TACKLING WATER MANAGEMENT IN MINING

Water is essential for any mining activity, but the industry faces many challenges in the management of this precious resource. Yamuna Balasubramaniam and Ashit Panda look at strategies the industry can adopt to effectively manage water in its operations.

The mining industry plays a major role in the country’s economy, but it faces a number of water management challenges. Water is essential for any mining activity, with the quantity and quality needed depending on the exact nature of the mining activity and the associated process – for example, the water quality can vary from treated sewage to seawater.

Mining water use is for the extraction of minerals that may be in the form of solids such as coal, iron, sand and gravel; liquids such as crude petroleum; and gases such as natural gas. Processes include quarrying, milling (crushing, screening, washing, and flotation of mined materials), re-injecting extracted water for secondary oil recovery, and other operations associated with mining activities.

Australia is a land of contrasts: 80 per cent of the continent receives less than 500mm rain annually, while some areas can receive almost 500mm of rain in a day. This means it is critical for miners to work with government and communities to ensure sustainable water use and protection of the environment, in collaboration with regulators, NGOs and investors.

A coherent approach should aim at managing water for both drought and flood situations; using “lower quality” water sources not used by other sectors, such as sewage effluent, seawater, poor quality groundwater or recycled mining withdrawals; demonstrating good water stewardship by implementing accurate, consistent and transparent water accounting frameworks; and understanding environmental impacts and community concerns and cumulative impact assessment.

A determination of water withdrawals that are put to beneficial use in mining operations can be difficult, especially when dewatering is necessary for extraction of the mineral. Water produced from dewatering varies in quality, from fresh to saline, and is generally disposed of through surface discharge, ponding or re-injection. Some of the less mineralised water may be reused for irrigation or livestock.

This article focuses on understanding what water means to the mining industry, how much is used during production, the effects of industrial water use on the surroundings, and water treatment processes for consumption and disposal. Water is being recognised as a strategic resource for the mining industry and increasing demand has pushed the industry to look for non-traditional and alternative water supplies. Seawater desalination and untreated seawater use, or domestic and industrial effluent reuse, are some of the solutions adopted by different mining projects to adapt to this new scenario.

The increasing cost of water has also obliged the mining industry to be more efficient in its use, reducing losses and recycling as much as possible. This requires the development of sound and reliable water balances. The impact of mining activities and of mine waste deposits on water quality in the area surrounding the mining project is another important concern for the mining industry.
A BRIEF OVERVIEW OF WATER USE IN MINING

Water is a vital natural resource and changes in its availability impact on the environment, the economy and society. Water availability is now a limiting factor on development in Australia. Mining is a large water user and consequently faces a number of water management challenges.

Mining in one form or another has existed since ancient times. The modern industry has evolved by incorporating gradual improvements into common practice. Mining fundamentally involves the removal of ore from the ground. This can be done by removing the ground surface to expose the ore or by digging under the surface.

The mining industry is classified as follows, based on the operations: coal mining; oil and gas extraction; metal ore mining; other mining; and services to mining. The services-to-mining industry accounts for a very small proportion of water use and is incorporated into the ‘other mining’ subdivision along with constructional metal mining and mining exploration.

Mining water use includes water used for the extraction and on-site processing of naturally occurring minerals including coal, ores, petroleum and natural gas. Basically, minerals are broken up in the earth and transported to the surface where they are crushed, ground and separated from the host rock material. They are then sent for smelting and refining, both of which are considered to be industrial uses.

Water returned to the environment after contact with mining or processing activities has a potential environmental and social impact because its quality may have been altered. Mining affects availability of freshwater through heavy use of water in processing ore, and water quality through water pollution from discharged mine effluent and seepage from tailings and waste rock impoundments. Mining, by its nature, consumes, diverts and can pollute water resources. Technology improvements and innovation in the water supply industry will assist in meeting future water demands.

