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A Comprehensive Review of Soil Pollution, Crop Productivity, and Human Health Interconnections: Insights from Industrial Regions with Emphasis on Korba District, Chhattisgarh

Prakash Das Padawar, Dr Dhanesh Singh*

Govt Kirodimal Arts and Science College, Shaheed Nand Kumar Patel, University, Raigarh (C.G)
prakash.chem78@gmail.com
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ABSTRACT –

Soil pollution, particularly from industrial sources, poses a significant threat to agricultural productivity and human health. This review focuses on the pervasive soil contamination in industrial regions, with a detailed case study of Korba district, Chhattisgarh, India a hub for coal mining and thermal power generation. Elevated levels of heavy metals and toxic pollutants have degraded soil fertility, disrupted nutrient balances, and diminished crop yields in Korba. These contaminants bioaccumulate in food crops and infiltrate groundwater, exposing local populations to serious health risks, including neurological, respiratory, and chronic diseases. Multiple exposure pathways, including direct contact, ingestion of contaminated soil, and consumption of polluted food and water, compound these risks. The Korba case underscores the urgent need for robust environmental monitoring, effective remediation, regulatory enforcement, and community awareness to safeguard soil health, food security, and public wellbeing in industrial landscapes.

Keywords : Soil pollution, contaminants , bioaccumulate, industrial, community

Introduction –

Soil serves as the very foundation of terrestrial life, influencing ecosystem productivity, biodiversity, and the sustainability of food systems. Healthy soil regulates water cycles, recycles nutrients, sequesters carbon, supports plant growth, and forms a critical barrier against environmental pollutants(1-2). Soil's living matrix teeming with microorganisms, insects, and organic matter directly determines the quality of air and water, the resilience of crops, and, consequently, the nutritional security and overall health of human populations. Degradation of this precious resource undermines not only crop productivity, but also ecosystem stability and public wellbeing. In recent decades, industrialization has fueled economic growth but has also introduced profound environmental challenges worldwide. Among these, soil pollution has emerged as a critical issue, fuelled by the release of heavy metals, persistent organic pollutants, agrochemicals, and industrial effluents into terrestrial environments. These contaminants accumulate in soils, reducing fertility, disrupting ecological cycles, entering the food chain, and posing significant risks to flora, fauna, and humans. The irreversible nature of soil degradation and its direct impact on human health have prompted urgent calls for action, research, and policy reforms at both local and global levels. Korba district, located in the state of Chhattisgarh, India, exemplifies the intersection of rapid industrial development with environmental and health concerns. Widely recognized for its extensive coal mining operations and the presence of multiple thermal power plants, Korba has become a focal point for studies on industrial pollution. The district's dependence on agriculture for livelihoods, coupled with its status as a major industrial hub, presents a unique opportunity to examine how soil contamination influences crop productivity, food safety, and public health in real-world settings. Studying Korba not only sheds light on local challenges but also provides valuable insights for other industrial and mining regions facing similar ecological pressures (3-10).

Industrial soil pollution

Soil pollution is the presence or build-up of harmful substances in the soil, which adversely impacts the soil's ecological function and endangers plant, animal, and human health. Industrial soil pollution is primarily characterized by the accumulation of persistent and potentially toxic substances owing to anthropogenic activities (11-12). The major categories include:

a) **Heavy Metals**:

Lead (Pb): Commonly released from mining, battery manufacturing, paint industries, and vehicular emissions. It accumulates in soil and has severe neurotoxic effects, especially in children (13).

Cadmium (Cd): Originates from mining, metal plating, cadmium-nickel batteries, and phosphate fertilizers. Cadmium is known for its high soil retention and can cause kidney dysfunction and skeletal damage (14).

Mercury (Hg): Generated by coal combustion, chlor-alkali industries, and certain pesticides. Mercury is highly toxic and bioaccumulates through food chains, impacting neurological health (15).

Arsenic (As): Major sources include mining, smelting, and the use of arsenic-based pesticides. Chronic exposure is linked to skin lesions, cancer, and cardiovascular diseases (16).

b) **Organic Pollutants**:

Polycyclic Aromatic Hydrocarbons (PAHs): These are generated during the incomplete combustion of coal, oil, wood, and other organic substances, prevalent around power plants and heavy traffic zones. PAHs persist in soil and can be carcinogenic (17).

Polychlorinated Biphenyls (PCBs): Used in electrical equipment, paint, and hydraulic fluids. PCBs are resistant to degradation, magnify in food chains, and have been linked to endocrine disruption and cancer (18).

Other Agro-industrial Chemicals: Soil is increasingly contaminated by excess pesticide, insecticide, herbicide, and fungicide application. These disrupt soil microbial communities, reduce fertility, and may enter the human food chain (19).

Global Scenario

Hotspots and Affected Regions:

China: Soil pollution is severe in mining provinces and industrial zones such as Hunan, Guangdong, and the Yangtze River delta. A 2014 survey revealed that over 16% of sampled Chinese soils exceeded national pollution standards, mainly due to lead, cadmium, and arsenic contamination (20).

