be defined as any gaseous, liquid or solid material that is discarded from an Industrial process with an apprehension that it has no further apparent use. Industrial wastes generally contain a spectrum of some organic and inorganic chemicals including trace metals such as Mercury (Hg), Lead (Pb), Cadmium (Cd) and Arsenic (As) which are poisonous, even at very low concentrations. Adsorption and leaching processes mostly facilitate the transfer of these metals into soils. This results in soil pollution.

Environmental pollution is one of the major problems of world and increasing day by day due to urbanization and industrialization. Large number of industrial effluents discharged due to rapid industrialization is a serious threat to India. Industrial effluents are rich in organic and inorganic matter including heavy metals [1]. Saltwater encroachment associated with over drafting of aquifers or natural leaching from natural occurring deposits are natural sources of groundwater pollution including in dissolved conditions of heavy metals. The groundwater contamination has associated with pollution created with human activities.

The contamination of Industrial solid wastes including mine wastes has become a worldwide concern. Several authors have shown a relationship between atmospheric elemental deposition and elevated elemental concentrations in plants and top soils, especially in cities and in the vicinity of emitting factories [2, 3, 4, 5, 6].

Worldwide environmental pollution is continuously increasing. Industrial and agricultural activities have

contributed to the increasing occurrence of heavy metals in the ecosystem [7]. The heavy metals such as manganese (Mn), copper (Cu), iron (Fe), zinc (Zn) and nickel (Ni) are essential mineral nutrients for higher plants. Cu also induces toxicity in tissue concentrations slightly above its optimal levels [8]. Excess Cu in soil results not only from its increasing use industry, like mining and smelting, but also from its use as a pesticide (e. g., the Bordeaux mixture), and its presence in sewage sludge amendments [9, 7].

1) Sources of Heavy Metal Pollution

The heavy metals are naturally occurring elements that are found throughout the earth's crust, Due to the astounding increase of the use of heavy metals, it has resulted in an imminent surge of metallic substances in both the terrestrial and aquatic environments. Most environmental contamination and human exposure have dramatically increased from anthropogenic activities such as mining the metals and smelting operations, industrial production, pharmaceutical, domestic and agricultural use of metals and metal - containing compounds [10]. Natural phenomena such as weathering and volcanic eruptions have also been reported significantly contributed to heavy metal pollution. Environmental contamination can also occur through metal corrosion, atmospheric deposition, soil erosion of metal ions and leaching of heavy metals, sediment re - suspension and metal evaporation from water resources to soil and ground water [11]. The sources such as metal processing in refineries, coal burning in power plants, petroleum combustion, nuclear power stations and high - tension lines, plastics, textiles, microelectronics, wood preservation and paper processing plants are also responsible for environmental pollution [12].

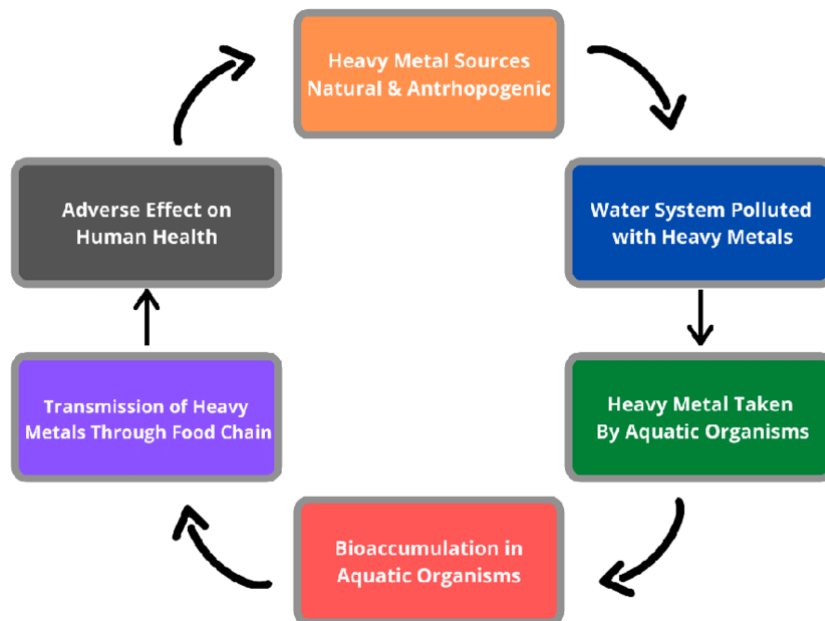


Figure 1: Sources and Transmission of Heavy Metals through food chain

Source: https://www.researchgate.net/figure/Transmission-of-Heavy-Metals-through-Food-Chain_fig2_344872496

2) Essential and Non - Essential Metals

The heavy metals are classified into two major groups namely essential and nonessential heavy metals based on their roles in biological system [13]. Essential heavy metals are important for living organisms and may be required in

the body in quite low concentrations. Non - essential heavy metals have no known biological role in living organisms. Some metals like copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) are examples of essential heavy metals.

