1. Title

WATER TREATMENT AND VALORIZATION OF MINE BYPRODUCTS IN THE WESTERN US

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3. Focal Area(s):

Water, in the form of both supply and waste, is a major liability for mining and mineral processing of critical materials. These are the critical materials that make next-generation energy technologies and essential national security systems. Reshoring mineral production to the US is occurring because of economic drivers and national security goals. Developing methods to better treat mine waste at the point of production and to track previously released waste (fate and transport) is a priority that will grow with domestic mining. Leaks and catastrophic failures of mine byproduct containment systems are a significant threat to our national aquifers and water supply. This threat is especially true for the water stressed and the agriculturally rich western United States where most mining has taken place in the past[1] and is expected to take place in the next few decades. Aimes to reduce the water-based externalities of mining also creates the opportunity to collect more primary and secondary minerals from the waste streams to pay for the cost of water treatment. A research program to serve the western United States by reducing the risks of “mine waters” and increase amount and breadth of mineral recovery would assist in facilitating a mining resurgence in the US.

4. Existing Challenge

Water contamination in the form of leaks and catastrophic failures is a hazard of mining and mineral processing. These are technical challenges with technological solutions. These solutions also have the potential to capture more of the primary and secondary minerals, valorizing the waste while reducing risk.

Examples of mine failures include the 100-year-old mine tailings of the Gold King mine in Colorado which flooded the Animas River 2015 (Figure 1). The California Mountain Pass Rare Earth Mine was closed in 2002 in part due to a leak of wastewater containing naturally occurring radioactive material (NORM) into the Mojave Desert[2] and in part from competition from China in the rare earth element market. Currently there is concern about water from the Pebble Mine copper mine impacting the salmon of Alaska's Bristol Bay[3]. The Martin County coal slurry spill in 2000 was 28

Figure 1. Animas River, CO 2015 waste from an abandoned Gold King mine (operated 1890-1920) which produced 9.9 metric tons of gold.

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times larger than the Exxon Valdez oil spill and included arsenic and mercury.[4] It killed entire rivers and contaminated the water supply for over 27,000 people. For many US mine tailings piles, such as phosphate tailings associated with the production of fertilizer, even after the mining is done there is no end-state at which point maintenance is not required. These are forever mortgages, a perverse legacy for future generations. However, all these legacy wastes contain valuable materials that could be accessed through an economic means of recovery.

Current domestic mining practices give only part of story because most critical minerals and non-critical minerals are produced internationally and shipped to the US as midstream feedstocks or finished products. Mining byproduct challenges at international mines are serious and importing the practices used at these mines will hinder mining in the US. Example of this international dependance and hazard include Vale's operation in Brazil which makes it the largest iron ore miner in the world, producing 33%, or 390 million metric tons, of iron ore on an annual basis. These Brazilian iron mines have had two major slurry pond failures in recent years, the Mariana dam disaster in 2015[5] and the Brumadinho dam disaster in 2019 (Figure 2)[6,7] together killing nearly 300 people and causing enormous amounts of property and environmental damage. Another example is the Democratic Republic of the Congo (DRC), the source of 84% of the world's Cobalt, is largely operating in an environmental, health, and safety vacuum with extensive pollution and hazard to human life.[8] Finally, Indonesia produces 40% of the global supply of Nickel (the largest global producer) has polluted their rivers and dumping mine wastewaters into the Ocean via deep-sea tailings disposal (DSTD), a practice used around the world.[9] Despite being overseas these are the US's current sources of minerals.

Figure 2. Brumadinho dam disaster, Brazil 2019, 270 deaths Córrego do Feijão iron ore mine, part of Vale's operation the largest iron ore miner in the world, producing 33%, or 390 million metric tons, of iron ore on an annual basis.

Effectively the US has externalized mining liabilities by offshoring essential mineral production to developing nations. While this approach in the near-term has ensured that commodity prices stay low, in the long-term it has created a national security risk by incurring a mineral dependence on other nation states. This risk has been actively exploited by China in recent years to help them dominate global mineral processing. Bringing mining back to the US, to achieve self-sufficiency in critical materials, means bringing back the risks and hazards currently experienced by international mining operations if traditional mining practices are employed.

5. Near-Term Opportunity

Tagert technologies must be developed and derisked that eliminate physically unstable waste forms (slurry storage to dry storage), partial chemical mobilization of toxic metals (better leaching and final waste form chemistry/mineralogy), and selective extraction of trace metal with significant toxicity and value. Making these treatments economically viable means valorization of these wastes through increased mineral recovery (avoiding partial mobilization without capture) and ensuring immobilization of anything returned to the environment or used as aggregate. This will involve pulling low levels of minerals from solutions and slurries then concentrating them to a solid salt, oxide, or reduced metal in a cost-effective manner. Addressing the mining and mineral processing risks at the point source we will be able to safely produce critical materials essential to the nation's next generation energy systems.

The mining industry, while large, invests less than 1% of its revenue into research and development[10], much lower than other industries[11]. This limited historic investment enhances the potential for disruptive change. The technology pipeline is not primed with early-stage work and advances in adjacent technologies can be transferred to mining. There is an opportunity for a federal sponsor to make a significant impact in the research space of “mine slurry and wastewater valorization” with a program comparable to historic Office of Energy Efficiency and Renewable Energy efforts. There is an especially strong need for investment in early stage applied technology given there are related higher TRL efforts supported by other DOE entities.

6. Success Measure

Success would be characterized by increased onshoring of mining activities in a way that minimizes local and regional environmental risk. This would be enabled by implementing deep tech that can treat quantifiable volumes of wastewater relative to quantities of critical materials produced and the associated economic and energy benefit. Not only the absolute quantity of critical material but the fraction produced domestically can be evaluated. This space would see the greatest return on investment to an early-stage (i.e. low TRL) investment as there is a very limited amount of early-stage mining technology research currently being supported.

7. References

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