



Recovery of Phosphorus from Sewage Sludge and Subsequent Purification Using Reactive Extraction.

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Highlights

- Development of new process for the recovery of phosphorus from partially or fully dried sludge
- Removal of heavy metals during purification by reactive extraction
- Solid-liquid equilibrium modelling in MATLAB for process optimization

1. Introduction

Phosphorous (P) is an essential element for life and has a limited availability in nature. Mineral P is mainly produced from phosphate rock, which was classified by the European Commission as a critical raw material in 2014. As a result, significant research has been directed towards finding economical ways of recycling P from waste streams which otherwise would be lost to landfills. The Phos4You (P4Y) project, funded under the Interreg North-West Europe Program, is aiming at improving the recovery potential of P from municipal wastewater and sludge, which could substitute for about 26% of mineral P demand in NWE.

In the framework of the P4Y project 6 different technologies for recycling of P will be demonstrated on pilot-plant scale. The university of Liège is developing one of the processes to be demonstrated which is called the PULSE (Phosphorus ULiège Sludge Extraction) process to recover P from fully or partially dried sewage sludge. The PULSE process is a modification of the PASCH process developed at RWTH Aachen to extract P from ashes obtained by incineration of sewage sludge [1]. Acidic extraction (leaching) of sludge or ashes is one of the most common method used for recovering P, however one big challenge is that the acidic leaching also results in dissolution of detrimental metals. Therefore, the removal of metals or purification of leach liquor is required before proceeding to the final step where final P products can be obtained either as salts of calcium or magnesium (struvite) by precipitation or as phosphoric acid.

2. Methods

At ULiège, the recovery of P from partially or fully dried sludge is carried out using acidic leaching. The process is optimized by systematic variation and combinations of different acids, pH, concentration of oxidizing agent, and drying levels. For the purification of the leach liquor, two approaches are tested using reactive extraction: extraction of metals from the leach liquor and extraction of P itself while leaving behind the metals in the aqueous phase. For this purpose, different extractants have been selected based on their extraction mechanism and tested for extraction efficiency. Further, different diluents were tested in order to find the best option in terms

of efficiency of extraction and toxicity, which are compared to at least one bio-diluent such as bio-diesel. Finally, depending on the extraction approach used above, the final product of the PULSE process can either be obtained as phosphate salt or phosphoric acid.

In the first part of the research, the experiments for determining the best process options for each of the unit operation of the PULSE process are conducted at lab-scale applying the cascaded option-tree methodology [2] for guiding through the process development. A solid-liquid equilibrium speciation model developed in MATLAB is used for optimizing process parameters for leaching, extraction, and precipitation.

3. Results and discussion

The leaching of P from dried sludge mainly depends on the pH of the leaching solution, while the type of acid used has little to no influence. The degree of drying and the drying temperature also affect the leaching of P. For the removal of metals, different extractant and combinations were tested. The extraction of metals strongly depends on the type of extraction mechanism, pH of the aqueous phase and also the metal complexes that exist in the aqueous phase. The code written in MATLAB simulates the pH and complexes existing at the corresponding pH. This information is further used to optimize the process conditions.

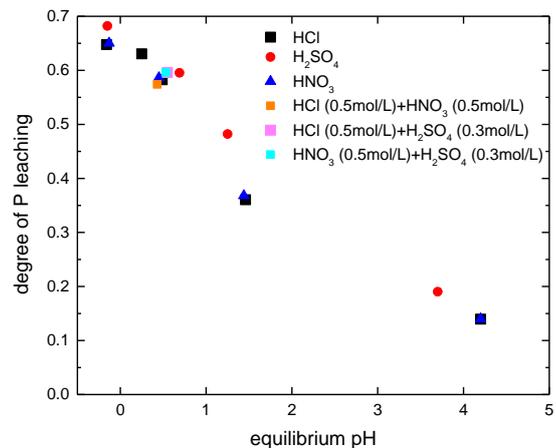


Figure 1. degree of P leaching from fully dried sludge with different acids

4. Conclusions

Drying results in ease of handling and storing of sludge, reduces the consumption of acid required for leaching and also filtration of solids after leaching is much easier. The leaching of P from undigested sewage sludge is optimal at a very low pH < 1. At this pH other metals and heavy metals are also leached, which have to be removed before producing the final P product. In the PULSE process metals are removed by using reactive extraction and finally salts of calcium phosphate are precipitated.

References

- [1] Doetsch, P., Pinnekamp, J., Montag, D., Rath, W., Grömping, M., 2010. Rückgewinnung von Pflanzennährstoffen, insbesondere Phosphor aus der Asche von Klärschlamm. Institut für Siedlungswasserwirtschaft, RWTH Aachen, Aachen.
- [2] Bednarz, A., Rüngeler, B., Pfennig, A., 2014. Use of Cascaded Option Trees in Chemical-Engineering Process Development. Chem. Ing. Tech. 86, 611-620.