INTERACTION OF MINES WITH WATER SYSTEMS

Most of the water used at a mine site is used in grinding and separating, but significant variations can occur depending on whether the mine is: (1) hard rock, sulfur, coal, sand and gravel, petroleum, or natural gas; (2) underground extraction, solution, open pit, or dredging; (3) in a dry or humid climate with a corresponding low or high water table; and (4) in a situation where the mine must generate its own power, particularly steam. Water may be recycled many times within the mine site, or excess water may be constantly discharged from the site.

Most water used in the mining industry is from self-extracted sources. Water is often obtained from mine dewatering, which occurs when water is collected through the process of mining and mineral extraction, or rainfall, runoff and water infiltration, and is later discharged. Mine dewatering is considered to be a self-extracted water source for the mining industry in the National Water Accounts. Produced formation water occurs naturally in oil and gas reservoirs. This is often extracted along with oil or gas in the production process. The water is separated from the oil or gas, treated and discharged.

Dewatering of the mine site, when water is discharged without being used in the production process, is considered to be in-stream use. If the workings are below the water table, the water table has to be lowered by removing groundwater to enable ore extraction. Rainfall or surface runoff that collects in the workings must be removed for the same reason.

Mining water requirements are complicated by seasonal climatic variability, as most mines need a steady and reliable supply of water. In periods of drought, local runoff will be small and supplies of water from rivers or aquifers may be restricted. Self-extracted water volumes and quality may vary with the location and depth of the workings, and water recycled from on-site processing may be of poor quality. Water use by mining facilities will vary depending on the size and type of mining operation.

The main operational phases in a mining operation life cycle with its associated water issues are depicted in Figure 1:

![Figure 1. Mining operation life cycle.](image)

TYPICAL WATER REQUIREMENTS IN MINING

Water and energy are directly or indirectly related in the mining industry; the connection is mainly through pumping power to transfer the water or aqueous slurries of mineral products to another location. The water cycle in mining is complex and needs to align with the entire mine life cycle. Most mines both consume and produce water, which often must either be imported for operating purposes from locations remote from the mine, or transferred as surplus mine water from within the mine to a treatment and/or discharge location.

Water use in mining operations can be divided into three categories: mining, processing and mineral conveyance. In most types of mining relatively little water is used in actual ore production. A notable exception is underground coal mining, where water is used as one of several measures to reduce the hazard of fires or explosions. Many mined minerals are partially processed in the immediate vicinity of the mine site. The particle size of run-of-mine ore from hard rock mines often measures from a few centimetres to 30cm along the longest dimension, thus particles must be reduced in size so that mineral values can be recovered in downstream processes.

Water is used in crushing, mainly for dust control, but screening, grinding and milling can also require significant amounts of water depending on the scale of operation. Once ore is crushed, the mined product can be transported through a pipeline as aqueous slurry to a processing plant some distance away. Water use depends on the flow properties of the slurry and, in some cases, the purity or contaminants in the water used to prepare the slurry.
Most mining operations require at least a nominal quantity of water with which to perform critical operations such as drilling, dust control and minimal ore processing. Many water uses are insensitive to water quality, merely requiring a nominal volume with which to perform essential operations. Other uses, typically mineral concentration based on flotation, might dictate that certain minimum standards of quality be maintained to recover economic percentages of mineral values at sufficient grade to keep the mine profitable.

Most mining operations reuse water to the largest extent possible, within constraints imposed by quality requirements, water availability and discharge considerations. Surplus water from precipitation or from the mine is discharged if it is not needed to operate the mine and associated crushing and grinding systems.

Transport of mineral products over long distances through conveyance pipelines can cause water resources at the point of origin to become depleted and introduce contaminants into the water during conveyance that make the water undesirable at the final destination. This can occur with coal, for example, with the leaching of common salts, boron, heavy metals, fluoride and other undesirable constituents. Water that accompanies coal through long-haul pipelines is not normally returned to the point of origin to be reused for additional coal shipments because of the cost of constructing a second, parallel pipeline, and because contaminants leaching from the coal would accumulate after many cycles of reuse. Figure 2 shows a typical distribution of water use in mining.

Figure 2: Typical breakdown of water use in mining.

