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Salt solution: How UCT research is paving the way for zero-waste water treatment

The first full-scale working unit for Eutectic Freeze Crystallisation (EFC) treatment of wastewater will soon be operational at the Tweefontein colliery in Mpumalanga. This is the story of how dedicated research, student participation and private sector support has led to a world first in wastewater treatment.

From a distance the first full-scale EFC unit does not look that complicated. The unit, purchased by Glencore, built and designed by Prentec, and based on research done by staff and students at University of Cape Town's (UCT) Faculty of Engineering and the Built Environment, is composed primarily of steel scaffolding and several three-storey metal tanks. While it may look unassuming, this is the culmination of many years of research and experimentation. When the unit starts operating, it will transform briny wastewater into clean water and valuable salts.

What is eutectic freeze crystallisation?

The story begins in 2000 when the Department of Chemical Engineering at UCT first started research into industrial crystallization. In 2006, Professor Alison Lewis, Dean of Engineering and the Built Environment, became one of the founding members of the Crystallization and Precipitation Research Unit (CPU).

"As part of our research we started considering the viability of eutectic freeze crystallisation technology for the South African context. We worked in collaboration with the only other people in the world doing this kind of research. They were a group in the Netherlands but the equipment they were using was far too complicated to be useful locally," she says.

The term eutectic refers to a mixture of substances that melts or freezes at a single temperature. EFC can be thought of as the opposite of distillation. As

Lewis describes it, "A briny solution is cooled to its eutectic temperature which causes the water in the mixture to crystallise as ice, which floats, and the salts to crystallize out as solids, which sink."

The team immediately recognised the potential of this technology for a country like South Africa. Lewis explains that two major problems currently facing South African water users are the declining availability of sufficient quantities of water and the deterioration of the quality of the available water. She explains: "With the increasing use of water recycling, the result has been an increased generation of inorganic brines and concentrates. Eutectic Freeze Crystallization offers a novel, sustainable method for treating brines and concentrates. With EFC, pure water and pure individual salts can be recovered, thereby making a significant leap towards achieving zero effluent discharge."

From theory to reality

Two years later, in 2008, chemical engineer Peter Gunther was part of an Anglo American team working with Coaltech to find new ways to treat the large amount of wastewater produced as a by-product of coal mining.

"The most prevalent method then, as now, is the use of evaporation ponds. These require a huge amount of land and each one costs upwards of R100 million to construct. The life span for such ponds is only about five years and the risk of leaks into the surrounding soil is a danger. There is also the fact that using evaporation ponds means that the valuable resource of water is lost during the process."

When Gunther heard about the UCT research into EFC he recognised the potential applications immediately, in particular for the mining sector. At the time the Water Research Commission had provided R500 000 (by 2008) to fund further research and work at UCT was intensifying – with promising results.

Gunther set about turning these scientific advances into reality. Several years later, now working as managing director for water treatment company Prentec, Gunther played a leading role in the construction of the eMalahleni Water Reclamation Plant, the first mine water desalination plant in South Africa to transform 30 Ml/day of mine water into drinking water every day. The project was recognised by the UNFCCC in 2011 as one the Lighthouse Projects in their Momentum for Change awards at COP17.

Following on from the success of the eMalahleni project, Gunther set his sights on constructing a full-scale EFC plant as soon as possible.

Why does EFC matter?

The value of the EFC process is fourfold. Firstly, it results in zero waste since all components of the process are recycled. Secondly, it avoids the extensive land use and possible environmental dangers of evaporation ponds. Thirdly, the process itself is not as energy intensive as other methods, such as heat evaporation. "The heat of fusion of ice is six times less than the heat of evaporation of water, the energy required to separate the water as ice is significantly less than that required to separate it by evaporation, although obviously the energy for freezing will be more expensive than that for heating," says Lewis.

The applications for such technology are also vast and encompass a wide range of human activity from agriculture to mining. In South Africa EFC technology could be useful in the mining industry, for treating paper and pulp waste, as well as textile wastes. There is also the possibility of such technology being used as a means of treating the brines that are produced when drinking water is provided through the desalination of seawater.

Adrian Viljoen, technical advisor at Prentec, says that the company also sees applications far beyond the treatment of brines. "Many crystallization applications typically undertaken with evaporative crystallization will in future be carried out using Freeze Crystallization. This is because of its low capital cost, energy efficiency and ease of operation. Examples would be for sodium sulphate recovery in minerals processing, metallurgy and papermaking. Heat sensitive crystallization could also be used in the pharmaceutical business, and in salt production."

The role of students

Before work could begin on a full-scale EFC plant, every stage of the process had to be developed and evaluated. It was at this juncture that the work of UCT chemical engineering students came to the fore. Over the last decade almost 40% of the CPU postgraduate student cohort have explored aspects of EFC in their theses.

Today Jemittias Chivavava is the Chief Scientific Officer for the Crystallisation and Precipitation Research group but his interest in EFC started years ago when he chose to make EFC the subject of his MSc studies. According to Chivavava, postgraduate students (MSc & PhDs) conduct research aimed at developing and ironing out kinks in the EFC process and present their work to various audiences at local, regional and international forums. "As they engage with the physical EFC process in the laboratories, the students solve 'interesting' problems, which enhance their engineering skills," says Chivavava. "Also, our Chemical Engineering undergraduates are afforded an opportunity to conduct experimental work on our laboratory scale EFC facilities and some attend the crystallization and precipitation course where they learn about the underlying fundamentals."

At present the team behind the research plays the role of expert advisors, rather than seeking to apply any intellectual property rights to their discoveries. "We have approached this from a knowledge and human capacity development perspective with a view to produce personnel who are well versed with this technology such that they can develop it further if they get an opportunity wherever they would be working," explains Chivavava.

A zero waste future

When the EFC plant starts operating at Tweefontein it will be the tangible result of model partnership between an academic institution and the private sector. Not only will the EFC plant produce valuable salts as a by-product of wastewater treatment but it will also produce 500 000 litres of potable water each day. At the current suggested consumption rates in Cape Town, this amounts to the water allowance for 5000 people.

Gunther sees the opening of the plant as a culmination of many years of work. "At Prentec we believe that in time EFC will become a mainstream process recovering valuable materials through the deconstruction of waste products."

"I believe that cutting edge technologies like EFC have a great future. We need these kinds of innovative processes that offer multiple benefits, including eliminating waste ponds, the ability to treat hypersaline brines, the advantages of water recovery, salt recovery and potential revenue generation. One of the biggest drawbacks of desalination as a solution for Cape Town's water crisis is what to do with the hypersaline brines that will be produced. EFC offers a potential solution," says Lewis.

Story by Ambre Nicolson

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