Table 1: Sources and Health Effects of Heavy Metals

	Heavy metal	Sources	Health Effects
Essential heavy metal	Zinc (Zn)	Oil Refining Plumbing Brass manufacturing	Gastrointestinal disorders, Kidney & Liver abnormal functioning
	Copper (Cu)	Copper polishing Plating Printing	Abdominal disorders, Metabolic activity abnormalities
	Iron (Fe)	High intake of iron supplements & oral consumption	Vomiting Diarrhea Abdominal pain Dehydration & lethargy
	Cobalt (Co)	Hip alloy replacement case	Hematological Cardiovascular Hepatic Endocrine
Non – Essential heavy metal	Chromium (Cr)	Steel fabrication Electroplating Textile	Lung disorders (bronchitis, cancer), Renal and reproductive system
	Lead (Pb)	Batteries Coal combustion Paint industry	Serious effect on mental health (Alzheimer’s disease), Nervous system
	Arsenic (As)	Atmospheric deposition Mining pesticides	Highly effects dermal region (Cancer), Brain & Cardiac problems
	Mercury (Hg)	Coal combustion Fish Mining Paint industry Paper industry Volcanic eruption	Sclerosis Blindness Minamata disease Deafness Gastric problems Renal disorders
	Cadmium (Cd)	Plastic Fertilizers pesticides	Osteo related problems Prostate cancer Lung diseases Renal issues

While the heavy metals cadmium (Cd), lead (Pb), and mercury (Hg) are toxic and are regarded as biologically nonessential and has no known biological role in living organisms. Metals like cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), magnesium (Mg), nickel (Ni), zinc (Zn) and selenium (Se) are among essential micronutrients which are required for normal physiological and biochemical functions of living organisms and their insufficient supply may result in deficiencies diseases [14]. Because of their presence in trace concentrations, they are also known as trace elements but they become toxic when they exceed threshold concentration [15, 16]. However, the lists of essential heavy metals may be

different for different groups of organisms such as plants, animals, and microorganisms. It means a heavy metal may be essential for a given group of organisms but nonessential for another one [17].

3) Contamination of Soil, Water and Air by Heavy Metals

Pollutants may enter the ecosystem in various ways and can enter into the hydrosphere, lithosphere and atmosphere. Apart from entering through natural ways as mentioned earlier (through volcanic activity and weathering of rocks), anthropogenic activity is a big cause of pollutants entering the ecosystem. Heavy metals released into the atmosphere in

volcanic eruptions and in different industrial emissions also ultimately return to the land and cause contamination of waters, soils and air. Since heavy metals are persistent in the environment, they either accumulate in biota or leach down into ground waters. Contamination of biota and groundwater with potentially toxic heavy metals has important implications for human health [13]. It is important to evaluate the amount of heavy metal pollution in the ecosystems by investigating the concentration of these elements and their distribution.

(i) Effects on Water

Water is the “life - blood of the biosphere” Since water is a universal solvent, it dissolves different organic and inorganic chemicals and environmental pollutants. Aquatic ecosystems, both freshwater and marine, are vulnerable to pollution. Contamination of water resources by heavy metals is a critical environmental issue which adversely affects plants, animals, and human health [18]. Pollution of water bodies with heavy metals is a worldwide problem because of the environmental persistence, bioaccumulation, and biomagnification in food chains and toxicity of these elements [19]. Aquatic ecosystems are contaminated by heavy metals through different industrial effluents, domestic sewage, and agricultural run - off, whereas the release of industrial effluents without treatment into the aquatic bodies is a major source of pollution of surface and groundwater [20]. Heavy metals are extremely toxic to aquatic organisms even at very low concentrations and these elements can cause significant histopathological alterations in tissues of aquatic organisms such as fish. Moreover, high bioaccumulation of heavy metals in the aquatic body can lead to genotoxic damage of aquatic species and high concentrations of heavy metals can have cytotoxic, mutagenic and genotoxic effects on fish species [21]. Consumption of fish having high level of heavy metal can be a serious health hazard for the human population [22]. To limit the risks for humans and the environment, many countries have legislated limits for each heavy metal. Specific limits have been defined in drinking water, and surface waters (lakes, rivers, seas). There are also limits in agricultural products, sea foods and animal feed.

