RESEARCH BRIEF
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NAWI National Alliance for Water Innovation

Energy-efficient selective removal of metal ions from mining influenced waters (MIW) using H-bonded Organic-Inorganic Frameworks (HOIFs)

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Challenge

Acid mine drainage (AMD) waters are generated as a byproduct from mining operations. Typically, AMD waters contain substantial quantities of sulfates (SO_4^{2-}), commonly above 5,000 mg/L, with some AMD streams exhibiting up to 40,000 mg/L. High concentrations of metal(oid)s are also expected to be found in AMD waters (e.g., Al, Fe, Cu, Mg, Mn, Zn, Cd, Co, Ni, As, Se, Pb). It is estimated that approximately 20,000 to 50,000 operational and closed mines across the U.S. are discharging AMD water, impacting more than 10,000 miles of waterways and 180,000 acres of freshwater reservoirs.[1, 2]

Overwhelmingly, the standard method for treating AMD in the mining industry is the use of high-density sludge, in which neutralization proceeds via the addition of a base (e.g., lime), likely followed by membrane treatment (e.g., reverse osmosis) to remove residual total dissolved solids. While effective, this approach is often inefficient, cost-ineffective, energy-intensive, and non-selective. Furthermore, this approach does not recover valuable metals, such as copper, and instead pushes these constituents into a brine, which is costly to dispose of. A more targeted approach to selectively remove contaminants with the potential to reduce the energy intensity of the desalination treatment processes while reducing complexity and waste management costs is essential.

Research Approach

The main objective of this project is to validate an emerging class of adsorption materials, termed Hydrogen-Bonding Organic-Inorganic Frameworks (HOIFs), as an energy-efficient, scalable, and economically attractive alternative to traditional metal extraction routes in AMD. HOIFs have been shown to be a robust scavenger of copper,[3] but more research is needed before the benefit of these materials can be fully realized. As such, this project will further study the mechanism of copper-HOIFs adsorption and their regeneration pathways, the stability and functional durability of HOIFs for selective copper capture in extreme AMD environments, the scalability of HOIFs synthesis, and will explore the development of new HOIF chemistry for recovering other metal ions (Zn, Mn, Cd) that occur at higher concentration in AMD.

Impact

If successful, the HOIF technology will bring tremendous value into the treatment of non-conventional waters with reduced energy consumption, system complexity, and waste management costs while providing unmatched brine valorization and profit recovery. Furthermore, the precision separation and recovery of metals in AMD waters could expand the availability of critical materials and help alleviate the US dependency on metal supply chains.

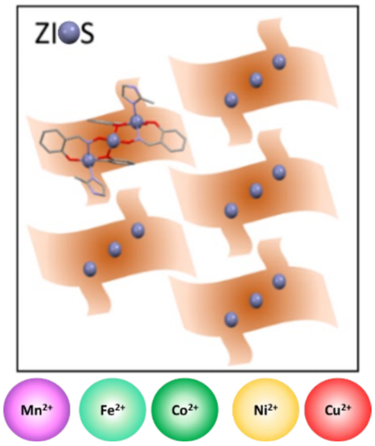

Figure 1. Schematic diagram of a ZIOS network created by periodic stacking of trinuclear units (top); Representative transition metals of study (base). Note that the true colors and sizes of these ions are not reflected in this figure.

RESEARCH PARTNERS

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