Systems biology of acidophile biofilms for efficient metal extraction (SysMetEx)

Making copper flow faster

In copper mining by bio-heap leaching, microorganisms help extract the metal from rock. The international research team from ERASysAPP project SysMetEx aims to speed up this relatively slow process. The researchers are analyzing just how the colonization of the rock by these bacteria progresses.

The worldwide demand for copper is high. This metal is mainly used in the construction industry, coining, electronics and mechanical engineering. However, the remaining resources are largely present in rock only at low concentrations, and their extraction is laborious and polluting. Conventional extraction involves heating copper-containing rock to very high temperatures, which releases, amongst other substances, sulfur dioxide. This toxic gas is the cause of acid rain, which leads to soil acidification and forest dieback.

Bio-heap leaching presents a relatively environmentally friendly alternative. In this process, metals are extracted from rock with the help of acid and microorganisms. But this method, with which around 15 percent of the world's copper is currently mined, has a huge disadvantage: it's slow and therefore economically unattractive. This is especially true for mining from chalcopyrite, the most common mineral containing copper.

The international consortium of the ERASysAPP project SysMetEx, which comprises scientists from Sweden, Luxembourg, Germany and Switzerland, is now working together on the ambitious goal of speeding up bio-heap leaching. The scientists are tackling the problem by looking at the microorganisms that are used in this process and investigating whether more systematic deployment of these tiny little helpers can make the leaching process more economically viable.

Microorganisms as catalysts

In bio-heap leaching, the metal-containing rock is crushed and piled into large heaps, which are sealed from the ground with plastic sheeting. The heaps are ventilated by means of an embedded pipe system, drizzled with acid and injected with microorganisms. These act as catalysts to accelerate the chemical reaction by which the acid gradually releases the copper ions from the rock. In chalcopyrite ($CuFeS_2$), the bacteria oxidize ferrous iron, thereby turning it into ferric iron and removing sulfur compounds that accumulate on the mineral surface.

The liquid that drips from the heap and is collected in reservoirs must first reach a certain metal ion concentration before extraction by electrowinning becomes worthwhile. In the case of

In bio-heap leaching, metals are extracted from rock with the help of acid and bacteria. Photo: Talvivaara Mining Company Plc chalcopyrite, it can take up to a year from setting up the bio-heap until the copper trickles from the pile of rock in the required concentration.

Searching for the best bacterial cocktail

A crucial factor in determining how fast the copper is dissolved is how soon the bacteria attach themselves to the rock and form a biofilm, which is a sort of colloidal layer that is generated when bacteria adhere to the rock surface and in which these microorganisms live and multiply.

With the help of three model types of acidophilic leaching bacteria, which are introduced to interact with the surface of the rock either individually or in different combinations and sequences, the scientists investigate the bacterial films that form. Does the particular sequence in which the different types of bacteria are introduced to the rock play a role in how fast a biofilm forms? To what extent do the bacteria help each other during the formation of the biofilm? And what combination dissolves the most copper in the shortest time?

The researchers do not have their own bio-heap at their disposal; the bacteria grow under controlled conditions in flasks. The scientists analyze their activity using transcriptomic and proteomic methods. This enables them to find out how many proteins and RNAs the bacteria form and, as a result, to draw conclusions about their interactions with each other, or about metabolic changes under differing conditions. In addition, microscopy methods are being used to track the colonization of the rock surface by the various bacteria strains over time.

All of the data generated by the involved research groups is poured into models, which should in future allow predictions to be made about how to achieve optimal results in the mining of copper from chalcopyrite.

Strongly application-oriented research

The chalcopyrite samples that the scientists are using for their research is provided by a Swedish copper mining company, which will directly benefit from the results after the conclusion of the project. The Swedish firm TATAA BIOCENTER AB, a project partner of SysMetEx, will develop a kit to test whether a bio-heap accommodates a microorganism community suitable for effective leaching.

The researchers have not yet published any concrete results, but they have already shown that the sequence and combination of bacterial strains play a crucial role in bio-heap leaching. The effect is evidently so strong that the right blend of bacteria could potentially cause the opposite effect by halting unwanted leaching, which could be applied, for example, in disused mines.

More info about SysMetEx: **www.sysmetex.eu**
More info on ERASysAPP: **www.erasysapp.eu**

The international SysMetEx team: (from left) Igor Pivkin, Emma Hermansson, Stephan Christel, Kjärstin Hagman Boström, Paul Wilmes, Mark Dopson, Olga Ilie, Ansgar Poetsch, Mario Vera, Sören Bellenberg, Antoine Buetti-Dinh, Malte Herold.

SysMetEx at a glance

Research groups:

- Prof. Mark Dopson (principal investigator), Department of Biology and Environmental Sciences, Linnaeus University, Kalmar, Sweden – Biomining, metal extraction, -omics analysis
- Prof. Wolfgang Sand, Biofilm Centre, Aquatic Biotechnology, University of Duisburg-Essen, Germany – Advanced microscopy, leaching experiments
- Prof. Paul Wilmes, Luxembourg Centre for Systems Biomedicine, University of Luxembourg – Biomolecular extraction, integrated -omics analysis, bioinformatics, data management
- Prof. Igor Pivkin, Institute of Computational Science, Faculty of Informatics, Università della Svizzera italiana – Mathematical modeling
- Dr. Ansgar Poetsch, Department of Plant Biochemistry, Ruhr University Bochum – Proteomics, bioinformatics
- Prof. Mikael Kubista, TATAA BIOCENTER AB, Gothenburg, Sweden – Industrial partner

Total budget (2015–2018): CHF 2.5 million, including CHF 487,000 from SystemsX.ch

Project type: International Project – As a partner in the European research network ERASysAPP, SystemsX.ch has co-funded six international application-oriented projects in which Swiss consortium partners are involved.