Rare and Precious Part 3 -- from Abandoned Mines

By John Benson

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1. Introduction

This didn’t start out as a three part series. Finding Rare Earth and other critical elements is serious. We need these constituents for modern devices required to mitigate climate change, like electric vehicles (EVs), wind turbines and battery energy storage systems (BESS). I would have been really happy if I was able to create one good paper about this search. As it turned out, I wrote the original paper, which outlined this issue and discussed a conventional approach to finding these elements. Shortly thereafter a second source that used an advanced approach (artificial intelligence or AI) to perform the same task appeared. Shortly thereafter I found the information for this third post – a completely different approach as described in the title.

The first two “Rare and Precious” posts are described briefly above and linked below.

https://energycentral.com/c/rm/rare-and-precious


This post focuses on extracting important elements of the remnants of abandoned mines. In mines that were producing anywhere from a few decades to over a century ago, the miners were seeking one or two specific target elements. For example these might be silver and/or gold. Although these are still important, they completely ignored many elements that are really valuable now, but not so much then (like cobalt, lithium and many rare earths). These were left in the mine’s tailings, in the mine itself or in other nearby “waste” areas. And, they are still there.

This post is about extracting these rare and precious elements and also mitigating the risks posed by the old mines today. The income generated by selling these elements could help remediate the risk.

2. The Challenge

The development of environmentally friendly technologies (e.g., electric vehicles, wind turbines, solar panels, and lithium-ion batteries) to achieve a low-carbon future will require large quantities of critical minerals and metals. Mining and extraction of these materials are anticipated to generate substantially larger volumes of mine wastes, including waste rock and tailings. The release of contaminated water from mine wastes can cause long-term environmental damage and land degradation, posing challenges for pollution control and environmental remediation. Resource extraction from contaminated water, mine wastes, and mine workings (e.g., unexploited open pits and underground tunnels) at abandoned mines could potentially address the increased demands of critical minerals and metals for decarbonization. However, careful planning is required to ensure that negative environmental effects are not exacerbated during resource recovery at abandoned mines.

Mining activities can have long-term positive impacts by supplying valuable minerals and metals to advance economic development, energy transition, infrastructure construction, and technological innovation. However, mining has also caused environmental and societal harm. Vast quantities of potentially chemically reactive wastes are accumulated over large land footprints at mine sites. Globally, land that has been affected by mining amounts to 66,000 km², including waste-rock piles, tailings impoundments, and open pits as well as mining and processing infrastructure. Much of this mining-affected land includes abandoned mines, which are neither in operation nor managed. Mines are abandoned for a variety of reasons, including depletion of ores, commodity price fluctuations, and technical challenges associated with mining deeper ores. The global area of land use and contamination level at abandoned mines are unknown. Yet, there is a distinct contrast between the number of active mines and the much larger number of abandoned mines. For example, in Canada, there are ~200 active mines compared with more than 10,000 abandoned mines.

Each abandoned mine has distinct attributes, including the physicochemical and geotechnical characteristics of mine-waste deposits and mine voids. These characteristics strongly influence the impacts to land, water, and ecosystems, including releases of water contaminated with high concentrations of toxic metals and metalloids [e.g., acid mine drainage (AMD)] and releases of carbon dioxide (CO₂). Chronic releases of AMD and catastrophic failures of tailings dams lead to “dead zones” at mine sites, which exhibit biodiversity loss, land deterioration, and degraded surface water and groundwater and can be detrimental to human health. For instance, in 1999, an extremely low pH of −3.6 was reported in AMD from the Richmond Mine of the Iron Mountain copper deposit, USA, which was mined in the early 1900s. This AMD resulted in fish death and vegetation denudation. Additionally, release of dissolved contaminants and alteration of groundwater and surface water flow systems can harm aquatic ecosystems, such as effects on salmonids (ray-finned fish) and their habitat in northwestern North America as a result of tailings dam failures, such as that at Mount Polley Mine, Canada, in 2014.

