Use of evaporation ponds in the mining industry. How necessary and effective is this in various parts of the world

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Abstract

Water resources and their sustainability are increasingly under threat in several parts of the world due to scarcity and to the added complication of climate change. The preservation and optimal use of water should therefore be made a priority across all domestic, industrial, and commercial sectors and countries to avoid shortages and potential future conflicts. In this context, funding for development and/or closure of mining projects, which often have an impact on water resources, are increasingly dependent on Environmental Social and Governance (ESG) principles to encourage companies to act responsibly.

The rapid growth of ESG investment funds in recent years is revolutionising current water use and environmental regulations worldwide, and mining companies may encounter constraints on mine water management practices that are perceived as counter to the principle of preservation of water resources. In this context, to pre-empt further changes in water use regulation, a question arises regarding the use of evaporation ponds as a water management tool at mine sites - Are evaporation ponds an appropriate strategy for managing excess water at mine sites, or do evaporation ponds waste water and should alternative strategies or technologies be considered?

This paper examines the use of evaporation ponds in mining projects from the following perspectives:

- The various contexts in which evaporation ponds are utilized.
- Current regulations and permitting of evaporation ponds in various parts of the world.
- Potential environmental and social effects of evaporation ponds and related studies.
- Potential alternatives to evaporation ponds considering their effects, technical feasibility, and cost.

Keywords: Water resources, climate change, ESG, evaporation pond, Mine Water Management

Contexts in which evaporation ponds are utilized in mining

Evaporation ponds in the mining industry are employed at mine sites around the world for disposing of excess or unusable water, i.e., water not needed nor suitable for other activities at the mine site. This water cannot be easily separated from the dissolved constituents and can range from salt water to a solution containing metals, minerals, organic and/or inorganic compounds, and micro-organisms. Evaporation ponds are primarily used at mine sites for two purposes:

1. Mineral extraction/processing, and
2. Management of mine water.

A common characteristic of both applications is that the influent (source water) is of insufficient quality to be used by people, animals, or plants.

Other uses of evaporation ponds include disposal of poor-quality surface water runoff, storage of excess water used by the mine facilities or processes, or management of low-flow draindown solutions in closure.

Mineral extraction/ processing

Most evaporation ponds in the mining industry are used to evapo-concentrate mineral rich brines as a key step in the processing and recovery of minerals or metals. Lithium, Potash (Potassium Chloride) and sea salt are products mined in this manner. An example operation would be the Sociedad Química y Minera (SQM) site on the Salar de Atacama in Chile. In this process, mineral enriched groundwater is pumped from the halite crust on the salar and placed in a succession of lined evaporation ponds to concentrate the brine through passive evaporation. Salts from the brine are left to precipitate on the bottom of the pond where they are harvested using excavators. The first product is sodium chloride with the supernatant transferred to a sylvinite pond, then carnalite pond and finally a pond designed to maximise the concentration of lithium chloride.

Management of mine water

Mine water at a mining operation can be generated from several sources including 1) excess water from mine dewatering, 2) acid mine drainage from underground workings, tailings piles, or low pH native soils from disturbed areas, 3) residual effluent from the mine process circuit, and 4) sewage treatment plant effluent. Natural evaporation of mine water containing metals, minerals, etc. can reduce cost while safely storing contaminants in lined facilities. Use of evaporation ponds to dispose of mine dewatering water may have the most potential for alternatives to be considered due to the typically high volumes of water and large areas of land required for this use.

In-situ mining

In-situ mining is another sector of mining industry that utilizes evaporation ponds. Salt, Potash, Uranium and Copper are commodities extracted by In-situ mining. In this process, a wellfield is established within the orebody and water with reagents (lixiviant) is circulated through the orebody to leach metals or dissolve minerals. For Salt and Potash mining the ponds are used for mineral extraction; for Uranium and Copper mining the ponds are used to concentrate the spent liquid effluent from the plant or to concentrate effluent from groundwater restoration activities.

Other uses

Runoff from mine impacted soils can be diverted and collected in evaporation ponds as a source control measure to minimize effluent of contaminated surface water off site.