(ii) Effects on Soil

Heavy metals and metalloids are released into soils from the parent material (lithogenic source) and different anthropogenic sources [22]. Factors affecting the presence and distribution of heavy metals in soils include composition of parent rock, degree of weathering, physical, chemical, and biological characteristics of soil and climatic conditions [23]. Since metals are not biodegradable hence, remain persistent in the environment for a very long time. They cannot be broken down; moreover, heavy metals present in soils and sediments remain present for an extended period until they are eluted to other compartments. They can also react with other elements in the soil or sediment and form or degrade to become more toxic. An example of this is the formation of poisonous methyl mercury from the inorganic mercury by the activity of bacteria found in water, sediment and soil [24]. Significant enrichment of heavy metals has been reported in soils receiving more input of fertilizers and Cu fungicide compared to virgin soils and soils receiving low inputs [25]. In urban areas, soils may be contaminated

with heavy metals from heavy vehicular traffic on roads, soil samples in urban areas have elevated concentrations of Pb, out of which 45–85% is bio - accessible [26]. The bio availability of heavy metals in soils is very important for their fate in the environment and for their uptake in plants. Different heavy metals have different bio - availabilities in soils, and this bioavailability is dependent on metal speciation and on different physicochemical properties of soils. Farmers sometimes use sewage sludge and mix it in the soil, though this may contain heavy metals, primarily if the sludge has been produced by industries. Heavy metals, such as copper, zinc, lead, cadmium and chromium have been found in the soil of these agricultural lands at a high concentration [27]. Smelting causes localised pollution through atmospheric pollution, which then deposits on the soil. Some areas where smelting occurs shows dead vegetation and absence of life such as earthworms and woodlice, which help in vegetation to be decomposed. Lead contaminated gasoline was used with a high concentration of lead, lead shotgun pellets, and lead fishing weights all contributed to lead being found in our environment [28]. Shotgun pellets have been taken up by birds, and then this moves through the food chain, the weights have caused lead to be found in wetlands also. Metals are bound more to the soil if the clay content, organic matter and the pH are higher. The more acidic the soil, the less elements have been found as these become more soluble and leach lower in the ground where the roots do not reach causing nutrient deficiency to the plants [24, 29].

(iii) Effects on Air

The increased industrialisation and urbanisation have recently made air pollution as a major environmental problem. The air pollution was reported to have been accelerated by dust and particulate matters (PMs) particularly fine particles such as PM_{2.5} and PM₁₀ which are released through natural and anthropogenic processes. Natural processes which release particulate matters into air include dust storms, soil erosion, volcanic eruptions and rock weathering, while anthropogenic activities are more industrial and transportation related [30]. The Particulate matters are important and require special attention as they can lead to serious health problems of skin and eye irritation, respiratory infections, premature mortality and cardiovascular diseases. These pollutants also cause deterioration of infrastructure corrosion, formation of acid rain and eutrophication. [31].

4) Symptoms of Heavy Metal Poisoning, Causes and Diagnosis

The groundwater contamination can be related to waste disposal by man (private sewage disposal canals, land disposal of solid waste, municipal wastewater, land spreading of sludge, mine wastes, deep - well disposal of liquid wastes, animal feedlot wastes, radioactive wastes) or not directly related to waste disposal (accidents, certain agricultural activities, mining, acid rain, improper well construction and maintenance).

Dumpsites are the sources of environmental pollution and reports have shown that they introduce additional heavy metals into the surrounding soil and ground water reported [32, 33].

Table 2: Exposure, Symptom Causes and Diagnosis of Heavy Metals Poisoning

Exposure Symptoms of Heavy Metal Poisoning	Caused and Risk factors of Heavy Metal Poisoning	Heavy Metal Poisoning Diagnosis
Short term Exposure of Acute Heavy Metal Poisoning: <ul style="list-style-type: none"> • Confusion • Numbness • Nausea • Vomiting • Falling into a coma 	Industrial Exposure	<ul style="list-style-type: none"> • Complete blood count with blood smear • Kidney function tests • Urine test • Liver function test • Electrocardiogram (EKG)
	Air or water Pollution	
Foods		
Long term exposure of Chronic heavy metal Poisoning: <ul style="list-style-type: none"> • Headache • Weakness • Tiredness • Muscle pain • Joint pain • Constipation 	Medicines	
	Improperly coated food containers, plates, and cookware	
	Ingestion of lead - based paints	
	Ingestion of insecticides, herbicides, and pesticides	

(Source: <https://www.healthline.com/health/heavy-metal-detox#symptoms>)

Groundwater is an important source of drinking water in most of Indian cities. Rapid increase in industrialization and urbanization has led to deterioration in water quality [34, 35].

