

LEAD POLLUTION AND ITS REGULATION: A REVIEW**Prof. Thyagaraju Kedam***

UGC BSR Fellow, Dept. of Biochemistry, Sri Venkateswara University, Tirupati 517 502
AP, India.

Article Received on 12 June 2026,
Article Revised on 03 July 2026,
Article Published on 16 July 2026,
<https://doi.org/10.5281/zenodo.21356889>

Corresponding Author*Prof. Thyagaraju Kedam**

UGC BSR Fellow, Dept. of
Biochemistry, Sri Venkateswara
University, Tirupati 517 502 AP,
India.



How to cite this Article: Prof. Thyagaraju Kedam*. (2026). Lead Pollution And Its Regulation: A Review. World Journal of Pharmaceutical Research, 15(14), 202–213.
This work is licensed under Creative Commons Attribution 4.0 International license.

ABSTRACT

Lead contamination remains a significant public health concern due to its detrimental effects on neurological development, particularly in children. The removal of lead from the environment is essential for safeguarding communities and enhancing living conditions. This paper discusses various methods for lead remediation across different mediums, including soil, water, and indoor settings. Soil remediation techniques such as excavation, soil washing, phytoremediation, and stabilization are explored, highlighting their effectiveness based on contamination levels. Water treatment options, including filtration, chemical treatments, and ion exchange, are reviewed for their capacity to reduce lead concentrations in drinking water. In indoor environments, strategies for lead paint abatement, cleaning protocols, and the use of HEPA vacuum

systems are analyzed for their efficacy in mitigating exposure. Additionally, the importance of ongoing monitoring, community education, and industrial containment measures is emphasized to ensure sustained public health protection. The multifaceted approach to lead removal underscores the need for tailored interventions, professional expertise, and community engagement in combating lead contamination and its associated health risks.

INTRODUCTION

Lead (Pb) is a heavy metal and is known for its historical reactions and toxicity. Lead element number is 82 on the periodic table and belongs to group 14 (the carbon group). Here is an overview of the key chemical properties, uses, and environmental impacts of lead. Its molecular mass is 207.2 u, and electronic configuration is [Xe]4f145d106s26p2. This metal

exhibits two oxidative states +2 and +4, +2 is more stable common compound. Lead is inert at room temperature however it reacts with hydrochloric acid and converted to lead chloride and hydrogen gas. It forms oxides and sulfides upon reaction with oxygen (PbO_2) or sulfur (PbS). Lead is used in batteries, mirrors, to shield atomic units, and used in paints. This metal has influence on various biological systems.

Lead can enter the body through inhalation, ingestion, or dermal contact. Common sources of lead exposure to biological systems include Lead-based paints (especially in older buildings), Lead-contaminated soil, Plumbing pipes and fixtures made of lead, Occupational exposures (e.g., battery manufacturing, construction, and painting), and Imported goods (toys, cosmetics, and traditional medicines) containing lead. Lead is a toxic heavy metal that poses significant health risks to humans and the environment. Its biological effects are primarily due to its ability to interfere with various physiological processes. Here are some of the key biological effects of lead exposure:

1. **Neurological Effects:** Lead exposure, especially in children, can lead to cognitive deficits, reduced IQ, and learning disabilities. The developing brain is particularly vulnerable to lead's neurotoxic effects. Children exposed to lead may exhibit increased aggression, hyperactivity, and other behavioral problems. In adults, lead exposure has been linked to mood disorders and cognitive decline. Chronic lead exposure can lead to peripheral nerve damage, resulting in numbness, pain, and weakness, particularly in the extremities.
2. **Hematological Effects:** Lead interferes with hemoglobin synthesis by inhibiting enzymes involved in blood production, leading to anemia (a decrease in red blood cells). A specific type of anemia, sideroblastic anemia, is characterized by the presence of ringed sideroblasts in the bone marrow and results from inadequate incorporation of iron into hemoglobin.
3. **Renal Effects:** Lead exposure can impair kidney function. Chronic exposure leads to glomerular and tubular damage, and it can result in chronic kidney disease over time. The presence of abnormal levels of protein in urine can occur due to kidney damage from lead.
4. **Cardiovascular Effects:** Lead exposure is associated with increased blood pressure, which can contribute to hypertension and related cardiovascular diseases.
5. **Reproductive Effects:** In females Lead exposure during pregnancy can lead to adverse outcomes such as low birth weight, preterm birth, and developmental delays in the child and

in males Lead exposure has been linked to reduced sperm count and motility, affecting male reproductive health.