In mine closure, draindown of process solutions in heap leach pads and tailings impoundments will decrease exponentially until a stable flow is achieved. These low-flows can be managed in an Evaporation Cell (E-Cell). An E-Cell utilizes a matrix of soil, rock or engineered material that can store low volumes of drain down with evaporation from the soil surface.

Considerations & Limitations

Some considerations and limitations on use of evaporation ponds include the following.

- They require an arid to semi-arid climate where annual evaporation considerably exceeds annual precipitation. Their application in some parts of the world is therefore limited.
- They can require a large land footprint for adequate water disposal and are not suited for mine sites with limited land positions. As influent flow rates increase, more land is required to increase the surface area of the ponds to increase evaporation volumes.
- For passive management of excess water in mine closure, evaporation ponds or E-Cells are limited to low flow systems.
- In mine water reduction applications, precipitates and/or sediment need to be regularly removed from the pond to maintain design capacity.
- Due to the slow rate of the evaporation process, they are not suited for situations in which a rapid inventory reduction is required.
- If the mine process does not optimize the recycling and reuse of process

water, evaporation ponds could result in a permanent loss of water that might otherwise be re-used in the mine circuit.

Current regulations and permitting of evaporation ponds

The regulations and permitting that govern evaporation ponds as part of mining operations extend over multiple areas (environmental, water, land use, industrial safety) in most jurisdictions. Use of these facilities as part of mining operations or on its own can have effects and present risks to receptors such as land, water, air, wildlife, and the socioeconomics, health and safety of the nearby communities as described in the next section. Thus, most of the regulations and permitting requirements are aimed to avoid the negative effects and risks of evaporation ponds to the named receptors. A brief overview of the Australian, Chilean, Kazakh, and the United States' regulations and permitting related to evaporation ponds in mining is provided below.

Australia

In Australia, environmental regulations are primarily governed by state and territory laws, while the federal government also oversees matters related to the environment and climate change. The Environment Protection and Biodiversity Conservation Act 1999 (Cth) manages developments that may significantly impact "matters of national environmental significance" through an additional approval process. For instance, a proposed project that could severely affect a nationally listed threatened species or ecological community necessitates approval from the federal government, as well as state or territory-level approvals.

Significant developments, such as mining projects, must undergo an environmental impact assessment to ascertain whether they will have a "major" impact on the environment and, if so, under what conditions they may proceed. Potential effects on the social environment, including communities and First Peoples, are relevant considerations, in addition to the effects on landscape, flora, and fauna. The legislation promotes in order of priority application of the following water management strategies for mines, with only strategies 6 to 8 applicable to the evaporation ponds:

1. Avoidance,
2. Reduction,
3. Reuse,
4. Recycling,
5. Recovery of energy,
6. Treatment,
7. Containment,
8. Disposal

Environmental laws take precedence over all mining rights. Mining projects are required to undergo environmental assessment and obtain necessary environmental approvals before proceeding. In recent times, both state and federal governments have increasingly introduced intricate legislation, policies, and mechanisms, along with heightened penalties, to regulate industries and activities with the potential to negatively impact the environment. This may affect the favourableness of the use of evaporation ponds as the legislation evolves. Currently, evaporation ponds are a suitable means of managing excess water if no alternative method is available or cost-effective.

Chile

In Chile, the principal authorization required to operate an evaporation pond as part of a mine is the environmental permit, also known as the Environmental Qualification Resolution (EQR). The EQR follows an environmental assessment (EA) process, the environmental authority grants this permit. The EA process involves the participation of all public entities with environmental competence in a centralized manner, and if applicable, citizen participation processes and indigenous consultations are conducted. The National Environmental Assessment Service (NEAS) oversees this process.

The Chilean government is soon to announce a policy aimed at development of new mineral deposits. As part of this policy, lithium projects specifically, will be required to use a more targeted or precise process that will lead to significantly lower evaporation levels. Major Chilean lithium producers are exploring these methods, which have not been widely tested in commercial settings. The Chilean government supports the direct lithium extraction (DLE) process, where the brine is reinjected back after the extraction of lithium. This would result in lesser environmental effects on the groundwater system and a reduction of land disturbance for evaporation ponds.

