Biomining - an innovative strategy to recover metals from secondary resources

J.Kisser[1], T. Rosenkranz[2], M. Puschenreiter[2], H. Gattringer[1], A. Zraunig[1],Veronika Reinberg[1], and M. Iordandopoulos-Kisser[3]

[1]alchemia-nova GmbH, Institute for innovative phytochemistry & closed loop processes, 1140 Vienna, Austria

[2] University of Natural Resources and Life Sciences Vienna, Institute of Soil Research, 3430 Tulln, Austria

[3] Technical office MJKISSER, 3001 Mauerbach, Austria

Keywords: biomining, waste incineration residues, metal recovery

Presenting author: jk@alchemia-nova.net

The exploration of novel technologies for metal recovery gains more importance, as primary resources get scarce and expensive. New technologies should be efficient and less energy consuming, also supporting a low carbon economy. Sewage sludges as well as ashes from waste incineration plants are known accumulation sinks of many elements that are either important nutrients for biological organisms (phosphorus, potassium, magnesium, etc.) or valuable metals when considered on their own in pure form (nickel, chrome, zinc, etc.); they are also serious pollutants when they occur in mixtures at localised anthropogenic end-of-stream points. The process of recovery of those metals by accumulation in biomass and subsequent separation and purification is called biomining.

A previous project (Bio-Ore, Austria FFG, No. 8389609) aimed to explore new pathways to concentrate metals from diluted sources such as sewage sludge and wastewater by using highly efficient biological absorption and accumulation mechanisms. The process is called bioaccumulation and can be most effectively observed in hyperaccumulating metalophytes, which were studied for its suitability to be incorporated in metal recovery processes. In a series of preliminary tests the best substrate mixtures for optimisation of heavy metal concentrations without resulting in acute toxicity for the selected plants, were evaluated. It was found that high concentrations of soluble salts (chloride, sulphate, sodium) in both sewage sludge and the waste incineration ashes where limiting factors for plant growth. These salts can be leached with only minimal losses of heavy metals. In a following systematic series of tests under laboratory conditions the accumulation behaviour for metals such as cobalt, manganese, nickel, zinc, rare earth metals and many others of a selection of candidate plants growing on a mix of sewage sludge and incineration ashes was assessed. Growth performance of these plants as well as the most suitable substrate properties were evaluated. In the end, a mixture of 50% (w/w) sewage sludge, 5% waste incineration ashes and a mixture of quartz sand, some compost and straw clippings was found to be an acceptable substrate for all the tested plants. In this mixture the presence of chromates probably plays a key role in setting a limit regarding toxicity for higher plants. Nickel, molybdenum, rubidium and manganese were hyperaccumulated to a notable degree in plants like *Alyssum murale* or *Phytolacca americana* under certain conditions, up to a factor of 20 when compared to the concentrations in the initial substrate. At the same time, the concentration of environmentally dangerous metal pollutants in the original substrates (lead, cadmium, mercury, etc.) could be lowered by an average of 30% in total after the cultivation period.

Within another project (Bergwerk Pflanze, Austria FFG, No. 843643, which is still ongoing until March 2017) waste incineration residues, especially bottom ash was thoroughly characterised for all parameters that might have impact on plant growth, like cation exchange capacity or bioavailability. In following hyperaccumulating plant species were first cultivated under laboratory conditions on bottom ash and the accumulation behaviour for many elements were studied. In this step several amendments were tested for improving plant growth. In the next step, the best candidate plants growing on these incineration residues were selected for further employment in field trials set up in large containers at the landfill. The main target in the actual phase of the project was evaluation of the growth performance of these plants in laboratory and field experiments, as well as the assessment of the most suitable substrate properties. Pot experiments with five plant species (*Brassica napus*, *B. juncea*, two different clones of *Nicotiana tabacum*, *Sedum plumbizincicola*, and *Alyssum pintodasilvae*) on waste incineration bottom ash and material from mechanical biological waste treatment showed that the hyperaccumulators *S. plumbizincicola* and *A. pintodasilvae* have problems to cope with the difficult substrate. Concentrations of metals in the plants show that further omptimisation strategies have to be developed, to reach sufficient accumulation rates. The amendment test series showed best results after addition of 20% compost, 10% biochar, and ageing of the bottom ash in open air for two months. Brickdust, zeolithes, microbes and other tested materials showed no real improvement of the growing conditions. The first preliminary results of the field trials did not yet show very high accumulation rates of certain metals, although these analyses are still not yet finished. In 2016 the field trials are planned with a slightly different set-up and other further publishable results are expected. In the next step (starting in January 2016) possible strategies of extraction and purification of the target metals from the biomass will be started.

In the newest project GRecoMet (Austria FFG) results from former and ongoing phytomining-experiments are combined and tested with additional strategies of biomining (for metals such as cobalt, magnesium, gallium and light rare earth elements) again derived from waste incineration residues:

- Bioleaching - enhanced mobilisation of metals from a substrate through acids and chelators which are secreted by microorganisms
- Rhizofiltration – phytoextraction from liquid medium
- uptake of metals by algae
- biosorption - passive accumulation of metals in dead biomass like residues from agriculture and algae or selective binding of metals to proteins

Hydrometallurgical ways to recover metals are further developed and compared with pyrometallurgical methods. All technologies are tested in a process-integrated setup and possibilities of utilisation of residual biomass (after extraction of metals) will be drafted.