

Introduction to Heavy Metals

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Study guide – concise, organized, and easy to read

1. What Are Heavy Metals?

Definition	Typical Characteristics
Heavy metals are metallic elements with a high atomic weight and density (generally $>5\text{ g/cm}^3$).	• Poorly biodegradable • Can exist in elemental, ionic, or compound forms • Often toxic to living organisms at low concentrations • Frequently released by industrial activities, mining, agriculture, and combustion processes.
Commonly referenced in environmental and health contexts.	

Key examples

- **Lead (Pb)** – battery production, paints, ammunition.
 - **Mercury (Hg)** – coal combustion, dental amalgams, artisanal gold mining.
 - **Cadmium (Cd)** – batteries, pigments, phosphate fertilizers.
 - **Arsenic (As)** – semiconductor manufacturing, wood preservatives (note: metalloid).
 - **Chromium (Cr)** – stainless steel, plating, leather tanning.
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2. Sources & Pathways

Source Type	Typical Release Mechanism	Environmental Compartment
Natural	Weathering of ore deposits, volcanic eruptions	Soil, water, air
Industrial	Smelting, metal finishing, waste incineration	Air (particulate), effluents
Agricultural	Phosphate fertilizers (Cd), pesticides (As)	Soil & crops
Urban	Vehicle exhaust, brake wear (Pb, Cu)	Air & deposition
Domestic	Batteries, electronics, consumer products	Landfills & leachate

Transport pathways

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- **Atmospheric deposition** ? surface soils & water bodies.
 - **Runoff & leaching** ? rivers, lakes, groundwater.
 - **Food chain bioaccumulation** ? plants ? herbivores ? humans.
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3. Chemical Behavior in the Environment

Property	Environmental Implication
Speciation (oxidation state, complexation)	Determines mobility & toxicity (e.g., Cr(III) vs. Cr(VI)).
Solubility	Highly soluble ions (e.g., Pb^{2+}) travel farther in water; insoluble forms may settle in sediments.
Adsorption	Metals bind to organic matter, clays, and oxides, influencing retention in soils.
Redox reactions	Reducing conditions can convert toxic species to less toxic forms (e.g., Hg ⁰ volatilization).
pH & ionic strength	Low pH often increases metal solubility, raising bioavailability.

4. Toxicological Effects

System	Typical Symptoms / Effects	Representative Metals
Nervous	Cognitive deficits, neuropathy, tremors	Pb, Hg
Renal	Kidney dysfunction, proteinuria	Cd, Hg
Respiratory	Pulmonary edema, bronchitis	As, Cr(VI)
Skeletal	Osteoporosis, bone pain	Pb, Cd
Carcinogenic	Lung, bladder, skin cancers	As, Cr(VI), Cd
Endocrine	Hormonal disruption, reproductive effects	Pb, Cd

Mechanisms: oxidative stress, enzyme inhibition, DNA damage, disruption of ion channels, and interference with essential metal homeostasis (e.g., Fe, Zn).

5. Human Exposure Routes

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1. **Ingestion** – contaminated water, food (rice, fish, leafy greens)