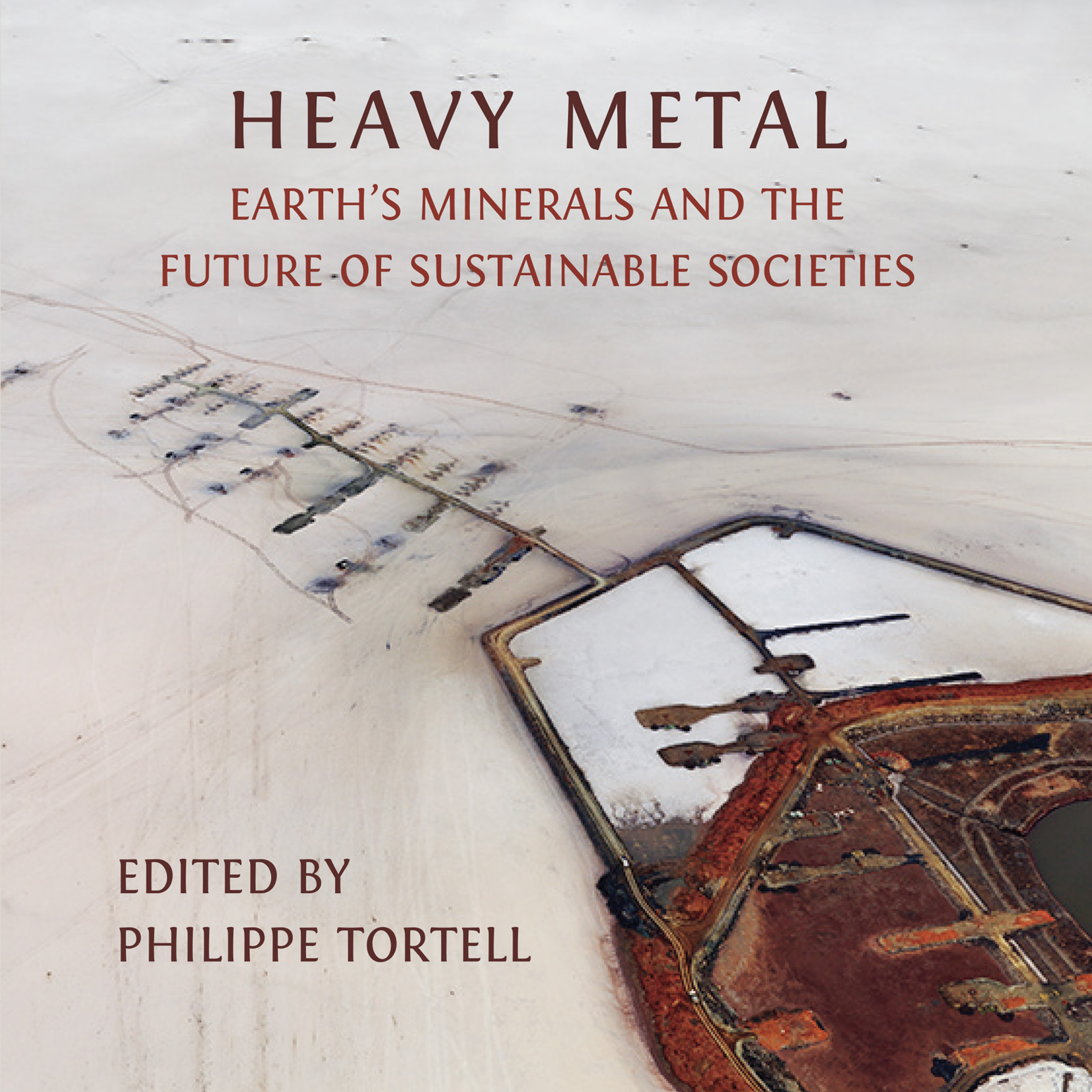
HEAVY METAL

EARTH'S MINERALS AND THE FUTURE OF SUSTAINABLE SOCIETIES



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Metal and Water

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The Atacama Desert stretches over more than 100,000 square kilometers of northern Chile and southern Peru and Bolivia. It is one of the driest places on Earth, with an average rainfall of just fifteen millimeters per year, and less than two millimeters in many places. The desert soil is so barren that National Aeronautics and Space Administration (NASA) scientists use it to examine the feasibility of finding life on Mars.[1] This sparsely populated region is home to Indigenous Atacameños, whose culture can be traced back more than a thousand years. Today, most of the desert's population is spread between the small coastal cities of Arica, Iquique and Antofagasta. About one hundred kilometers from Antofagasta, at an altitude of 2,400 meters above sea level, the small commune of San Pedro de Atacama is a destination for tourists from around the world, who congregate there to see an otherworldly landscape, known as El Valle de la Luna (the 'Valley of the Moon').