The prolonged discharges of industrial effluents, domestic sewage and municipal solid waste disposal have caused groundwater to become polluted, and as a result many health problems have been cropped up in many cities of India. Most of the industries discharge effluents without proper treatment in unlined channels reported [36]. These effluents percolate underground and affect groundwater quality [37, 38]. Water pollution not only affects water quality but also threatens human health, economic development and social prosperity [39, 40]. Heavy metals in groundwater are toxic even at low concentrations [41, 42].

Human activities have increased the concentrations of heavy metals in the environment. For example, industry, agriculture, and solid waste disposal increase the contents of heavy metals in water, soil, air, fruits, vegetables, fish, etc. [43]. According to the World Health Organization, every year more than 2.2 million people from developing countries die from diseases associated with the lack of access to safe drinking water and inadequate sanitation [31, 44].

Environmental problems related to industrial effluent disposal on land have been reported from various parts of the India. Disposal on land has become a regular practice for some industries and creates local/regional environmental problems [45, 46, 47, 48, 49, 50, 14, 51, 52, 53, 54, 55].

Generally, groundwater accounts for about 98% of the world's fresh water resources and it is well distributed throughout the world [56, 57]. It has been reported that the water quality of major cities such as Sialkot, Gujarat, Faisalabad, Karachi, Qasur, Peshawer, Lahore, Rawalpindi and Shekhupura is deteriorating because of unchecked disposal of untreated municipal and industrial wastewater and excessive use of fertilizers and insecticides [58].

The rapid industrialization and urbanization activities have become a major environmental concern due to dispersal of

wastes generated on the ecosystem. Heavy metals are one of the most hazardous contaminants that may be present in the aquatic ecosystem. Heavy metals are elements having an atomic weight between 63.54 and 200.59 and a specific gravity greater than 4 M. have reported [46].

In India, most of the vegetable crops are grown in the areas situated between the urban and rural centres. Soils in most of these areas have been subjected to industrial pollution, the influence of which on different crop plants are not properly known. Rarely, the impacts of soil pollution were considered, despite the fact that in many areas, the crop yields have been affected by the soil pollution [59]. The Phyto - remediation has also emerged as an alternative to the engineering - based methods. In this approach, plants are used to absorb contaminants from the sludge and transfer them to the all parts of the plant [60].

The "Effect of Alum sludge waste on growth and yield of red pepper crop (*Capsicum annum* L.)" indicate that the results of the present study indicate that the ASW (Alum Sludge Waste) changed the soil characteristics and affect the nutrient uptake capacity of Red Pepper crop. *Capsicum annum* L. had 98.7% germination in control and the percent Germination decreased on exposure to increasing concentrations of the water extract of the ASW. In some cases, the effects of ASW pollution may not limit only to the growth and yield of the crop, but also may cause health problems to consumers if the crop is Al tolerant and can accumulate Al in higher concentrations has reviewed [61].

The Effect of Oil and Gas Industrial Solid Waste on the Seed Germination and Plant growth of *Solanum melongena* L. (Brinjal) indicate that the ISW of an Oil and Gas Industry, Kakinada, Andhra Pradesh, India. The oil and gas Industrial Sludge Waste (ISW) collected at the outlet of the release channel of the Oil and Gas Industry at Kakinada, was air - dried and brought to the laboratory for the analysis of its physico - chemical characteristics. The Seed germination was 53% at WE₄ concentration for *Solanum melongena* L. (Brinjal plant). After that conducted POT experiment for different concentrations of the (5%, 10%, 30% and 50%) Industrial solid waste. The fruit yield of brinjal reduced by

3.73% over the control soils in A₁ soils. Thereafter the rate of reduction steeply rose to 40.29% in A₂, 49.65% in A₃ and finally reached 70.50% in A₄ soils. Thus, the ISW even at 10% concentration is potential to reduce the fruit yield and result in considerable economic loss to the farmers as reviewed [62].

2. Conclusion and Recommendations

The present study highlighted and focused on heavy metal contamination of industrial area in India, the following conclusion and recommendations are suggested to control the heavy metal contamination in industrial areas.

- Industries should be followed Zero Liquid Discharge of water and also maintain the international standards.
- All the industries should be submitted their industrial solid waste to Authorized agency.
- The treated waste water needs to be used for gardening purpose.
- Encourage research on remediation of ground water, Soil and Industrial solid waste contaminated sites in industrial areas.
- Phyto remediation is a better solution to the problem, it is environment friendly and ecologically responsible solar driven technology with good public acceptance.

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