6. Effects on Bone and Teeth: Lead can be stored in bone and teeth, replacing calcium and disrupting normal bone mineralization. This can contribute to osteoporosis and increase the risk of fractures.

7. Carcinogenic Potential: Though classified as possibly carcinogenic to humans (Group 2B by the International Agency for Research on Cancer), evidence of lead's carcinogenic effects is not as clear as for some other heavy metals. Long-term exposure may increase the risk of certain cancers, such as lung and stomach cancer (Fig1).

8. Immune System Effects: Lead has been shown to negatively impact on the immune system, potentially increasing susceptibility to infections and altering immune responses.

This paper reviews various lead remediation strategies across different environments, including soil, water, and indoor settings, highlighting the importance of tailored interventions and community engagement

Review of Lead Toxicity, propagation and eradication methods

Given the significant biological effects of lead, particularly in vulnerable populations such as children and pregnant women, it is critical to minimize exposure to this toxic metal through public health interventions, regulatory measures, and public awareness campaigns. Regular monitoring and prevention strategies are essential for reducing lead exposure and mitigating its health impact.

Lead Toxicity Levels

Lead exposure can have detrimental effects on a wide range of living organisms, including animals, plants, rats, and humans. The specific toxic levels can vary significantly among different species, and the effects are influenced by factors such as the duration of exposure, age, and health status.

1. Humans: The lead toxicity threshold values in blood level (BLL, Blood Lead Levels) are above 5 µg/dL (micrograms per deciliter) are considered elevated and may warrant intervention, particularly in children. For adults, the recommended action level is often higher, but no safe level of lead exposure is recognized. The Levels above 10 µg/dL in children are associated with significant neurodevelopmental impacts, while levels greater

than 25 µg/dL can cause more severe health effects and require medical intervention. Further Chronic exposure can lead to neurological deficits, anemia, renal impairment, and other systemic effects.

2. Animals: Animals can also suffer from lead poisoning, with symptoms and thresholds often similar to those seen in humans, though species-specific differences exist in exposure and tolerance and the birds Lead exposure from ingesting lead shot or sinkers is common. Toxic levels can start at BLLs greater than 10 µg/dL, leading to neurological impairment, reproductive issues, and mortality. In dogs and cats' Clinical signs of lead toxicity can occur at BLLs greater than 30 µg/dL. Symptoms include vomiting, lethargy, and seizures.

3. Rats: In laboratory studies, lead exposure to rats often shows effects at doses of 100 to 400 mg/kg body weight in feed, resulting in hematological and neurological effects. Normal blood lead levels in rats are typically below 2 µg/dL. Rats' Chronic exposure can lead to decreased growth rates, impairment in cognitive functions, and reproductive issues.

4. Plants: Lead can inhibit plant growth at relatively low concentrations. Soil lead levels above 100-300 mg/kg can significantly impair seed germination and root development. The lead effect Symptoms include chlorosis, stunted growth, and reduced photosynthesis. Plants can absorb lead from contaminated soil or water, and the lead can accumulate in various plant tissues, posing a risk to herbivores and, consequently, to the food chain.

Role of Plants in spread of Lead Toxicity

Plants can play a significant role in the bioaccumulation and transfer of lead toxicity to animals and humans through several mechanisms. Here's how this process occurs:

1. Uptake of Lead from Contaminated Soil

- Soil Contamination: When lead is present in the soil, either from industrial pollution, historical use of leaded petrol, or other sources, plants can absorb lead through their roots.
- Accumulative Potential: Different plant species have varying abilities to take up lead, with some being more efficient at accumulating heavy metals than others. This uptake can lead to elevated levels of lead in plant tissues.

2. Bioaccumulation in Plant Tissues

- **Concentration in Plant Parts:** Lead can accumulate in various parts of the plant, including leaves, stems, roots, and fruits.
- **Phytotoxicity:** High concentrations of lead can hinder plant growth and metabolism, potentially affecting the plant's ability to photosynthesize and grow properly.

3. Transfer to Animals

- **Herbivory:** Animals that consume contaminated plants can ingest lead, leading to absorption and bioaccumulation in their tissues. This particularly affects herbivorous animals that rely on plant material for food.
- **Food Chain Dynamics:** If herbivores consume lead-contaminated plants, predators that consume these herbivores (carnivores) may also be exposed to lead, leading to biomagnification through the food chain. This can result in higher concentrations of lead in higher trophic levels.