**Sources of Water**

Access to a secure and stable water supply is critical to mining operations; without water a mine cannot operate. Water sources often need to be shared by multiple users, while at the same time leaving enough water for ecosystem functioning. Mines obtain water from a variety of sources, including direct harvesting from the environment (surface water and groundwater), water reused from other sources, on-site recycling and town water supplies, in line with approved water management plans.

Mines often use water that is unsuitable for other purposes, such as deep saline groundwater or town sewage effluent. This lower-quality water can be used directly for purposes such as dust suppression, or it can be treated to a higher quality.

Sometimes mines experience a natural and continuous inflow of water, for example in the pit or underground tunnels, and this water needs to be removed (through pumping) so that access to the mine workings stays open. This is known as dewatering. This water is often either released into a receiving water source or used by the mine in the production processes. However, dewatering can lower groundwater tables or deplete surface water.

Many mines recycle a significant amount of their water for reuse on-site, with some mines recycling up to 80 per cent of all water used. In other cases, mines source water from external effluent streams, with some mining operations sourcing up to 50 per cent of their water from local effluent. These practices reduce demand on water drawn from the environment.

Most mines penetrate into water-producing formations or fracture systems during exploration or operation. Depending on the nature of the ore and the geochemical conditions of the formation, this groundwater might either be of good quality or be contaminated to the extent that treatment is needed before discharge.

Mine water must be removed from operating mines to prevent flooding, the removal rate equaling the inflow rate. Except for cases in which the mine is elevated above the surrounding topography, mine water must be pumped to a treatment system or to a discharge point. Energy consumption can be significant, not only because of large volumes, but also because of appreciable lift from deep within the mine to the surface, often several thousand feet. If water is used in mining or in ore processing at a mine site, the mine water can be used for production. Some mines are water deficient, necessitating the import of water from offsite.

**Environmental Impacts**

Successfully treating mining effluents presents major challenges for water treatment companies, which are frequently faced with remote sites and extreme environmental conditions, significant fluctuations in water quality, and a variety of contaminants. Each mine requires a tailored wastewater treatment system to ensure the treated effluents (which can also be from tailing processes or mine dewatering) meet site-specific conditions and the required quality to allow reuse of the water within the mine. Ensuring sustainability of the water supply is an important factor for any mining operation. Wastewater quality fluctuates significantly from mine to mine.

The impact of the mining industry on the environment has been a public concern, with growing appreciation of the natural environment and increasing awareness of the possible harmful effects that the industry's activities can cause. The extractive nature of mining operations creates a variety of impacts on the environment before, during and after mining operations. The extent and nature of impacts can range from minimal to significant, depending on a range of factors associated with each mine. These factors include: the characteristic of the ore body; the type of technology and extraction methods used in mining, and the on-site processing of minerals.

The environmental impacts of mining include erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater and surface water by chemicals from mining processes. Mining can deplete surface and groundwater supplies. The lowered pH and increased metal content may damage aquatic animals and vegetation, as well as humans and other organisms that drink from the streams or eat plants and animals that have bioaccumulated hazardous substances from the stream. Groundwater withdrawals may damage or destroy streamside habitat many kilometres from the actual mine site.

Groundwater can be contaminated when there is a hydraulic connection between surface and groundwater, when there is mining below the water table, and when waters infiltrate through surface materials (including overlying wastes or other material) into the groundwater. Blasting, underground mine excavation and collapse, and exploration drilling can all create pathways for water seepage through mines into groundwater.
Groundwater is also affected by the pumping of mine water that creates a cone of depression in the groundwater table, increasing infiltration. Mining effluents may contain many different types of contaminants, including those such as extreme pH values, heavy metals, suspended solids, materials, dissolved solids, and high conductivity. It can take decades or centuries for groundwater to return to its pre-mining level after pumping stops. The key environmental impacts are:

1. Acid Mine Drainage

Acid Rock Drainage (ARD) is a natural process whereby sulphuric acid is produced when sulphides in rocks are exposed to air and water. Acid Mine Drainage (AMD) is essentially the same process, greatly magnified. When large quantities of rock containing sulfide minerals are excavated from an open pit or opened up in an underground mine, they react with water and oxygen to create sulfuric acid. When the water reaches a certain level of acidity, naturally occurring bacteria kick in, accelerating the oxidation and acidification processes, leaching even more trace metals from the wastes. The acid will leach from the rock as long as its source rock is exposed to air and water and until the sulfides are leached out – a process that can last hundreds, even thousands, of years. Acid is carried off the mine site by rainwater or surface drainage and deposited into nearby streams, rivers, lakes and groundwater. AMD severely degrades water quality and can kill aquatic life, making water virtually unusable.

