IMPROVING MINERAL RECOVERY AND INDUSTRY EFFICIENCY

Declining ore-grades are impacting the economics of mineral recovery.

That has inspired COEMinerals researchers to test and advance creative new ways to recover more minerals from ore, resulting in process innovation, operational efficiencies and reduced environmental impact. The discoveries open the door for industry change and higher mineral recovery rates than traditional methods ever allowed.

An aerosol approach attracts industry interest

Separating coarse mineral particles during ‘flotation’ is a challenge, as they require greater hydrophobicity (water repellence) to lift them to the surface as compared to smaller particles.

Their mass means they are also more likely to ‘fall off’ the bubbles that are trying to carry them to the surface as part of the flotation separation process.

Recovering coarse mineral particles as early as possible in the separation process reduces the need for additional, energy-intensive grinding of ore particles to make them smaller and it improves the efficiency of later stages of mineral processing.

The big impact of a small change

COEMinerals PhD Candice Brill, working with other Centre researchers at UQ node, has found that using an aerosol delivery method for adding the ‘collector’ ingredient (also known as 'surfactants') to the mix enables the recovery of more coarse chalcopyrite (copper) mineral particles than the conventional dosing method (where the collector/surfactant is added to the mineral slurry liquid).

Collector ingredients help mineral particles float during the flotation process, commonly used by industry for mineral separation.

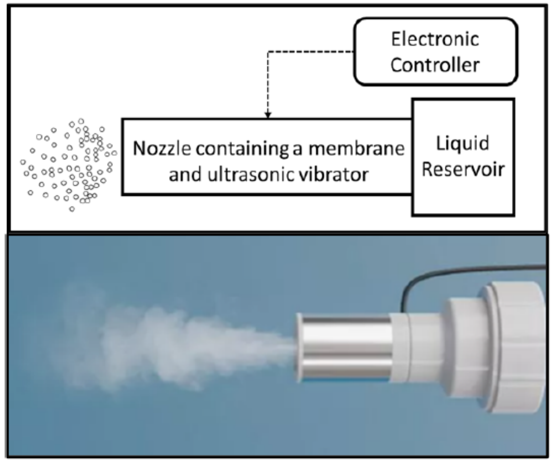
Candice shares: “*Our research*[1] *shows that when the collector ingredient is delivered via an aerosol (spray) method, it ‘coats’ bubble surfaces before they enter a flotation cell. As a result, particles colliding with the bubbles in the cell get a much denser coating of collector, which ‘glues’ them more tightly to the bubbles and more coarse particles of copper are recovered at an early stage of processing.*”

How the aerosol method works

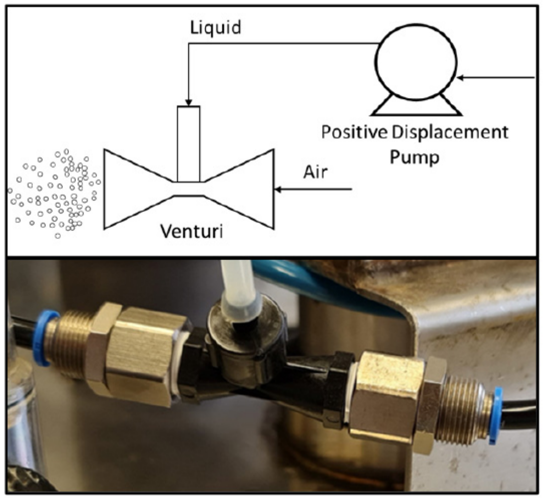
There are two potential ways to install the aerosol delivery method:

- Option 1 - Piezo-electric nebuliser (is a small device that turns liquid into a fine mist)
- Option 2 - Venturi tube (is a simple device that makes a fluid (air or liquid) move faster and drop in pressure by squeezing it through a narrow section of pipe)

Both can easily be installed into existing flotation cell air supply lines.