Thus, traditional passive evaporation is considered less favourable than other more selective or direct processing techniques. If the new policy in Chile is approved, it is unlikely that NEAS will grant an EQR to use evaporation ponds to extract lithium, possibly prohibiting use of traditional evaporation ponds in the future.

Kazakhstan

The main legal act in Kazakhstan that governs the design and permitting of evaporation ponds is the Environmental Code. It requires that the selection and substantiation of water treatment technologies prior to the commissioning of an evaporation pond must be part of the environmental impact assessment process.

The majority of the evaporation ponds in Kazakhstan are used to manage excess water from the dewatering of mine workings. While some of the pumped water is non-contact "clean" water, in many cases the chemical composition of the pumped groundwater (including mineralization) does not allow for direct discharge into the environment without prior treatment which is expensive due to the required methods and volumes. Notably, while the use of evaporation ponds is legally possible, the Environmental Code treats them as a "last resort" in the hierarchy of water management techniques and is permitted when no other option is possible. The use of this "last resort" option must be justified during the environmental impact assessment process.

United States

In the U.S., the Clean Water Act (CWA) as amended in 1972, establishes the basic structure for regulating discharges of pollutants into waters of the United States. The Environmental Protection Agency (EPA) administers the requirements of the CWA through the National Pollutant Discharge Elimination System (NPDES), making it unlawful to discharge any pollutant from a point source to waters of the U.S. Specific regulations governing mining operations are promulgated by each state based on the requirements of the NPDES program and other federal or state statutes.

Mining projects must go through an Environmental Impact Statement (EIS) process that documents baseline studies, proposed effects of mining, mitigation measures and alternatives. Public comments regarding the use of evaporation ponds may require additional studies or documentation to demonstrate the use of evaporation pond is an appropriate strategy.

Potential environmental and social effects of evaporation ponds

Potential Risks on Water Resources

There are two mechanisms that could lead to negative effects of evaporation ponds on water resources, as follows:

- Breach of the evaporation pond embankment, which could occur due to (1) physical instability of the embankment, 2) internal erosion through the embankment, and 3) overtopping from within the pond.
- Seepage and infiltration of contaminated water through the embankment and/or within the pond footprint.

The first mechanism results in failure of the dam and downstream consequences to the environment and potential loss of life. For the second mechanism, which consists of seepage of contaminated water through the pond embankment and/or footprint, impact on water resources can occur if a contaminant source-pathway-receptor system is present, as illustrated in Figure 1.

The Source is the evaporation pond, the Pathway is a (lateral or vertical) preferential flow path via porous medium or fracture network that connects the source to an underlying aquifer or surface water body. The presence of each of the three elements should therefore be demonstrated as part of risk assessment, before potential effects on water resources or users can be envisaged.

Potential Environmental and Social Risks

Depending on site setting, common social and environmental effects that may occur

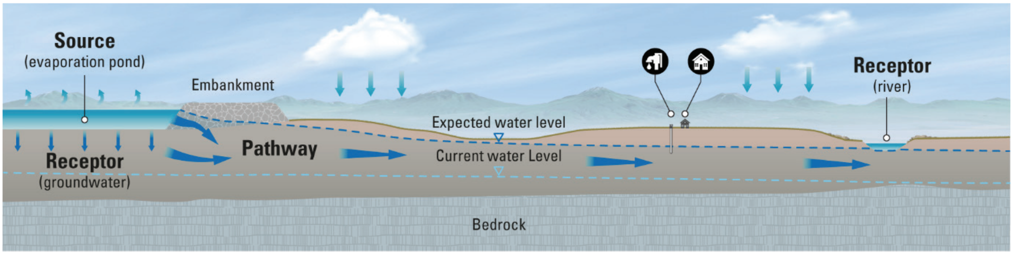

***Figure 1** Illustration of contaminant source-pathway-receptor concept*

because of discharge of excess water into an evaporation pond can be summarised as follows:

- Impact and possibly destruction of protected or sensitive flora and fauna species
- Social impact (water users and stakeholders) due to Contamination of water sources

Potential Geotechnical and Stability Risks

Key common geotechnical risks of evaporations ponds could be summarised as follows:

- The risk of overtopping the facility exists if strict operational limits are not specified and maintained during the operational life of the facility. If foundation materials are collapsible, seepage underneath the embankment may lead to excessive settlement
- Weak foundation material may lead to global embankment instability leading to total or partial collapse of the embankment and potential release of ponded water
- Excessive seepage through the foundation and embankment, due to high exit hydraulic gradient for example, may lead to piping failure in the foundation materials.

