Waste to Wealth: Research-Driven pathway for Sustainable Resource Recovery

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Abstract—As global waste generation escalates and primary mineral reserves become increasingly depleted, the shift from conventional mining to urban mining has become critical for sustainable resource security. This presentation highlights recent advances in the "Waste to Wealth" research framework, which reimagines waste, not as an endpoint, but as a resource through innovative strategies combining bioremediation, nanotechnology, and circular economy principles.

Unlike conventional mining, which relies on large-scale excavation and generates significant environmental disturbance, urban mining leverages anthropogenic waste such as electronic devices, industrial effluents, and process residues as alternative sources of valuable metals. This approach reduces ecological impact, energy use, and carbon emissions while enhancing resource efficiency.

This presentation will describe some previous research which have been published in the past 5 years. Key innovations include bioremediation of acid mine drainage (AMD) using sulfate-reducing bacteria (94% metal removal), the development of low-cost adsorbents from agricultural and biomass waste for AMD remediation and selective recovery of rare earth elements (on-going). In parallel, microbial bioleaching systems have been optimized to extract base (copper and iron) and precious metals (gold and silver) up to 99% of recovery from electronic waste, offering a low-impact, scalable alternative to traditional smelting and chemical leaching processes.

Additional breakthroughs involve the use of agro-waste-derived functionalized bioadsorbents and green solvents to recover precious metals (gold, platinum, palladium) from printed circuit boards (PCBs), along with the synthesis of iron and silver-based nanomaterials for the removal of toxic hexavalent chromium from industrial wastewater (>95% removal). Iron nanoparticles have also been applied to enhance flotation performance in mineral processing, reducing chemical use while improving yield.

This body of research bridges the gap between laboratory innovation and real-world application, demonstrating the viability of urban mining as a cornerstone of sustainable resource recovery. Future directions emphasize cross-sector collaboration to implement these technologies at industrial scale, contributing to a resilient, low-waste, and carbon-conscious global economy.

Keywords— Waste To Wealth, Urban Mining, Sustainable Metal Recovery, Bioremediation, Circular Economy, Acid Mine Drainage, Bioleaching, Chromium Removal, Nanomaterials