Option 1: Tekcekeo Micronice® vibrating mesh nebuliser



Option 2: Gas/Liquid venturi nozzle, with a peristaltic pump propelling the liquid

[1] https://www.tandfonline.com/doi/full/10.1080/08827508.2025.2540316

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The aerosol method leverages the complex interaction between hydrodynamics and thermodynamics, delivering change in two complementary ways to make coarse particles float:

1. Coarse particles are more likely to collide with bubbles than small particles. In this way, the collector is preferentially delivered to bigger particles
2. More collector is adsorbed by bubbles at the 'gas interface', helping the particles colliding with collector-coated bubbles to receive a thicker coating of collector, which acts as a strong 'glue' to hold the particles and bubbles together

On-site, pilot trials by industry

Multiple organisations[2] have expressed interest in trialling the aerosol method, with the path to industry adoption helped by the fact that it's a tweak to existing processes and does not rely on any new collector chemicals, major capital works investment or disruptive process changes.

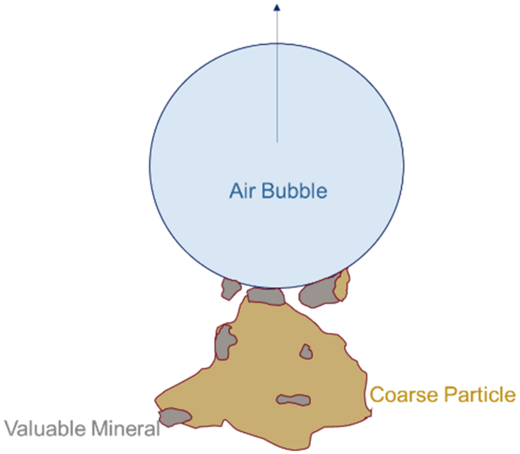
"*We'll be putting the aerosol approach through its paces in three different site trials in 2026, working with three different industry partners and testing the technique on three different mine site flotation systems,*" shared COEMinerals CI A/Prof Liza Forbes (UQ).

Next steps

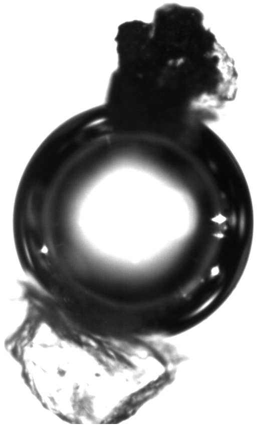
The research team believes the aerosol approach may also increase recovery of coarse particle minerals beyond copper and potentially fine particle recoveries during flotation as well.

The UQ research team is also at the early stages of testing the aerosol method with COEMinerals/ Monash-created, eco-friendly collector ingredients.

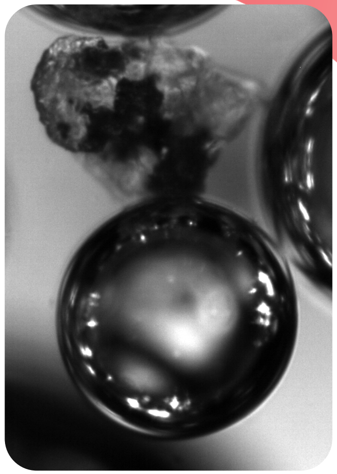
If the replacement collector works equally well or better, industry would have the opportunity to replace collector ingredients and further reduce the overall environmental impact of their mining/ mineral separation operations.



Coarse and fine particles attached to a bubble, highlighting that coarse particles are typically less securely attached than fine particles



Two coarse composite particles attached to a bubble



A composite coarse particle (chalcopyrite, pyrite & quartz) attached to multiple bubbles

[2]Industries represented in the Collaborative Consortium for Coarse Particle Processing Research (CPR). CPR was initiated by the Sustainable Minerals Institute's Julius Kruttschnitt Mineral Research Centre (JKMRC) to tackle the multidisciplinary aspects of coarse particle processing.

Recovering valuable minerals inside ore particles

Copper is in demand as a strategic material in Australia and a critical mineral in the USA and other countries around the world. COEMinerals researchers are developing a technique that could make Chalcopyrite (copper) recovery more efficient for even minuscule amounts of the valuable mineral hidden inside ore particles.

