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Long-term water protection drives water treatment strategies for mine closings

Countries with major mining industries have begun calling for responsible, long-term mine closure plans to protect water resources. Hu Fleming of the Aquarion Group Advisory Board discusses considerations in developing closure strategies and technology solutions for treating mine wastewater.

The mining sector, including industry focused on oil and gas extraction, collectively represents one of the largest global industries. Over the past decade, growth in mining has been extensive, with capital spending rising at an annual rate of at least 15 percent. Even with the current global slowdown in mining, the industry's tier-one companies are all still spending in excess of US$5 billion annually in operating costs and more than $2 billion in capital costs. This market is projected to expand well into the next decade, given the fundamental shortage of metals and related natural materials, and taking into account global expansion and population growth.

Mining activities can be categorized by distinct phases of the mine life cycle, which include exploration, planning and construction, production, and closure. Historically, the closure stage of this cycle has been largely ignored and not well planned. But in recent years, greater global awareness of the potential environmental and water-quality risks associated with abandoned mining operations has elevated the importance of mine closure activities, which are being increasingly recognized as a critical component of responsible mining practices.

Several countries with abundant mining activities are embracing this responsibility. Canada is a leader in this regard, requiring 50 years of continuous management following mine closure. The same applies for mines operating in the United States. Remediation and management of formerly used mines has become such a sensitive issue that many US states have passed legislation requiring mine owners to clean up existing mines prior to permitting any new mining ventures. Similar legislation exists in Peru, Chile, Australia, and many other mining regions of the world.

Australia and Chile require 20 years of post-operational management following mine closure. And other countries that have not yet adopted or enforced consistent mine closure management policies, such as South Africa, are now beginning to call for change.

Virtually all mines across the globe are now required to develop closure plans in order to access mining permits or modify existing permits. Such closure plans are an expensive prerequisite that can represent a significant portion of the total cost of a mine project. Additionally, new international accounting practice standards require that mine closure costs must now be accrued on current balance sheets. Based on these mandates, closure costs and closure activities have become paramount in mining strategy and management.

Within the context of post-mining monitoring and remediation, water management is a central issue, driven in large part by heightened concern regarding global water scarcity and the need to protect water resources. Indeed, the International Council on Mining and Metals (ICMM) has identified improvement in the industry's water management performance as a high priority, highlighting the need for mining companies to implement responsible water management practices that ensure their positive contribution to sustainable development over the long term.

Developing effective water treatment strategies that prevent water contamination and minimize impacts to water resources therefore plays a vital role within the scope and planning of mine closure programs. Based on this outlook, requirements for long-term water monitoring and treatment of closed mines are anticipated to increase demand for specialized services, technical innovation, and advanced water management solutions within this industry.

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An aerial view of the evaporation pond and water treatment facilities at an open pit copper mine
Photo by B Brown, Shutterstock

Challenges and considerations for successful mine closure management

Mining operations present a range of complex and unique water management challenges. Logistically, mines are often located in severe or remote regions of the world and can include climates ranging from freezing to hot and from very wet to extremely dry. Conditions can also feature acute variations in local weather patterns, resulting in extreme temperature and precipitation swings.

In wet environments and water-positive regions – where challenges are characteristically more demanding and typically driven by a continuous need – wastewater generated from rainfall or underground seepage can include volumes approaching millions of liters per day, necessitating the use of operator-based systems and more labor-intensive technologies, including the physical and chemical treatment of produced sludge.

In contrast, drier countries tend to produce mine wastewater that is smaller in scale, such as water collected in seepage wells over a period of time, and this water may only require intermittent treatment. In these cases, automated and simpler technologies requiring lower maintenance and a part-time operational capacity are preferred.

In approaching closure management of individual mine sites, it's important to note that the overarching water management strategy will most likely require treatment at multiple points, representing a vastly different methodology from point source control. This strategy can include the need to address water quality issues in tailing ponds, waste truck dumps, or at collection sites for rainwater run-off.

While conditions can vary significantly from site to site, mining companies and treatment providers can generally expect to encounter high salt discharge at every mining operation. Acidic wastewaters are also very frequent, whether they stem from acid rock drainage (ARD) – which can persist for a long time period following closure – or are a result of acidic extraction processes. Additionally, ARD and sulfate extraction processes can lead to sulfate contamination, which is another common issue. Further areas to address can include waste streams with concentrations of cyanide, arsenic, selenium, phosphates and various metals, depending upon the specific mining operation.

