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Hanna Kvarnström
Erika Lönntoft

Modelling of Metal Recovery using Sulfate Reducing Bacteria

Some industrial waste contains metals and other hazardous materials, which are left in the waste when deposing it. Metal recovery from industrial waste is therefore an improvement that could be done in today's society to lower the environmental impact. The metals in the waste is also a valuable resource and it could be beneficial to recover the metals as well as removing them. Precipitation of metal ions as metal sulfides using a biologically produced hydrogen sulfide as precipitation agent is one possible metal recovery process. To implementing a new process, describing it by a mathematical model and simulating this in computer programs is a way of evaluating the feasibility of the process before it is built and it can also be used to decrease the number of experiments needed for development.

The mathematical model that was developed in this project describes a metal recovery process starting with waste that had been treated with sulfuric acid to get metal ions accessible. The metal ions then enter tanks where the precipitation occurs with hydrogen sulfide, creating insoluble metal sulfides that can be recovered as products. The hydrogen sulfide is produced in a bioreactor where sulfate reducing bacteria perform redox reactions to convert sulfate to hydrogen sulfide. The bacteria use ethanol as a substrate converting it to acetate which subsequently can be used as a substrate.

The model is built on mass balances for all substances present in the different tanks where the change in concentration over time is defined with differential equations. The mass balances are dependent on what enters, exits, gets produced and consumed in the reactor. The rate of production for the biological process uses Monod kinetic to describe the substrate uptake rate. The uptake rate equations include multiple substrate uptake, pH and product inhibition from H_2S. There are also rates describing mass transfer between liquid and gas and acid-base dissociation for H_2S and CO_2.

The model for the precipitation tank is built in the same way but here the rates are solely assumed to be dependent on the mass transfer rate. The metals included in the model are copper and zinc. These metal precipitate at different pH, making selective precipitation possible. In this case pH 1.0 and 4.5 are used respectively for the metal ions.

The model was implemented in MATLAB and Aspen Plus, these two simulating programs are very different. In MATLAB everything is coded manually while Aspen Plus has built in mathematical relationships based on the chemical properties of the compounds. The model was successfully implemented into the two simulation programs and the outputs where compared with data from experiments obtained from literature. To improve the model further experimental values are required. Suggestions for improvement of the simulation tools are to add cost and energy calculations as well as waste management.