Best practice in waste water technology: Phosphorus recycling by electroflotation

Abstract

The aim of this work is to prove that electroflotation can do much more than simply purify waste water. Its potential can be attributed to electrochemically produced, flocculable hydroxides of iron and aluminium. Because these also form poorly soluble phosphates, phosphate elimination from waste water was an obvious research goal. Thus, with a phosphate input of up to 20 mg/l, we were able to remove approx. 99% of the phosphate from the waste water using electroflotation. The phosphate purification brought to our attention the issue of "phosphorus recycling" and its importance in combating a global fertiliser crisis that has only been further exacerbated by the war in Ukraine. We were fascinated by the idea of giving new impetus to phosphorus recycling by further developing electroflotation from an elimination to a recovery strategy.

Phosphorus recycling starts with electroflotation, whereby the use of Al electrodes proves to be advantageous. In waste water treatment plants, phosphate is commonly separated through the addition of flocculating agents. In both processes, it is attempted to convert the redissolved phosphate into the fertiliser salts magnesium ammonium phosphate (MAP) and calcium phosphate (Ca-P).

The advantages of the innovative electrochemical electroflotation method became clear when we compared it with the wet chemical flocculating agent method. We started by investigating the influence of the amounts of substance on the optimal precipitation of aluminium phosphate and the fertiliser salts Ca-P and MAP. We then determined the recovery rates. These are 20–30% higher with electroflotation than with the flocculating agent method. In terms of raw materials, precipitation with aluminium sulphate is approx. 10–12-fold more expensive than electroflotation with Al electrodes. That was one impressive result of our electroflotation study. We then tested the quality of the fertiliser salts obtained. It turned out that the Ca-P was phosphate lime with hydroxyapatite as the main component. The pure MAP content in the MAP obtained is approx. 75%. To our knowledge, the synthesis of MAP from aluminium phosphate has not yet been described.

Discussions with experts led to the development of a new recovery strategy that defines phosphoric acid as the target product of phosphorus recycling from waste water. This is in line with the recognition that phosphoric acid is well established as a platform chemical and has a broad range of applications. Phosphoric acid is also recommended as a target product for recycling because it considerably simplifies the process. The further processing of the output can then be designed in an open manner. The process is reduced to electroflotation with iron electrodes, the digestion of the precipitate, and the separation of the iron ions with ion exchangers, which are known from standard processes in waste water technology. Using a strongly acidic cation exchanger, it was possible to reduce the high iron content of the digested precipitate to zero in two passes through a chromatography column. With another strongly acidic resin, four passes were required. A combination of a less expensive anion exchanger and a strongly acidic cation exchanger also led to an iron-free solution after two passes. The concentration of the phosphoric acid obtained is 0.07% by weight with a recovery rate of 60–70% based on the phosphate input. The seemingly low concentration is due mainly to the small scale of the process at the school laboratory scale. It should be possible to further increase the concentration within the framework of process management.