Though largely inhospitable to life, the Atacama Desert is exceedingly rich in mineral deposits, including copper and lithium, two elements essential for society's transition to a low-carbon economy. For the past several decades, these desert rocks have allowed Chile to dominate global production of copper; the country currently supplies more than twice as much as its closest competitor and northern neighbor, Peru. Chile is also the world's second largest producer of lithium (after Australia). According

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to the United States Geological Survey, the country produced 5.6 million metric tons of copper, and 26,000 metric tons of lithium in 2021.[2] Altogether, the mining sector contributes almost 14% of Chile's gross domestic product (GDP) and nearly 60% of total exports.[3] As valuable as these minerals are to the Chilean (and global) economy, their production poses a growing threat to an even more precious resource; water. And, increasingly, resistance to mining in Chile has focused specifically on the industry's impact on the country's water resources.

Half a world away from the Atacama Desert, in northwestern British Columbia, Canada, mining activity is also expanding rapidly in an area known to miners as the Golden Triangle. This land, rich in gold, copper, silver and other metals, sits on the traditional and unceded territory of the Tahltan, Gitanyow and Nisga'a First Nations who have used Earth's minerals for millennia. Since the arrival of colonial prospectors in the late nineteenth century, more than one hundred and fifty mines have operated in the region. Here, the problem is not a scarcity of water, but rather the associated impacts of mining activities on pristine water bodies. To First Nations, the Golden Triangle is known as the 'Sacred Headwaters'; the shared birthplace of the Stikine, Nass and Skeena Rivers, with countless other lakes and streams that provide critical habitat and food for a wide variety of species, including salmon, bears, moose, caribou, elk and others. The expansion of mining activities in this region has the potential to cause devastating downstream ecological and cultural impacts.[4] This was most vividly demonstrated by the 2014 collapse of a tailings pond at the Mount Polley Mine in south-central British Columbia, which released more than twenty billion liters of mine waste and contaminated water into Quesnel Lake, Polley Lake and the Cariboo River, a major salmon spawning habitat. It was one of the largest mining disasters in Canadian history, prompting the Tahltan Nation to demand an independent review of the tailings dam for the Red Chris Mine located in their territory and owned at the time by the same company that operated Mount Polley.[5]

The contrasting examples of Chile and British Columbia highlight a fundamental characteristic of mining; regardless of where mines are located, they require and interact with enormous quantities of water. On a global scale, it is estimated that mining withdraws between six to eight trillion liters of water each year.[6] For perspective, this rate of water use could supply the basic needs of about 12% of Earth's human population and would drain the entire volume of Switzerland's Lake Geneva in about ten years. Water is a common currency that cuts across all forms of metal extraction and processing, from the concentration of lithium in brine pools, to the flotation of metal ores and the panning of gold from streams in small-scale artisanal mining operations. But not all aspects of mining and mineral processing have equal impacts on local water supplies, and these differences have important environmental and social implications. For example, artisanal gold mining, which employs millions of people worldwide, has also been identified as the main source of global mercury pollution.[7] On the other hand, larger-scale and technologically advanced mining and mineral processing pose their own diverse potential impacts on water.

In large-scale mining operations, the greatest use of water is during mineral flotation, which is the most common method used to separate valuable minerals from uneconomic waste. Flotation is a fascinating process, in which ground-up minerals are introduced into a chemical solution tank filled with rising bubbles. The valuable minerals attach to the bubbles and rise to the surface, while the uneconomic materials (the tailings) sink to the bottom to form a slurry. If the water contained in the waste slurry is not recycled or reused, it ends up in tailings storage facilities, where it evaporates or becomes locked up in the remaining liquid suspension. Once water is stored in a tailings dam, it is not trivial to reuse and recycle—imagine trying to squeeze water out of wet sand! Other uses of water in mining and minerals processing include slurry transport, fire control, equipment washing and cooling, and dust suppression, which alone can account for around 20% of water losses from arid mining sites.