2. Heavy Metal Contamination & Leaching

Heavy metal pollution is caused when metals such as arsenic, cobalt, copper, cadmium, lead, silver and zinc contained in excavated rock or exposed in an underground mine come in contact with water. Metals are leached out and carried downstream as water washes over the rock surface. Although metals can become mobile in neutral pH conditions, leaching is particularly accelerated under low pH conditions such as are created by Acid Mine Drainage.

3. Processing chemical pollution

Spilling, leaking or leaching of chemical agents (i.e. cyanide, sulfuric acid) from the minesite into nearby water bodies can cause considerable damage.

4. Erosion and sedimentation

Erosion of cleared land surface and dumped waste material can result in the discharge of significant sediment loadings into the adjacent water bodies, particularly during rainfall.

TREATMENT PROCESSES

Environmental concerns, stringent regulations, resource management and access to water (along with general acceptance by the local community of the operation of the mine) have become major issues for mining companies worldwide during the last couple of decades. While the major wastes generated by mines are waste rock, tailings and overburden, the bulk of emissions can be found in discharged mine water.

As mine water accumulates and water overflows from an open-pit surface mine or an underground mine, the water must be pumped or drained out of the mine to ensure safety and stability. Depending on the water availability and quality, it may be reused for process applications on site such as make-up water, dust suppression or mill operations, grinding, leaching and steam generation.

Of all the pollutants from the mining industry, 60–70% are emitted into water; so the removal of these contaminants prior to discharge is receiving significant attention. It is critical to avoid a discharge of toxic components into the environment. Water and wastewater treatment is thus becoming a major focus of mine operations, changing the landscape of site water management and treatment.

Treatment of both heavy metals and other water quality constituents of interest to lower levels requires different and more sophisticated water management and treatment approaches to maximise benefits and minimise costs. There is a variety of water treatment and brine management technologies in readiness to meet these requirements. Because freshwater aquifers often do not yield sufficient water to supply all of the mines and communities in the area, it has driven other solutions to be developed to treat the alternate water and wastewater sources. Some of the key technologies used in these solutions are:

- Membrane-based (e.g., Reverse Osmosis (RO), Nanofiltration (NF), Ultrafiltration (UF), Electro dialysis Reversal (EDR) and Electro dialysis (ED));
- Ion exchange (IX) (e.g., weak and strong base/acid polymeric resins, liquid extractants, adsorption media);
• Chemical treatment (e.g., iron precipitation methods for sulphate and TDS);
• Active biological treatment (e.g., anoxic/anaerobic attached and suspended growth biochemical purification processes);
• Passive biological treatment (e.g., vertical flow biochemical reactors and horizontal flow wetlands).

CONCLUSIONS
The water management strategy for each mining project involves segregation of catchment types to minimise the mine-affected water inventory, wherever possible meeting project demands with locally sourced water and releasing water from mine-affected catchments only when specific flow and water quality conditions are met in the receiving environment. The key aspects could be:

• Diversions: Re-routing the flow path of creeks or other waterways to prevent water from entering the active mining area;
• Water segregation: Separation of water based on quality in order to maximise opportunities for reuse and minimise the mine water inventory;
• Controlled disposal: Disposal of water from mining areas to the environment, taking into consideration flow and water quality characteristics of the receiving environment;
• Water demands and sources: Identifying and quantifying water demands and supply methods, and aiming for a balance of supply and demand;
• Recycling and reuse: Identifying the potential wastewaters that can be reused after further treatment.

Technology will continue to be developed to find innovative solutions to the challenges of obtaining water, reducing demand on water for mining processes, and designing more efficient and effective means of water management and treatment.

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