4. Risks to Humans

- **Consumption of Contaminated Plants:** Humans can be exposed to lead by consuming fruits, vegetables, or grains that have absorbed lead from contaminated soil. Even after cooking, lead remains in the plant material and can pose health risks.
- **Inhalation and Dermal Exposure:** Dust and particles from contaminated soil or plant material can become airborne, leading to potential inhalation or skin contact. For example, residents living near contaminated areas may be exposed to lead via airborne particles or dust that settles on edible plants.

5. Lead Cycling in the Environment

- **Leaching and Rainfall:** Rainfall can cause the leaching of lead into groundwater and affect nearby plants. Likewise, soil lead levels can fluctuate, leading to varying degrees of lead uptake by plants over time.
- **Decomposition of Plants:** When lead-contaminated plant material decomposes, it can release lead back into the soil and potentially lead to further contamination of surrounding plants and the environment.

Therefore, Plants can effectively spread Pb toxicity to animals and humans through several pathways

- **Uptake from contaminated soil:** Lead is absorbed by the roots of the plants.
- **Bioaccumulation:** Lead builds up in various plant parts, becoming concentrated.

- Animal consumption: Herbivores consuming contaminated plants ingest lead, which can then bioaccumulate in their bodies and transfer to predators.
- Human consumption: Humans may ingest lead through eating contaminated plants or become exposed via inhalation or dermal contact with contaminated dust or soil.

Industry and Lead contamination: Industries have historically played a significant role in lead pollution through various practices and processes that contribute to environmental contamination. Here are some keyways in which industrial activities contribute to lead pollution:

1. Mining and Ore Processing

Extraction of Lead Ores: Mining activities, including the extraction of lead ores (like galena), can release lead dust and particles into the environment. This dust can settle on surrounding land and water bodies.

Smelting: The smelting process used to extract lead from ores generates substantial amounts of lead-containing waste, including slag and emissions, which can contaminate nearby soil and air.

2. Industrial Manufacturing

Lead-based Products: Many industries manufacture products that contain lead, such as batteries, paints, plastics, and ceramics. The production processes can release lead into the air and water if proper controls are not in place.

Lead Paint and Coatings: Historically, lead-based paints were widely used. The manufacturing and application of these paints contributed to lead contamination in indoor and outdoor environments.

3. Automobile Industry

Leaded Gasoline: For many years, leaded gasoline was commonly used in vehicles, leading to atmospheric release of lead from exhaust emissions. Even after the phase-out of leaded gasoline, residual lead remains in soil and dust, particularly near roadways.

Battery Manufacturing: The manufacturing of lead-acid batteries generates lead dust and waste. Inadequate handling and disposal can lead to soil and water contamination.

4. Recycling Processes

Lead Recycling: Recycling industries that process lead-containing products (such as batteries) can release lead through inadequate containment practices and dust emissions. This

can lead to localized contamination around recycling facilities.

Improper Disposal: Improper disposal of lead-containing products can lead to soil and groundwater contamination.

5. Construction and Demolition

Many older buildings contain lead-based paints and plumbing. Uncontrolled demolition or renovation activities can release lead particles into the air and soil. Some construction materials, like certain types of roofing, pipes, and glazes, may contain lead, contributing to exposure during construction activities.

6. Industrial Emissions

Air Emissions: Industries may emit lead into the atmosphere through smokestacks and other ventilation systems. These airborne lead particles can settle on soil, plants, and water sources, continuing the cycle of lead contamination.

Waste Disposal: Industrial waste that contains lead, if not disposed of properly, can leach lead into nearby soil and groundwater, further contributing to environmental pollution.

7. Lack of Regulation and Enforcement

In some regions, insufficient environmental regulations or lax enforcement can allow industries to operate without adequate controls for pollution. Here cost-cutting measures may lead some industries to neglect proper safety and waste management practices, increasing the risk of lead contamination.

Considering the above, it can conclude that the industrial role in lead pollution is multifaceted, involving various stages from resource extraction to product manufacturing and disposal. The effects of industrial lead pollution are widespread, affecting air quality, soil health, and water resources, with serious implications for public health, particularly for vulnerable populations such as children and pregnant women. Effective regulation, improved industrial practices, and community awareness are essential in mitigating lead pollution and protecting both human health and the environment.

The contribution of cities to lead pollution

City waste, particularly in urban environments, can significantly contribute to the propagation of lead pollution through various pathways and activities. They are,

1. Municipal Solid Waste

Household and commercial waste can include lead-containing items such as batteries, electronics, paints, pipes, and ceramics. When these materials are disposed of improperly or mixed with general waste, they can leach lead into the soil and groundwater.