The sticky business of floating minerals

COEMinerals researchers have found a clever way to solve the problem of floating even microscopic traces of copper minerals on ore particles, which aids copper recovery during flotation separations.

Researchers from multiple COEMinerals nodes collaborated to develop a special oil-water mixture (surfactant/collector) that, rather than just sticking to the exposed areas of copper on the surface of a particle, spreads from the copper mineral 'patch' to the surrounding ore.

COEMinerals PhD Azeez Aregbe (UOM) explains: "*Ore particles that only have tiny amounts of copper showing on their surface do not stick well to air bubbles. However, we've developed an oil-water mixture that not only attaches to exposed copper on the rock particle, but spreads across the entire surface to make the whole thing more water-repellent (hydrophobic). This is important, as it helps the particles containing copper to stay connected to the rising bubbles for final recovery.*"

Less grinding = less energy and power = positive environmental impact

More copper recovery from coarse particles reduces the amount of ore that needs to be re-ground into a fine powder (to expose more copper on ore particle surfaces). Beyond increasing the amount of copper recovered, process improvements can save time, energy and water, as well as lower overall emissions and the environmental impact of mineral processing.

Azeez presented the research results on behalf of COEMinerals at the international Flotation '25 conference in Cape Town, South Africa, which attracted industry and academic delegates from 32 countries. A published paper on the technique demonstrates the first step in the process: controlled spreading from copper minerals to quartz to improve the hydrophobicity and recovery of composite chalcopyrite-quartz minerals in a mechanical flotation device[3].

Next steps

Work is now underway to further improve the technique, including testing a new, nature-inspired collector chemical (developed at Monash). So far, the results are promising.

PhD Azeez Aregbe (UOM) using a Denver Cell for flotation experiments in the lab at UOM

Harnessing acoustic energy to increase ultrafine mineral particle recovery

While flotation is efficient for recovering mineral particles in a certain size range, up to 20 percent of mineral particles outside this range - including ultrafine particles - can be lost in the process.

"*Based on published research*[4]*, losing 10% of minerals can equate to about 1.5M tonnes, which – depending on the mineral – may represent a loss of up to $10Billion in today's terms,*" shares COEMinerals CI Prof Seher Ata (UNSW).

Recovering the 'lost' value of minerals is a big incentive for industry and academics to solve the 'floating ultrafine mineral particles' problem.

Finding a solution is music to our ears

Supported by COEMinerals, as well as a 2025 Australian Economic Accelerator (AEA) Ignite Grant[5], COEMinerals researchers at UNSW are experimenting with using low frequency acoustic (sound) waves to address the low probability of ultrafine mineral particle-bubble collision during flotation.

Tiny 'micro-bubbles' in a flotation cell often fail to lift minerals to the surface/froth because they cannot carry them effectively. Further, the low rise-velocity of micro-bubbles means they tend to remain in the flotation cell or enter the waste stream along with any minerals attached to them.

[3] https://pubs.rsc.org/en/content/articlelanding/2025/lf/d5lf00275c
[4] https://www.sciencedirect.com/science/article/pii/S0892687522001194
[5] UNSW & UQ received $405,326 for Strategic and critical minerals recovery using a novel acoustic flotation technology in 2025

"*Finding a solution was actually quite complex. Because acoustic flotation draws from several disciplines; a major early challenge was finding practical and affordable ways to even do the experiment*," shared Prof Ata.

However, they did it!

Under lab conditions, the research team can now generate microbubbles to test new approaches using a venturi tube or a rotating packed bed in a flotation tank. Acoustic waves are then generated from a vibrating transducer, causing the microbubbles to move in a predictable way.

Vibrating bubbles like to 'dance' together

Researchers[6] have found that acoustic radiation forces (ARF) can promote the agglomeration of micro-bubbles, which enhances their buoyancy and makes the micro-bubbles move in a coordinated way when a low frequency beat is 'played'.