Another important consideration for successful mine closure involves the technical risk management aspects of engineering treatment strategies, which need to be evaluated with a long-term perspective in mind. The significant risks associated with potential system failures and water contamination play a highly influential role in terms of technology and operational decisions. Failures can bring devastating consequences that can result in significant reputational damage or lead to tremendous costs, which can potentially be much higher than the cost of treatment itself. For these reasons, miners have a large investment in the success of a long-term treatment system.

Mine closure technology solutions

A number of key factors should help guide decisions about which specific treatment technologies are the most appropriate to implement for successful mine closure management.

Considering the remoteness of many mine locations, it is imperative that treatment systems and supporting equipment are reliable, robust, and capable of performing in extreme environments and harsh conditions. Technologies should be efficient at treating inorganic contaminants including metals, acids, and salts at high concentrations.

Dependent on the mining operation and the predominant circumstances, it is not uncommon for mining wastewaters to exhibit dramatic volume fluctuations and pH changes driven by rainfall and groundwater releases. For this reason, solutions must be designed to manage highly variable waste streams.

Because the potential exists for significant multiplication of risk in the event of a failure, technologies should also be engineered to operate over long durations with minimal downtime. Based on this requirement, membrane-based treatment and ion exchange are leading options for implementation. Contingent on local factors, distillation and absorption are additional technologies that warrant consideration. However, in the same regard, biological treatment processes present a risky option due to requirements for ongoing maintenance and the relatively higher chance of system failure.

Since mine wastewaters are characteristically variable and dynamic in nature, technology solutions should not be designed through the use of standardized treatment methods. Conversely, solutions need to be flexible and customized to handle the particular volume requirements and water quality issues apparent for each distinct mining application. Solutions should also be streamlined and easily transportable to accommodate the remoteness of many mining sites.

The Aquarion Group and mine management solutions

The Aquarion Group is a leading provider of advanced water treatment systems, solutions, and technologies for the oil and gas industry, energy sector, and other process industries. The group specializes in addressing water quality issues in mining applications and designing advanced and sustainable water treatment technologies and systems provided by its group companies in many different regions throughout the world.

A key advantage of Aquarion Group's solution platform includes the capacity to design, build, and operate customized, field-deployable and packaged treatment units that are engineered for durability and treating the most challenging and problematic mining waste streams in extreme climates across the globe.

Among its capabilities are advanced recycling solutions for mine closure treatment that offer much faster amortizations compared to other systems. These closure solutions work to both recover raw materials from waste streams and treat mining process waters and wastewaters to extremely high purity levels, including and up to drinking water quality.

One such recycling solution that could be used in mine closure management includes the ZLD.eco2, a Zero Liquid Discharge system developed by Hager + Elsässer, an Aquarion Group company based in Germany, that uses a series of innovative filtration and separation technologies to reduce the subsequent evaporation of residual waste products to a minimum and lower energy requirements. The modular system is based on a new high-pressure reverse osmosis stage that uses Circular Disc (CD) module technology developed by Membran-Filtrations-Technik (MFT), another Aquarion Group company.

Historically, the closure stage of this cycle has been largely ignored and not well planned.

ZLD.eco2 includes a pre-treatment process, which can either be chemical-physical or biological depending on the user's needs, and an ultrafiltration stage to filter out residual organic material, followed by multi-stage membrane technology designed to concentrate non-organic waste material more densely. Compared with conventional systems without pre-concentration, ZLD.eco2 requires about 20 percent less energy, and since the evaporation system is smaller, less cooling energy is needed for the condensation process. These combined savings can amount to as much as 80 percent. Further energy savings are realized through the use of heat exchanger systems, which work to recover thermal energy and feed it back into the system for reuse, increasing energy efficiency.

In summary, mining companies and treatment providers can deliver effective solutions to complex water quality issues associated with mine closure operations by employing robust systems and advanced technologies that are designed for performance in severe environments and engineered to handle challenging waste streams containing metals, salts, and other difficult-to-treat contaminants.

Author's Note

Hubert (Hu) Fleming, a member of the Aquarion Group Advisory Board, is a respected senior executive in the global water infrastructure space and has a background in the technical arena as well as in financial management. Prior to forming his own management consultancy, he was president of Severn Trent Services, global director at Hatch, and chairman of CeramHyd SA. He can be reached at hufleming@msn.com

Above: Mine closure surface water impoundment
Photo by Aquarion