Microbial raw material recycling

While the use of biotechnological methods for the purification of water, soil and air has already been state of the art for quite a few years, the use of microorganisms for the recovery of metal and mineral raw materials from industrial and agricultural waste has also started to attract the interest of scientists. This dossier addresses this topic, explains what geobiotechnology and urban mining are all about and presents some of the activities going on in Baden-Württemberg.

From raw material problems...

It is becoming increasingly clear that industrial nations with a broad production base and high export share require adequate availability of raw materials. This scenario also applies to Germany. The German government has therefore put together a whole package of measures aimed at supporting the German economy. The German Mineral Resources Agency (DERA) was established in late 2010 to provide advice to German economic and political stakeholders. In addition, the German Federal Ministry of Education and Research has launched a broad range of funding programmes related to resource efficient technologies. The red-green Baden-Württemberg government is also putting a greater focus on the theme of resource efficiency. The first resource efficiency conference was held in 2012 and the government is currently preparing a relevant strategy.

... to tapping new raw material resources...

Many metal raw materials that are required for functioning economies have long been mined and a large number of easily accessible deposits are already depleted. For this reason, methods that also enable the economical production of metals from low-grade ore, i.e. ore with a small proportion of valuable minerals, are becoming increasingly important. Moreover, attention is shifting towards secondary raw materials (i.e. materials produced from waste), as these might often have higher metal contents than low-grade ores.

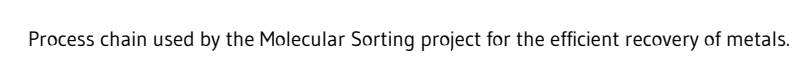
Cities, i.e. densely populated areas, have become what is called urban mines due to the huge stock of potentially useful metals in modern societies. The basic idea behind urban mining is to use anthropogenic stores of resources, identify quantities present and re-extract and recycle them. There is usually a differentiation between short-term mines that include domestic and industrial waste such as plastics packaging, electronics, paper and long-term mines that refer to buildings and waste disposal sites.

... to geobiotechnological methods.

In some cases, biotechnological methods might be the methods of choice for recycling secondary raw materials, including approaches that involve the use of microorganisms in mining and environmental protection. This branch of biotechnology, which is also referred to as geobiotechnology, is presented in detail in a 2013 DECHEMA status paper (see reference section below).

The technique of bioleaching has developed rapidly since the mid-1990s, in particular for the extraction of copper from copper sulphide ores. The German Federal Institute for Geosciences and Natural Resources in Hanover has compiled all known bioleaching data for the year 2010. Data show that in 2010 more than 8% of all copper was recovered using bioleaching. Large waste dumps of waste ores resulting from classical metal production are reprocessed using biotechnological methods. These low-grade ores, which contain only 0.2% copper rather than the typical 15%, can no longer be mined economically using traditional hydro- or pyrometallurgical methods. The largest bioleaching plant in the world is located in the Atacama desert in Chile, which has a total surface area of around 10 km^2. Heap bioleaching sites are also found in Europe, in Finland for example where a broad range of metals, including around 50,000 t/y of nickel, are recovered using biotechnological methods.

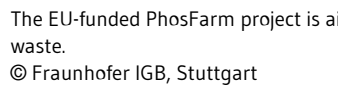
Synthetic biology and geomicrobiology as assistants



Process chain used by the Molecular Sorting project for the efficient recovery of metals.

The pool of microorganisms that can be used for biotechnological processes comprises more than 30 different species. In many cases, bacteria that can be isolated from acid mine water are used. One such bacterial species is Acidithiobacillus ferrooxidans; these are chemolithotrophic organisms that obtain the energy they need for growth from the oxidation of reduced metal and sulphur compounds. The biotechnological methods used for biomining can also be used for the recovery of metals from electronic waste, slag, fly ash and sewage sludge. However, this is currently only possible on the laboratory scale and still needs to be transferred to the industrial scale. Research groups from Baden-Württemberg are studying the suitability of metal-tolerant microorganisms such as gold-resistant Delftia acidovarans (see article entitled "Award-winning gold recovery with bacteria") or calcium-resistant Geobacter metallireducens for biomining (see article entitled "Biological soil remediation").

Phosphorus – an important mineral raw material



The EU-funded PhosFarm project is aimed at recovering valuable soil improvers and fertiliser salts from agricultural waste.

Phosphorus is vital for the growth and health of plants and therefore a major ingredient of fertilisers. However, it is only available in a few countries around the world and the phosphate rock reserves are limited and non-renewable. In response to dwindling phosphorus reserves, efforts are being made to look for new resources, in particular secondary ones. In addition to chemical and physical methods such as the recovery of ammonium phosphate from sewage treatment wastewater, new biotechnological approaches are aimed at making organic phosphorus from agricultural residues accessible. One of these approaches uses immobilised enzymes to release organic phosphorus compounds from the organic matter and recover them as phosphate.

Biomining is the extraction of metals such as copper and nickel from ore minerals using biotechnological methods. Biomining is already an established branch of biotechnology and also applied throughout Europe.

Bioleaching is the biological conversion of an insoluble metal compound into a water-soluble form.

Biooxidation is the extraction of metal (usually gold) from ores by oxidising the matrix in which the metal is embedded.

Source: Geobiotechnology, DECHEMA status paper.

References and further reading:

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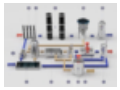

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