"*Interestingly, individual bubble movements are further accelerated when other bubbles are vibrating. When we look through a microscope at the microbubble behaviour while an acoustic beat is played, it looks like they are dancing, shimmying and shaking their way to be closer together and form a 'group', while carrying valuable microscopic mineral particles with them*," added Prof Ata.

Yes, you heard that correctly: ARF causes micro-bubbles to be attracted to one another and to form clusters (agglomerates), which increases their collective size and buoyancy. This increases their ability to move minerals to the surface. Previously, without the addition of sound, each microbubble would have been 'too small' to support the flotation recovery of ultrafine mineral particles. It also reduces the amount of minerals lost to waste.

[6]https://www.sciencedirect.com/science/article/pii/S1383586624050299

Proof of concept

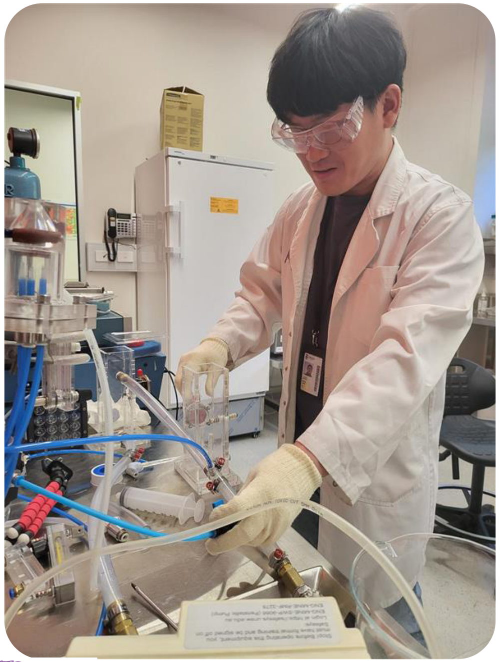
Researchers have achieved their goal of seeing if sound could add to the overall efficiency of an established mineral recovery process.

"*It's early days, but this research offers a new way to bring microbubbles together and agglomerate them inside the flotation cell, rather than simply creating more of them, which ultimately results in minimising ultra-fine mineral particle loss to tailings during flotation separations*," said Prof Ata.

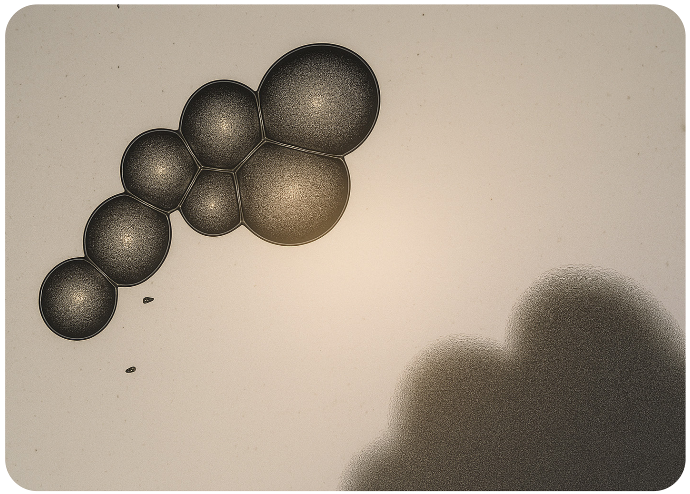
COEMinerals PhD Minuk Jung (UNSW) shared his perspective on the learning journey: "*What excites me about this research is the chance to explore ideas I never imagined and to test a variety of new methods. I hope our work helps advance more effective strategies for utilising microbubbles and sound, in flotation separations.*"

Next steps

With proof of concept delivered and a provisional patent achieved, the next stage is for continued testing in flotation environments, with the plan to attract commercial support to further develop the approach and technology.



PhD Minuk Jung (UNSW) working on acoustic energy experiements in the lab



AI-enhanced image of bubbles clustering as a result of acoustic radiation forces (ARF)