Although the stored mass of mine wastes is uncertain, an estimated global mass of tailings totals 223 billion metric tons generated from 1771 to 2019, whereas the total mass of waste rock is estimated to be about 10 times that of the mass of tailings. Exposure of sulfide-bearing mine wastes to water and oxygen triggers complex microbial-catalyzed biogeochemical reactions that generate acidic, neutral, and saline mine drainage. Mine wastes prone to AMD frequently cause the most severe water quality problems that persist for thousands of years, and thus AMD has been the focus of intense research and environmental remediation. However, neutral and saline mine drainage also have the potential to cause environmental degradation. Selective mining, segregation and encapsulation, subaqueous disposal, lime or limestone addition, cover construction to limit water infiltration or oxygen ingress, and passive techniques (including constructed wetlands, bioreactors, and permeable reactive barriers) have been widely applied to facilitate AMD mitigation either at the source or along the migration pathway. Typically, a combination of these techniques is implemented…
3. **Potential Solution**

Supplies from active mines cannot currently meet the increased demands for critical minerals and metals for decarbonization measures. Individual mines are operated to recover targeted commodities, which are determined by the economics of mining, processing, and global availability. Mine wastes at abandoned mines may contain recoverable concentrations of rare earth elements (REEs), platinum group elements, and metals—e.g., cobalt, copper, lithium, and nickel—that are more accessible than the low-grade ores that are currently mined. Many of these elements are indispensable in technology development to achieve carbon-zero goals. Therefore, AMD, mine wastes, and mine workings at abandoned mines are being evaluated as potential sources for these critical minerals and metals. Integration of resource exploration and recovery with environmental remediation provides a promising opportunity to gain value from mine wastes while tackling the environmental challenges associated with abandoned mines.

Assessing the resource potential of critical minerals and metals in AMD, mine wastes, and mine workings at abandoned mines is the first step. Abandoned mines are often located in remote locations with sensitive environments. Appropriate remediation designs, characterization studies, and monitoring programs are needed to assess the spatial distribution, bioavailability, and migration pathways of contaminants. Many national inventories of abandoned mines with different risk categories and national registries have been established. For example, national mine-waste registries in France, Hungary, Italy, Portugal, Slovenia, Spain, and the UK were created with basic information that can be used for evaluating potential resource recovery. Resource potentials of other critical minerals and metals (particularly REEs) in mine wastes should be jointly assessed in conjunction with site-specific characterization and monitoring programs to enhance knowledge of the behavior of critical minerals and metals as well as their geochemical interactions. These efforts will complement the knowledge gap in national mine-waste registries and facilitate decision-making to shift abandoned mines from a source of pollution to a resource for mineral recovery.

**Resource recovery and environmental remediation at abandoned mines:**

Minerals and metals that are in high demand could be recovered from abandoned mine wastes (tailings and waste rock) through heap leaching, which could also mitigate environmental contamination. Combining this approach with environmental remediation of any residual mine waste, such as with multilayer vegetated soil covers (including a geosynthetic clay liner (GCL)), could achieve long-term mitigation of the impacts of abandoned mines. However, potential pollution from heap leaching should also be addressed.
Advances in exploration and recovery techniques of critical minerals and metals from different waste streams are promising. In Europe, underwater robots, although still at the prototype stage, were successfully demonstrated for exploration of critical minerals and metals at flooded abandoned mines without dewatering costs and groundwater impacts. Traditional AMD treatment through neutralization using lime or limestone generates large quantities of sludges that are rich in iron oxyhydroxides, REEs, and other valuable minerals. High-grade aluminum, REEs, cobalt, and manganese were recovered from sludges during AMD treatment using neutralization reagents through a three-staged, pH-dependent precipitation and crystallization process.

REE = Rare Earth Elements

Heap leaching is a method for economical recovery from low-grade ores for the extraction of, for example, copper, gold, and uranium. This method requires the application of leaching solutions (such as sodium cyanide for gold) through ore-bearing heap pads. Leaching solutions dissolve targeted minerals and metals into pregnant leach solution ponds and are subsequently recovered; the barren solutions can then be mixed with fresh reagents and recirculated into the heap-leaching pads. Given that mine wastes might have higher amounts of critical minerals and metals compared with the low-grade ores that are currently mined, heap leaching could function as a feasible technique for resource recovery at abandoned mines. A combination of resource recovery through heap leaching with implementation of environmental remediation (e.g., a multilayer vegetated soil cover) may serve as a potentially sustainable solution for mine-waste management and pollution control (see the above figure).

Caution is needed to prevent the introduction of new environmental pollution and harm during resource recovery from mine wastes. For instance, a drainage protection layer should be implemented to prevent the infiltration of leach solutions into underlying soils and groundwater to avoid the long-term retention of hazardous materials in the subsurface. Residual solid wastes after heap leaching need further characterization for proper disposal through environmental remediation. Notably, industrial applications of heap leaching are mostly used for the recovery of copper, gold, and uranium from low-grade ores, whereas heap leaching for resource recovery from mine wastes is still under development. Further research is needed to evaluate the potential impacts of the commercialization of these exploration and recovery techniques through thorough monitoring and evaluation programs in laboratory-, pilot-, and industrial-scale applications and to make the extraction of critical minerals and metals from these waste streams environmentally friendly, socially acceptable, and economically feasible.