United States: The US Environmental Protection Agency (EPA) manages numerous heavily contaminated "Superfund" sites (e.g., Love Canal, Tar Creek), many of which are former mining, smelting, or chemical production zones. Regions like the Rust Belt and Appalachia are especially affected.

Eastern Europe: Poland, Romania, and the Czech Republic face extensive soil contamination from decades of mining, metallurgy, and chemical industries. The legacy of Soviet-era industrialization has left large swathes of polluted soils, especially around industrial towns and rivers (21-23).

Major Contributors: Mining and Smelting release metals, acids, and other toxic solids.

Power Generation coal-fired plants produce fly ash, bottom ash, and metal-laden particulates, often disposed in poorly contained ash ponds that leach into soils. Chemical and Petrochemical Industry: discharge persistent toxins like PCBs, dioxins, and chlorinated solvents. Waste Disposal Legacy and poorly managed landfills or hazardous waste sites are major pollution sources. Globally, soil pollution reduces agricultural productivity, contaminates food supplies, harms wildlife, and poses direct risks to human health via ingestion, inhalation, or dermal exposure (24-25).

Soil Pollution in India

National Data and Hotspots: According to the Central Pollution Control Board (CPCB), hundreds of 'critically polluted areas' exist, many in industrial or mining belts. States like Chhattisgarh (Korba), Jharkhand (Jharia, Dhanbad), Maharashtra (Nashik, Tarapur), and Gujarat (Vapi, Ankleshwar) are repeatedly flagged in national pollution indices. The 2021 National Green Tribunal and CPCB reports highlight that heavy metals (lead, cadmium, chromium) and persistent organic chemicals are found above safe limits in numerous industrial regions (26-28).

Major Industrial Belts:

Korba (Chhattisgarh): Known for extensive coal mining and multiple thermal power plants, resulting in persistent heavy metal, fly ash, and organic pollution in local soils. Singrauli (Madhya Pradesh/Uttar Pradesh): Major coal mining and power generation center. Vapi (Gujarat): Oldest and among the most polluted chemical industrial estates. Durgapur, Asansol, Raniganj (West Bengal): Intense mining and metal-based industries. Bhilai, Raigarh (Chhattisgarh) and Angul-Talcher (Odisha): Steel, aluminium, and coal-heavy industries (29-30).

Regulatory Frameworks: CPCB Guidelines establish limits for heavy metals and other toxins in agricultural and non-agricultural soils. The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, require treatment and safe disposal of industrial wastes. Soil Health Card Scheme launched by the Government of India, it assesses 12 essential soil parameters, including some metals and nutrients, at farmers' fields, promoting balanced fertilization. Environmental Protection Act (1986), and allied rules provide comprehensive legal power for pollution regulation at the Central and State level. Periodic surveys and public reports of pollution status are mandated. Remediation Initiatives some 'hotspots' are targeted for bioremediation, capping, or restricted usage, but progress is challenged by legacy issues, illegal dumping, and lack of strict enforcement(31-34).

Mechanisms of Soil-Crop Contamination

Bioavailability and Uptake of Metals, heavy metals like lead, cadmium, mercury, and arsenic present in polluted soils can become bioavailable, meaning they are in a form readily absorbed by plant roots. The uptake of these metals depends on soil pH, organic matter, and chemical interactions. Once inside the plant, these metals can accumulate in edible tissues, thus entering the food chain and posing risks to human and animal health. Crops grown in such soils may exhibit higher concentrations of toxic elements, even when external symptoms are minimal.

Disruption of Soil Microbiota and Nutrient Cycling i.e soil pollution by industrial chemicals and heavy metals disrupts the natural balance of beneficial soil microorganisms. This disturbance impairs vital processes like nutrient cycling, nitrogen fixation, and organic matter decomposition. When microbes are harmed, soil fertility declines, limiting the capacity of crops to access essential nutrients and reducing overall productivity and resilience (35-37).

Impact on Crop Yield and Quality: Stunted Growth, Chlorosis, and Reduced Fruiting:

Polluted soils often result in poor seed germination, stunted plant growth, yellowing of leaves (chlorosis), reduced flowering, and lower fruit or grain output. Toxic substances can interfere with root development, water absorption, and enzymatic functions, further impairing crop performance. Contamination of Edible Parts accumulated pollutants particularly heavy metals and residual pesticides in the edible parts of crops threaten food safety. Consumption of such contaminated produce can lead to a spectrum of health problems, ranging from mild gastrointestinal upsets to severe organ toxicity, neurological issues, and increased cancer risk.