Landfills can produce leachate (the liquid that drains or leaches from a landfill) that can contaminate surrounding soil and water sources. If lead-containing waste is present, the leachate can carry lead compounds into the environment.

2. E-Waste Disposal

Discarded electronics (e-waste) often contain lead in circuit boards and glass screens. When improperly disposed of, e-waste can release lead through landfilling or open burning, contributing to soil and air pollution. Informal recycling practices, where e-waste is dismantled without proper safety measures, can release Pb dust into the air, exposing both workers and nearby residents to health risks.

3. Construction and Demolition Debris

Old buildings commonly contain lead-based paints. When these structures are renovated or demolished, lead dust can be released into the air and settle on surfaces in nearby areas, contaminating soil and possibly entering the food chain. The disposal of construction debris in landfills can introduce Pb into the waste stream, particularly if the debris contains lead paint, pipes, or other lead-bearing materials.

4. Soil Contamination

Urban areas can accumulate contaminated soil due to the deposition of lead from various waste sources, including industrial activities, vehicle emissions, and waste disposal practices. This contamination can persist over time and impact public health. In cities where gardens and urban agriculture are part of the landscape, lead-contaminated soil can be a significant concern. Vegetables and fruits grown in lead-contaminated soil can absorb lead, resulting in health risks for consumers.

5. Airborne Particulate Matter

Open burning of waste, which may happen in some urban areas, can release lead particles into the air. These airborne lead particles can settle into nearby soil and water bodies, further propagating lead pollution.

6. Ineffective Waste Management

Poor waste management practices, such as the lack of proper segregation of hazardous waste from general municipal waste, can lead to lead contamination in landfills and the surrounding environment. Inadequate waste collection and disposal infrastructure can lead to illegal dumping of hazardous materials, including those containing lead, exacerbating environmental contamination.

7. Public Awareness and Education

Many residents may not be aware of the dangers of improper disposal of hazardous materials and the presence of lead in household items. This lack of awareness can lead to continued pollution.

City waste plays a significant role in the propagation of lead pollution through various channels, including improper disposal and inadequate waste management practices. Effective waste management strategies, public education on the safe disposal of hazardous materials, and regulation of e-waste and lead-containing products are essential to mitigate the risks associated with lead pollution in urban environments. Addressing these issues can help protect public health, especially vulnerable populations, and contribute to a cleaner environment.

Methods of removal of lead contamination

Removing Lead contamination from the environment is crucial for protecting public health and ensuring safe living conditions. The methods used for lead removal depend on the type and extent of contamination, as well as the medium (soil, water, or indoor environments).

1. Soil Remediation

Excavation and Disposal: This involves physically removing contaminated soil and disposing of it in a hazardous waste landfill or at a facility designed to handle toxic materials.

Soil Washing: A process that uses water, chemical agents, or both to remove lead from soil particles. The contaminated soil is mixed with water and the Pb is extracted, leaving behind cleaner soil.

Phytoremediation: This method uses plants known to absorb lead from soil. Certain plants, such as sunflowers and willows, can uptake heavy metals through their roots and remove them from the soil over time.

Stabilization and Solidification: This chemical treatment involves adding materials to

contaminated soil to chemically bind lead, preventing it from leaching into groundwater and making it less bioavailable.

Covering or Capping: If immediate removal isn't feasible, an interim solution may involve covering contaminated soil with clean soil or a barrier to minimizing exposure.

2. Water Treatment

Filtration: Point-of-use filters, such as activated carbon filters or reverse osmosis systems, can effectively remove lead from drinking water.

Chemical Treatment: Adding agents like phosphate or lime can precipitate lead out of water, making it less harmful and easier to remove.

Ion Exchange: This method involves exchanging lead ions in water with more benign ions, such as sodium or potassium, effectively reducing lead concentration.

3. Indoor Lead Removal

Lead Paint Abatement: For homes with lead-based paint, methods include:

Encapsulating: Applying a sealant over lead-based paint to prevent exposure.

Removal: Carefully scraping or stripping off lead paint while following safety protocols to avoid dust generation.

HEPA Vacuuming: Using high-efficiency particulate air (HEPA) filters to clean up lead dust from surfaces.

Cleaning: Regular wet cleaning to remove lead dust from surfaces, particularly in homes with children or pregnant women. This can include using damp cloths and mops to trap dust.

