

Chapter IV

Mineral and Energy Resources – Substances, Extraction Techniques, and Environmental Impacts

I. Introduction

Mineral and energy resources, derived from the geological substratum, form the foundation of economic and industrial development. Their exploitation enables the production of construction materials, metals, fertilizers, and energy. Effective management integrating geology, economics, and environmental considerations is essential.

II. Metallic Substances

2.1 Definition and Classification

A metallic substance is a naturally occurring chemical element in the form of an ore (oxide, sulfide, silicate, etc.) from which metal can be extracted through metallurgical processes.

Category	Examples	Typical Ore Minerals
Ferrous metals	Iron (Fe), Manganese (Mn)	Hematite, Magnetite, Pyrolusite
Common non-ferrous metals	Copper (Cu), Zinc (Zn), Lead (Pb), Aluminium (Al)	Chalcopyrite, Sphalerite, Galena, Bauxite
Precious metals	Gold (Au), Silver (Ag), Platinum (Pt)	Native gold, Argentite, Sperrylite
Strategic / Critical metals	Lithium (Li), Cobalt (Co), Rare Earth Elements (REE), Niobium (Nb)	Spodumene, Carrollite, Monazite, Pyrochlore

2.2 Extraction Techniques

a) Open-pit Mining - Conventional open-pit mines: step-wise benches, drilling, blasting, loading, and transport. Example: porphyry copper (Chuquicamata, Chile), iron (Carajás, Brazil). - Placer mining: gravity extraction for alluvial gold or tin using suction dredges, sluices, or shaking tables. - Heap leaching: oxidized copper or gold ores are piled and irrigated with cyanide solution (gold) or sulfuric acid (copper). Recovery occurs via activated carbon or solvent extraction.

b) Underground Mining - Room-and-pillar: for tabular deposits (zinc, lead). Pillars support the roof. - Cut and fill: narrow veins (gold, silver), mined in slices with backfilled waste. - Block caving: for massive, deep deposits (copper, molybdenum). Highly productive but can cause surface subsidence. - Hydraulic and in-situ methods: rock salt dissolution or in-situ leaching (ISL) for uranium/copper.

2.3 Environmental Impacts of Metallic Mining

Impact	Source	Consequences
Acid Mine Drainage (AMD)	Oxidation of sulfides	pH <3, heavy metal release → aquatic toxicity, groundwater contamination
Cyanide pollution (gold)	Heap leaching or tanks	Dam failures → mass aquatic mortality, health risks
Mercury pollution (artisanal gold)	Amalgamation without retort	Neurotoxic methylmercury formation, Hg vapor inhalation
Metal dust	Drilling, crushing, transport	Lead poisoning, cancers, silicosis
Waste rock and tailings	Flotation or gravity residues	Tailings dam failures, soil and river contamination

III. Non-Metallic Substances (Industrial Minerals & Ornamental Stones)

3.1 Definition and Classification

Non-metallic minerals are exploited for their physical and chemical properties (hardness, color, porosity) without metal extraction.

Group	Examples	Main Uses
Industrial rocks	Limestone, granite, marble, sandstone	Cement, aggregates, building stone, riprap
Fertilizing minerals	Phosphate, potash, gypsum	Fertilizers, soil amendments
Chemical minerals	Sulfur, halite, borates	Sulfuric acid, chlorine chemistry, detergents
Refractory minerals	Graphite, magnesite, chromite	Crucibles, refractory bricks
Filler minerals	Kaolin, talc, mica, calcite	Paper, paint, plastics, cosmetics
Gemstones & ornamental stones	Diamond, emerald, jade, lapis-lazuli	Jewelry, sculpture, decoration

3.2 Extraction Techniques

a) Open-pit Mining - Hard rock quarries: diamond wire sawing or drilling, low-charge blasting. - Soft rock quarries: mechanical excavation, dredging, or hydraulic mining. - Phosphate mining: scrapers or draglines (Gantour, Morocco; Sechura, Peru).

b) Underground Mining - Room-and-pillar: potash or rock salt. - Solution mining: freshwater injection dissolves salt, brine pumped out. - Gemstone mining: narrow galleries following veins, often artisanal.

3.3 Environmental Impacts of Non-Metallic Mining

Impact	Source	Consequences
Large-volume extraction	Open-pit quarries (>100 ha)	Habitat destruction, ecological fragmentation, farmland loss
Dust	Drilling, crushing, vehicles	Silicosis, air quality deterioration, vegetation deposition
Noise & vibration	Blasting, machinery	Human and wildlife disturbance, building cracks
Groundwater modification	Excavation below water table	Lowered water table, drying wells, flow reversal
Chemical pollution	Phosphogypsum (Ra-226, U, Th); chloride discharge	Soil salinization, eutrophication, heavy metal toxicity
Subsidence	Salt/potash mines after dissolution	Catastrophic collapses

IV. Summary Table – Substances, Methods, Impacts

Type	Examples	Extraction Method	Main Environmental Impacts
Metallic (sulfide)	Cu, Zn, Pb	Open-pit + underground	AMD, heavy metals, tailings dam failure
Metallic (oxide)	Fe, bauxite	Large-scale open-pit	Dust, deforestation, red mud
Metallic (placer)	Gold, tin	Dredging, gravity	Turbidity, riverbed alteration, mercury

Non-metallic – rocks	Limestone, granite	Open-pit quarry	Dust, noise, landscape loss
Non-metallic – evaporites	Salt, potash	Underground/solution mining	Subsidence, water salinization
Non-metallic – fertilizers	Phosphate	Open-pit	Radioactive phosphogypsum, Cd, eutrophication

V. Global Impacts of Extraction

- ✓ **Environmental Impacts:** - Air: dust, SO₂, NO_x, CO₂. - Water: acidification, dissolved metals, cyanide, mercury, turbidity. - Soil: erosion, contamination. - Biodiversity: habitat loss, fragmentation, toxicity.
- ✓ **Geotechnical Impacts:** - Subsidence, sudden collapse, slope failures.
- ✓ **Socio-Economic & Health Impacts:** - Positive: jobs, infrastructure. - Negative: displacement, occupational diseases, water conflicts, economic cycles.

VI. Sustainable Management & Best Practices

- ✓ **Impact Reduction:** - EIA, cyanide alternatives, tailings backfilling. - Dust control, acid water management, revegetation. - Post-closure monitoring, soil reconstruction.
- ✓ **Circular Economy:** - Metal recycling, urban mining, waste rock valorization.
- ✓ **Regulations:** - Mandatory EIA, rehabilitation guarantees, IRMA, ISO 14001, Global Tailings Standard.

VII. Role of Applied Geologist

- Exploration: mapping, geochemistry, geophysics, drilling.
- Evaluation: resource/reserve calculation (JORC, NI 43-101).
- Exploitation: grade control, 3D modeling, geotechnical monitoring.
- Environment: AMD prediction, remediation design.
- Closure: audits, rehabilitation planning.

VIII. Conclusion

Mineral and energy resources are essential for modern society. Mismanaged exploitation can cause severe environmental impacts. An integrated approach combining suitable extraction techniques, impact assessment, and active rehabilitation balances economic development with environmental protection.