Case Study from Korba : Korba district in Chhattisgarh, known as the "Power Capital of India," is heavily impacted by soil pollution due to intense coal mining and multiple thermal power plants. Industrial activities have led to elevated concentrations of heavy metals such as arsenic, nickel, lead, cadmium, and chromium in the soil, coupled with acidic pH levels and depleted organic carbon, which have severely compromised soil fertility and disrupted nutrient balance essential for crop growth. This contamination not only reduces agricultural productivity causing farmers to abandon lands due to poor yields but also results in the bioaccumulation of toxic metals in food crops, posing significant health risks to local populations. Additionally, contamination permeates groundwater resources, exacerbating exposure pathways. Health impacts reported among residents include respiratory and neurological disorders, skin ailments, and chronic diseases linked to pollutants present in the environment. The Korba case highlights the urgent need for comprehensive environmental monitoring, remediation efforts, strict regulatory enforcement, and community engagement to mitigate soil and water pollution, protect agricultural output, and safeguard public health in industrial regions.

Global Impacts: In China, soil pollution led to an estimated 12 million tons of grain being declared unfit for human consumption due to contamination with heavy metals, resulting in direct economic losses exceeding $2.6 billion. In the US and Eastern Europe, similar patterns are seen in regions with intensive mining and industrial activities, where persistent loss of soil productivity, crop contamination, and expensive remediation have become major concerns

Soil pollution and human health risks

Humans are exposed to soil pollutants through multiple pathways. Direct exposure occurs via ingestion of contaminated soil or dust, particularly common among children through hand-to-mouth activities, as well as through dermal contact during farming, gardening, or recreational activities where pollutants can be absorbed through the skin. Inhalation of contaminated dust particles, stirred up by wind or human activities, is another direct exposure route. Indirect exposure primarily happens through consumption of crops grown in polluted soils, which may accumulate heavy metals and toxic chemicals in edible parts, and through drinking water contaminated by leachates from polluted soils. Additionally, consumption of animal products from livestock raised on contaminated feed or in polluted environments can further transmit toxins to humans. These combined exposure pathways increase the risk of adverse health effects associated with soil pollution.

Table no.01 Major soil parameters, relevant WHO guideline limits and their consequences

Parameter	WHO Limit	Consequences
pH	6.5–8.5 (optimal)	Acidic soil reduces nutrient availability.
TDS (mg/L)	<1000 (drinking water)	High TDS harms soil fertility.
Moisture Content (%)	–	Variable moisture impacts plant growth.
Nitrogen (Kg/ha)	–	Nitrogen improves growth but varies widely.

Parameter	**WHO Limit**	**Consequences**
Sulphur Content (ppm)	–	Excess sulphur toxic to some crops.
Copper (mg/L)	0.05–2.0 (agriculture)	Elevated Cu is toxic to microbes and plants.
Zinc (mg/L)	1.5–3.0 (agriculture)	High Zn concentration inhibits some plants.
Manganese (mg/L)	–	Manganese toxicity affects root development.
Lead (mg/L)	0.01 (soil)	Pb is toxic, accumulates in crops.
Nickel (mg/L)	0.05 (soil)	Ni toxicity limits crop yield and affects human health.

Health Outcomes:

The health impact of soil pollution depends on the type and amount of contaminant, frequency and route of exposure, and individual susceptibility: Acute and Chronic Toxicity Acute effects include headaches, nausea, vomiting, respiratory distress, skin and eye irritation. Chronic exposure leads to depression of the central nervous system, damage to organs (kidney, liver), and impaired immune function.

Neurological, Renal, Reproductive, and Developmental Disorders:

Neurological: Lead, mercury, and some pesticides can cause cognitive deficits, developmental delays (especially in children), memory loss, and increased risk of neurodegenerative diseases.

Renal: Cadmium, mercury, and lead cause kidney damage/failure over prolonged exposure.

Reproductive: Exposure to endocrine-disrupting chemicals and pesticides is linked to infertility, birth defects, and disrupted hormones.

Developmental: Children exposed prenatally or early in life may experience learning disabilities, growth retardation, and behavioral changes.

Cancer Risks: Long-term exposure to soil pollutants such as arsenic, PAHs, PCBs, and certain pesticides is associated with higher risks of skin, bladder, lung, liver, and other cancers.

Vulnerable Populations: Certain groups are at greater risk due to heightened exposure and/or increased physiological sensitivity:

Children: More likely to ingest soil/dust, have developing organs and nervous systems, and absorb larger doses relative to body weight.

Pregnant Women: Exposure to soil-borne toxins can affect fetal development, increasing risks for birth defects, developmental delays, and miscarriage.

Farmers and Industrial Workers: Regular contact with soil, chemicals, dust, and polluted water raises exposure risk.

Residents near industrial sites: Poverty and proximity to pollution sources increase risk of chronic exposure and health burdens(38-40).

Conclusion –

The Korba district exemplifies the profound impact of industrial soil pollution on both agriculture and human health. Persistent contamination from coal mining and power plants has led to degraded soil quality, reduced crop productivity, and accumulation of hazardous substances in the food chain and water resources. These environmental challenges translate into heightened health risks for vulnerable populations, including children, farmers, and residents near industrial sites. Addressing soil pollution in Korba and similar industrial zones demands integrated approaches involving rigorous scientific assessment, pollution control measures, sustainable agricultural practices, and strong regulatory frameworks. Enhancing public education and stakeholder participation is equally critical to fostering resilience, ensuring environmental sustainability, and protecting human health in the face of ongoing industrial development.

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