Can microbes turn mine waste into a carbon receptacle?

Canadian researchers are exploring techniques to enhance natural weathering processes at mine sites to capture more carbon and recover residual metals

By Georgia Williams

Dealing with mine waste is one of the industry's oldest problems.

Finding innovative solutions to manage waste and tailings has resulted in new ways of extracting resource potential, while other technologies are examining ways of utilising the waste to aid in global decarbonisation.

Canadian Researchers at the University of Waterloo and Trent University have uncovered a way to do both.

Using microbes, Dr Jeanine McCutcheon and Dr Ian Power are developing a technique to retrieve critical metals from tailings while also capturing carbon dioxide. The process is outlined in the paper "Microbially mediated carbon dioxide removal for sustainable mining," published in the *PLOS Biology* journal in late March.

The initial idea for using microbes to reprocess and repurpose mining waste was born out of work the researchers were developing to sequester CO2 for the mining sector.

"The mines that we've investigated are historic[al] asbestos mines, nickel mines, [and] diamond mines, rocks that are magnesium-rich, alkaline mine waste," said Dr Power, co-author of the research paper.

While working at these sites, the basis of the concept was formed.

"The basic idea is that some of these alkaline minerals, as they weather or dissolve, react with carbon dioxide and potentially form a carbonate mineral that sequesters CO2 in an inorganic

The researchers are preparing to move into the large-scale testing phase
Photo: BrianAJackson

form," he said. "In the natural environment, microbes are very much involved in these processes, where they can facilitate weathering of minerals by generating organic acids or chelating agents."

These organic agents "sort of attack" the minerals in mine tailings and, as a result, help release magnesium and calcium.

"Then there are other microbial processes that can facilitate carbonate formation. And again, you see that in the natural environment. Power said processes like photosynthesis and algae could generate alkalinity and facilitate carbonate formation.

Despite being naturally occurring, these processes take time, time that the mining sector's decarbonisation goals cannot afford.

"If we can sort of engineer or manipulate a mine site in such a way that encourages the growth of certain microbes, then perhaps we can speed up these processes," said the paper's co-author.

Power explained that the researchers aren't introducing new bacteria or foreign substances to the ▶

microbes can also aid in the leaching of critical metals from low-grade ores and tailings

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environment. The microbes they target can already be found on-site.

"We do find examples in the ponds or with the tailings of microbial mats or biofilms [that] may be associated with carbonate crusts," he said. "You will find these happening on a small scale; it's a matter of engineering the system to facilitate or encourage those processes at the larger scale."

A POTENTIAL BREAKTHROUGH IN TAILINGS MANAGEMENT

Harnessing the natural ability of weathering to help regulate CO2 could be a game changer in how the industry looks at tailings. Considering the sector is already facilitating the process.

"Companies take rock, mine it, crush it and pulverise it, and that dramatically accelerates those weathering processes," he said.

Globally, silicate and carbonate rock weathering naturally consumes 1.2 gigatonnes (Gt) to 3Gt of CO2 annually.

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"The trouble that we have is that usually, the traditional approach with mine waste is [to] contain and isolate it. Which is obviously important if your tailings have metals or will generate acidity," said Power, noting that their research sites had very low sulphur and metals in the tailings.

"We need to really think about how we can manage these mine wastes differently to make use for carbon sequestration," he said.

In addition to carbon sequestering, the researchers are also examining the ability of microbes to aid in the leaching of critical metals from low-grade ores and tailings.

"In combination with metal recovery, microbial mineral carbonation can be applied at mine sites, turning them into industrial carbon sinks," states the research paper.

FACILITATING CARBON NEUTRALITY

Still, in the small-scale demonstration stage, microbially mediation may play an integral part in sustainable mining practices in the future.

While testing diamond mine tailings, the researchers found cyanobacteria could "contribute to both mineral weathering and subsequent microbial mineral carbonation."

"Even low rates of microbial mineral carbonation and associated biomass production using cyanobacteria could offset 34% of annual GHG emissions if this process were applied to the entire mine," the researchers noted. "Emission offsets could be increased through further process optimisation to achieve carbon-neutral or potentially carbon-negative mining."

Extrapolating that data globally, Powers and McCutcheon posit that alkaline and intermediate mine tailings can potentially remove 1Gt to 5Gt of CO2 each year.

"The mining industry has a unique opportunity to play a significant role in the future of green energy by working toward carbon-neutral mining of critical minerals," the report concludes.

GEOGRAPHIC LOCATION

Although the discovery is promising, it won't provide a one size fits all solution for the industry. According to Power, the process is better suited to specific geographic locations.

If we're looking at weathering processes or even microbial processes, wetter, warmer climates will be better for those [processes]," he said. "The Canadian High Arctic, where it's frozen over for a good portion of the year, that's something that would impact the efficiency."

After finding success at the lab scale, the researchers are preparing to move into the next testing phase.

"We want to do larger experiments, validate our approaches, determine our rates of carbon sequestration, look for opportunities to sort of recover metals during those processes," said Power. "And then continue to scale it up."

He continued: "I guess the ultimate goal is that you implement this process or these types of processes at the mine scale, and it becomes more standard practice."

Mining and carbon capture

Alongside mineral carbonation methods for treating mine waste, abandoned or depleted mine sites are also increasingly drawing attention for their potential to be repurposed for carbon storage.

Disused mines have the potential for carbon capture for several reasons:

- **Geological characteristics:** Abandoned or depleted mine sites often possess geological characteristics that make them suitable for carbon storage. These sites typically consist of porous rock formations, such as depleted oil or gas reservoirs or saline aquifers, which can provide secure containment for captured CO_2. These formations have been naturally holding hydrocarbons for millions of years, demonstrating their capacity for long-term storage.
- **Infrastructure:** Disused mines often have existing infrastructure that can be repurposed for carbon capture and storage (CCS) projects. This infrastructure includes access shafts, tunnels, and wells that can facilitate the injection and monitoring of CO_2. Utilising pre-existing infrastructure can significantly reduce the cost and time required to implement CCS projects.
- **Regulatory considerations:** In many regions, regulations for underground injection and storage of fluids already exist due to past mining or oil and gas activities. These regulations often provide a framework for permitting and monitoring carbon storage projects. The regulatory history and familiarity with underground activities in disused mine sites can facilitate the regulatory process for CCS initiatives.
- **Avoidance of environmental impact:** Repurposing disused mines for carbon storage helps avoid potential environmental risks associated with abandoned mines. Such risks may include water contamination, subsidence, or the release of hazardous substances. By utilising these sites for CCS, their environmental impact can be minimised, contributing to the restoration and reclamation of these areas.
- **Expertise:** Mining operations require expertise in underground operations, geology, and engineering. Leveraging this knowledge and experience can be advantageous for implementing carbon capture projects. The mining industry has developed expertise in managing subsurface operations, which can be applied to the safe and efficient injection and storage of CO_2.
- **Projects already underway include theScottish Carbon Capture and Storage (SCCS):** The SCCS project, based in Scotland, focuses on repurposing depleted offshore oil and gas fields and disused onshore mines for carbon storage. They have been investigating the potential of utilizing these geological formations to safely store captured CO_2 emissions from various industrial sources.

The CarbFix project in Iceland explores the concept of mineral carbonation for carbon capture and storage. The project captures CO_2 emissions from a geothermal power plant and injects them into basaltic rock formations, including a disused mine. The injected CO_2 reacts with the basaltic rocks, forming stable carbonates over time. The CarbFix project has successfully demonstrated the potential of using disused mines as a storage option for mineral carbonation.