Resource Recovery and Potable Water Reclamation from Open-Cast Mine Water using Advanced Electrochemical Technology

Open-cast mining operations constitute a significant component of India's mineral extraction and coal thermal power generation industry and generate substantial volumes of mine-affected water through pit dewatering, rainfall accumulation, groundwater ingress, and runoff interaction with exposed strata and overburden materials. During mining, exposure of mineral-bearing formations to atmospheric and hydrological processes leads to dissolution and mobilization of heavy metals into the water column. As a result, mine water frequently contains elevated concentrations of dissolved metals such as iron, manganese, copper, zinc, chromium, lead, and other trace elements.

Management of mine water is a critical operational and environmental challenge. Current treatment practices in many mining regions primarily rely on neutralization, precipitation, and sedimentation processes aimed at meeting regulatory discharge standards. While such approaches can reduce contaminant concentrations, they often generate substantial volumes of metal-rich sludge, incur recurring chemical costs, and fail to capture dissolved metals in recoverable forms. Consequently, metals of commercial value are irreversibly lost, and mine water continues to be treated as a disposal burden rather than a potential resource stream.

Simultaneously, global demand for base metals such as copper and zinc continues to rise due to infrastructure development, renewable energy systems, electrification, advanced manufacturing, and urban expansion. The sustained upward trajectory in market demand and value of these metals highlights a strategic opportunity: dissolved metals present in open-cast mine water represent an untapped secondary resource. Given the large volumes of water handled across mining operations, even moderate metal concentrations can translate into meaningful cumulative recovery potential when aggregated over time.

In parallel, increasing water stress across industrial regions necessitates improved water stewardship within the mining sector. Reclaiming mine water to near-potable or high-quality reuse standards can significantly reduce freshwater abstraction, lower environmental discharge loads, and strengthen sustainability performance metrics. An integrated solution that combines selective metal recovery with water reclamation would therefore generate dual benefits: economic value recovery and enhanced water security.

Lotus Enviro Systems Pvt. Ltd., an NABL-accredited environmental laboratory with expertise in water quality characterization and industrial systems validation, proposes the development of an advanced electrochemical treatment platform for open-cast mine water. The proposed system is designed to selectively recover valuable heavy metals in high-purity form while

simultaneously reducing residual contaminant concentrations to levels suitable for potable-grade polishing through tertiary treatment and disinfection.

Electrochemical approaches offer several advantages over conventional chemical precipitation systems. By applying controlled electrical potentials across engineered electrode materials, dissolved metal ions can be selectively reduced, deposited, or concentrated, enabling recovery as metallic solids or purified compounds. This minimizes secondary sludge generation, enhances selectivity, and allows higher-value product streams compared to mixed hydroxide sludge. Furthermore, electrochemical systems can be modular, energy-efficient, and scalable to suit varying mine water volumes and compositions.

The proposed project aims to design, optimize, and validate a modular electrochemical recovery unit tailored to open-cast mine water conditions. The system will focus on:

1. Selective recovery of commercially valuable heavy metals such as copper and zinc from representative mine water matrices;
2. Reduction of toxic metal concentrations to near-potable limits;
3. Integration of downstream tertiary filtration and disinfection to produce reclaimed water suitable for industrial reuse or safe discharge;
4. Minimization of sludge generation and reduction of chemical dependency; and
5. Development of a scalable process model adaptable to diverse mining environments.

The project will progress from laboratory-scale proof-of-concept to pilot-scale validation under simulated or site-representative conditions. Key performance indicators will include percentage metal recovery, product purity, treated water quality compliance, energy consumption, operational cost per cubic meter treated, and comparative reduction in waste generation relative to conventional treatment systems.

Anticipated outcomes include:

- High-efficiency removal and recovery (>90%) of targeted heavy metals;
- Production of recoverable metal outputs with defined commercial value;
- Treated water meeting near-potable standards following tertiary polishing;
- Demonstrated reduction in sludge generation & lifecycle treatment costs;
- A validated modular system design suitable for field deployment in Indian mining operations.

The successful implementation of this technology would transform open-cast mine water from an environmental liability into a circular resource stream. By enabling simultaneous metal recovery and potable-quality water reclamation, the

project aligns with national priorities of sustainable industrialization, water security, and value-added resource utilization.

This initiative positions Lotus Enviro Systems Pvt. Ltd. at the forefront of industrial innovation by leveraging advanced electrochemical science to deliver economically viable, environmentally sustainable solutions for the Indian mining sector. The proposed system has strong potential for commercialization across mining regions nationwide and contributes toward building resilient, resource-efficient industrial ecosystems.