In recent years, there has been increased attention on the risks posed by tailings storage facilities, especially following several high-profile tailings dam failures in Canada and Brazil, which led to significant environmental damage and (in Brazil) hundreds of human fatalities.[8] These disasters led to heightened investor, community and regulatory scrutiny on tailings storage facilities at a global scale, with increased pressure on the industry to mitigate the associated legacies.[9] Given the close relationship between water and tailings, many of the solutions to the tailings problem require innovations in mine water management. This is especially true for sites located in wet regions, where water accumulation in tailings storage facilities creates a potential trigger for infrastructure collapse.

From a technical perspective, there are two broad approaches that can reduce the amount of water needed in a mining operation. Technologies at the 'back-end' of the minerals processing chain, such as thickeners, filter presses and dry-stack tailings can be used to reduce the volume of water retained in tailings, while 'front-end' technologies, such as coarse particle flotation, can improve metal recovery and lower the overall water consumption and volume of tailings generated per metric ton of metal extracted. Water losses from a mine can also be reduced by installing covers to reduce evaporation from water storage facilities, or by minimizing the use of water for dust suppression and equipment washing. There are also approaches that can minimize the legacy effects of mining on water—for example, the selective handling of waste during rock excavation to separate potentially acid-generating material from more benign wastes. This segregation of wastes leaves a smaller volume of hazardous material to be treated and stored. As novel technical approaches are developed and refined, new regulatory frameworks require improved practices to manage tailings, with the goal of minimizing water use and pollution.

Beyond the technical innovation needed to better manage water use in mining operations, companies must also engage with potentially impacted communities and rights-holders who are increasingly concerned about the mining-related water impacts in both arid and wet regions. Between 2000 and 2017, water-related issues were implicated in nearly 60% of mining-related complaints filed with the Compliance Officer Ombudsman (CAO), an independent accountability mechanism for projects supported by some units within the World Bank Group.[10] Community concerns about water and mining can vary widely, ranging from fears of local drinking water depletion, to concerns about the long-term contamination of surface and groundwater systems.

In the bone-dry Atacama Desert, mining-impacted communities worry about their access to scarce groundwater resources, and the potential effects of seawater use on artisanal fishing communities (the desalination process leads to warming, increased salt content and turbidity in coastal seawater).[11] Meanwhile, communities in the Yukon territory of Canada wonder if the economic benefits that accrued over the twenty-year operating life of the Faro lead-zinc mine, were sufficient to justify the perpetual rehabilitation and cleanup costs. These cumulative costs—from the mine's closure in 1998 and in perpetuity—are estimated to be upwards of two billion dollars for the treatment of seventy million metric tons of abandoned tailings and 320 million metric tons of waste rock.[12] Such long-term legacy effects have led many to question whether they should support the expansion of new mining projects in the future.

To earn the trust of communities and broader societal support for continued operations, there is no doubt that the mining industry of tomorrow must manage water issues much more proactively than they have done in the past. Recognizing this, many major mining companies and industry organizations have begun adopting the concept of 'water stewardship', which encourages improved management of water systems beyond the mine lease boundary and seeks to build enhanced relationships with communities and regulators around water governance issues. This differs from the more inward-looking 'water management' approach that companies adopted in the past, which focused more narrowly on preventing water discharge from mine sites and optimizing water reuse to meet production needs.

The adoption of a more holistic water stewardship paradigm requires a deeper understanding of inherent cost-benefit trade-offs associated with different water management approaches. In Chile, for example, regulators have encouraged companies to use seawater as an alternative to scarce groundwater resources. Chile's state copper commission, Cochilco, estimates that 68% of the water used by the industry will be sourced from seawater by 2032, and the national government's mining policy seeks to increase this to more than 95% by 2040.[13] While some mining companies laud the increased use of seawater as a sustainable approach to meet mining-related water needs, this overlooks the negative effects of desalination on coastal ocean ecology and artisanal fishing, as well as the potential socio-environmental effects of infrastructure expansion. A further challenge is the eye-watering costs and energy needs required to transport seawater to mines in the high Atacama Desert, hundreds of kilometers inland and thousands of meters above sea level. These trade-offs are a stark reminder that there is no 'free lunch' when it comes to improving mine water management, and that diverse perspectives are essential to understand the implications of alternative technological choices.