4. Industrial and Occupational Settings

Containment: In industrial environments, contaminated areas may be sealed off to prevent exposure, and procedures are implemented to minimize dust and waste release.

Vacuum Systems: Using vacuums equipped with HEPA filters for cleanup in areas where lead dust may accumulate.

5. Monitoring and Assessment

Continuous monitoring of soil, water, and air for lead contamination levels. Remediation effectiveness should be assessed periodically to ensure that lead levels are decreasing and remain below safety thresholds.

6. Public Awareness and Education

Educating communities about lead sources and the importance of lead testing in homes, especially in homes built before 1978 when lead-based paint was commonly used.

Successfully removing lead contamination requires a combination of methods tailored to specific situations. Careful assessment of the contamination level and the environment is essential to choose the most effective remediation strategy. Moreover, professional services should be engaged, especially for serious contamination cases, to ensure compliance with safety standards and regulations. Preventing future contamination through better waste management and public education is equally important in the long-term management of lead pollution.

In summary, the Lead contamination poses a significant public health threat, particularly due to its adverse effects on neurological development in children. This paper reviews various lead remediation strategies across different environments, including soil, water, and indoor settings, highlighting the importance of tailored interventions and community engagement. The introduction provides a foundational understanding of lead, its uses, and pathways of exposure, emphasizing its toxicity and biological effects which include neurological impairment, hematological issues, renal dysfunction, cardiovascular risks, reproductive effects, bone and dental impacts, carcinogenic potential, and immune system interference. The review of lead toxicity levels indicates that while certain thresholds exist for humans, animals, and plants, any exposure poses health risks. Lead can accumulate in living organisms, thus entering the food chain through contaminated plants and animals. The role of industrial practices in lead pollution is significant; mining, manufacturing, recycling, and inadequate waste management can facilitate widespread contamination. Urban environments contribute to lead pollution through municipal solid waste, e-waste disposal, construction debris, and soil degradation. Effective methods for lead removal include soil remediation techniques like excavation, soil washing, phytoremediation, and stabilization. Water treatment options span filtration, chemical treatments, and ion exchange. For indoor settings, lead paint abatement and rigorous cleaning protocols are essential. Monitoring and continuous assessment are critical to ensure the effectiveness of these remediation efforts. Overall, addressing lead contamination requires a comprehensive approach that integrates effective remediation methods, public education, ongoing monitoring, and regulatory measures to protect vulnerable populations and enhance community health.

Left

Right

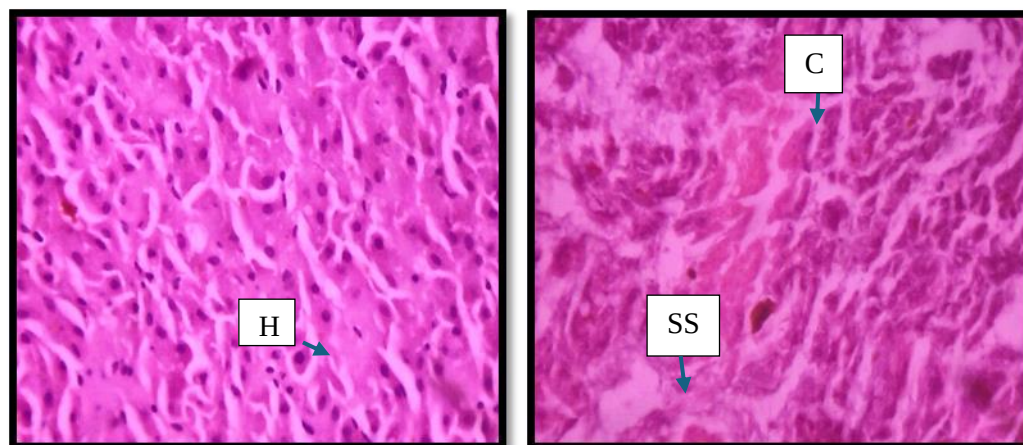


Fig. 1: Microscopic analysis of Chick embryo liver Control (left) and Pb Treated (Right) (10x40x).

Note H is Normal hepatocyte, C is for congestion and SS is sinusoidal spaces.

REFERENCES

1. Pallavi Chittoor (2016) PhD thesis entitled “Effect of Lead acetate on the liver Glutathione s transferases of Chick embryo” submitted to Sri Venkateswara University, Tirupati 517502 AP, India.
2. World Health Organization, Lead Poisoning, June 10, 2026.