Potential alternatives to evaporation ponds

Passive evaporation has the obvious advantage of needing little or no energy beyond that produced by the sun to facilitate water removal from enriched brines or mine water. Per the limitations discussed earlier in this paper, operators in non-arid climates for example, must resort to using alternative methods for the treatment and removal of excess water from the mine. These alternative methods are technologically more sophisticated than evaporation ponds.

Mechanical evaporation using various technologies is an increasingly common approach deployed on mine sites. This includes spraying and atomising water in the atmosphere (using mist canons) to increase the evaporative surface area thereby greatly accelerating the evaporation process. The utility of mechanical evaporation depends on local climatic conditions but has the advantage of being modular and portable and provides flexibility for use at mine sites. Limitations of this technology include potential drift of atomised water droplets containing salts or metal compounds being deposited outside of lined containment.

The other form of actively promoted evaporation technology is the thermal brine concentrator and crystallisation plant. Unlike mechanical evaporation, this technology is a substantial and fixed piece of infrastructure that is frequently an extension of the mine process circuit. It is also a more costly method, both in terms of initial capital outlay and operational costs. However, it achieves a high clean water recovery rate and is uniquely suited for removing high salt levels (TDS > 50g/L) with a solid waste product that is easy to package and remove from site.

At lower TDS, operations tend to use Reverse Osmosis (RO) or exotic variants of it such as High Efficiency RO and Osmotically Assisted RO to remove excess water. These also produce clean water, but the liquid brine discard (waste) still needs to be disposed of, which means there are additional costs implications.

Another alternative to the evaporation pond is the injection well, which has been used by some mining operations to dispose of highly saline water into ground. The viability of the approach is very dependent on there being favourable hydrogeological conditions near to the mine site, i.e., a deep disposal location with high permeability and storage, isolated from the surface by a naturally impermeable capping layer. This method has a lower capital and operating cost than the other alternatives and needs no water treatment. However, it does require a high degree of maintenance, is logistically complex and faces challenges as far as environmental compliance is concerned. These and the absence of favourable ground conditions means that removal of surplus water using injection wells is not a common practice in the mining sector.

Furthermore, in some cases, depending on the level of contamination, the hydrogeological setting and local regulation, use (creation) of wetlands to discharge mine water, especially from dewatering, can be envisaged.

Conclusions

Use of evaporation ponds in the mining industry is a low-cost, effective method for concentrating mineral rich brines and/or to reduce mine water volumes in dry- to semi-dry climates. Regulations governing use of evaporation ponds are increasingly focused on prudent use of water resources, which parallels the growth of ESG investment funds and interest in adhering to ESG principles. In this sense, water loss in mining projects due to engineered evaporation may not be considered an ideal outcome in a water scarce environment if that water could have been reused. This paper has highlighted some alternative technologies such as thermal brine concentrators and RO that do conserve water, but which by comparison, are costly processes that may not be economically viable for some marginal operations. Due to the high relative impacts of evaporation ponds as a strategy to dispose of mine dewatering water, they may face tighter scrutiny in this application by regulators looking to preserve water resources.

To answer the question posited in this paper whether evaporation ponds are an appropriate strategy for managing excess water at mine sites, the answer is – they are where climatic conditions are favourable, land is plentiful, and the reuse and recycling of the impacted water is optimized as part of processing and infrastructure engineering. If it cannot be shown that reuse and recycling have been optimized, in line with responsible water stewardship practices, and that there is an over-reliance on fresh surface and groundwater sources to make up the shortfall, then it becomes increasingly difficult to make the case for evaporation as a sustainable strategy.

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