Going forward, improved water management and stewardship by the mining industry will require increased collaboration across disciplines, and between individuals and organizations involved in various aspects of a mine's life cycle, from mineral exploration to site closure. Abandoned mining projects, such as Faro in the Yukon, with their long-term environmental impacts and astronomical rehabilitation and closure costs, should warn us of the dangers of deprioritizing environmental legacies such as water. Yet, there are decisions that can be made much earlier in the mine life cycle to prevent such impacts. A current challenge to such upstream decision-making is the rigid organizational structure of many mining companies, which impedes collaborative problem solving among disciplines and sub-groups.[14] Additionally, different worldviews and competing priorities across departments and management levels within large organizations can prevent decisions that are more desirable from a systems perspective. As an example, the economic case for investing in new technologies is rarely quantified by technical staff, even though this is a key driver of decision-making by upper management.

The policy and regulatory environments are also crucial for driving positive change by mining companies. Currently, miners pay considerably less for water than they do for other operating expenses, and this low cost can hinder the economic case for water efficiency. Yet, when the industry is pushed to change, it can do so quickly. For example, on the cusp of a major drought in the Gladstone Region of Queensland in the late 1990 and early 2000s, alumina refineries were able to quickly and dramatically reduce their water use following legislated water restrictions.[15] It is also essential that the remediation costs of mining-related environmental pollution are adequately quantified within the financial planning for mine closure. Currently, these costs are woefully underestimated in many mining jurisdictions. For example, the closure costs for the Faro Mine in the Yukon, estimated at five hundred million dollars in 2017, increased to over two billion dollars just five years later.[16] Inadequate quantification of mine closure costs reduces the economic incentives for companies to invest in technologies that could reduce their environmental legacies. This can lead to sub-optimal decisions, from both a financial and socio-environmental perspective.

Beyond economics, there is also a need for miners to recognize the important cultural and spiritual value of water for many community members and Indigenous rights-holders within mining-impacted regions. Many have argued that these values cannot be adequately captured in economic terms, requiring that miners employ decision-making processes that consider economics alongside more qualitative measures and criteria.

While the mining industry has made great strides towards recognizing water as a key business risk, a changing operating environment will continue to demand innovation. One such external pressure relates to the increased variability in global climate, which will intensify existing water management challenges for some sites and create new problems for others. For example, mines in northern Canada will face greater environmental risks, as tailings dams and other critical infrastructure become destabilized on thawing permafrost. For other sites, changes in the timing and intensity of peak snow melt and river discharge will require increased attention to the dynamics of mine water balances across seasons. Similarly, changes in the water cycle may directly impact the reliability of energy supplies for mines that rely on hydropower. In many water-scarce mining regions, such as Australia, anticipated warming and increased drought are expected to present both negative and positive effects. Operating mines in a drier climate will exacerbate water scarcity challenges, while also reducing the risks of water overflow from abandoned mining pits.

The changing nature of accessible mineral deposits will also create new water-related risks. As the availability of high-grade ore deposits dwindles, companies will shift to lower-grade ore deposits that will demand more water and energy unless disruptive innovations are embraced. Additionally, the increasing depth and geological complexity of mines,[17] creates new hydrogeological challenges as operations increasingly interact with the groundwater table. Indonesia's Grasberg copper mine, for example, receives up to five meters of rainfall per year, necessitating a complex web of dewatering systems to prevent the collapse of its block caving operations.[18] New automated technologies can help mitigate the associated safety risks, by removing the need to place people in potentially hazardous environments.

Other technologies, including data science and remote sensing also offer exciting opportunities to advance mine water management and governance. These technologies can help improve the reliability of water balance models by filling data gaps, which are common due to the remote locations of many mines and the associated high costs of monitoring equipment. For regulators and community groups, the increased availability of high-quality data may enhance the real-time control of mine sites and prediction of their associated impacts on water systems. These new approaches, along with fundamental shifts in how water is valued and prioritized, will hopefully ensure that future mines are more environmentally responsible, from exploration through to closure, across diverse operating contexts in all corners of the world.

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