Treatment of Phosphoric Acid Sludge for Rare Earths Recovery I: Effect of Polymeric Flocculant Properties on Filtration and Recovery

Ghazaleh Allaeddini, Florida Polytechnic University, Lakeland, USA
Patrick Zhang, Florida Polytechnic University, Lakeland, USA

ABSTRACT

A total of nine polymers were first tested. Correlations between molecular weight and sludge settling rate were identified for three types of polymers with a general trend of higher molecular weight giving a faster settling rate. Among the non-ionic polymers, the medium molecular weight polymer produced the best results (1831.88 ppm). Among the cationic flocculants, the lowest molecular weight polymer resulted in more REEs distribution (2478.81 ppm). It was concluded that the super high molecular weight of anionic flocculants works best for treating phosphoric acid sludge which resulted in REE concentration of 2568.69 ppm. Five co-polymers with different anionic ratio were tested as well. A higher anionic ratio resulted in faster settlement. It was found that the higher was the anionic ratio of the flocculant, the higher was REE concentration in the final solids and the highest anionic ratio polymer resulted in 2999.64 ppm of REE. This trend was attributed to zeta potential change due to addition of the polymer.

KEYWORDS

Anionic Ratio, Molecular Weight, Phosphoric Acid Sludge, Polymeric Flocculant, Rare Earths

INTRODUCTION

There is an ever-increasing demand for phosphorous as the world’s population expands. Since high-grade resources are depleting rapidly, researchers are motivated to design and develop new methodologies to extract phosphates from low-grade ores and other secondary resources. Tailings and wastewaters produced from the phosphate industry are the main secondary sources of phosphates (Alsafasfeh et al., 2017).

Phosphate is not only a necessary resource for plants growth and fertilizer industry, but also a significant secondary resource for many critical materials such as rare earth elements, uranium, magnesium and thorium (Zhang, 2014). These elements play an important role in green energy and high-tech industries. In order for the phosphoric acid to be suitable for high-grade phosphate fertilizer, such as di-ammonium phosphate (DAP), production, washing and floatation are generally required.
for upgrading P₂O₅ content and reducing gangue materials in the phosphate rock product extracted from phosphate ore. After desliming and sizing, the phosphate flotation feed is conditioned with fatty acids and fuel oil. Then, the apatite, which is one of the main minerals of phosphate rock, is floated from silica and carbonates in the rougher stage. The rougher concentrate is scrubbed with acid using a dilute sulfuric acid solution in order to remove the collector adsorbed on apatite particles. Then the rougher concentrate undergoes cleaner flotation with a cationic amine collector. In this step, silica is floated out leaving apatite in the sink fraction, which constitutes the final product. P₂O₅ in the rougher concentrate is 18.5-25% usually, and a cleaner concentrate contains around 30% P₂O₅ (Zarrinpour et al., 2009).

Mine tailing and industrial residues from phosphate processing streams are potential resources for recovering rare earth elements (Binnemans et al., 2009). There have been many studies for enhanced filtration of phosphoric acid sludge and recovery of rare earths. One of the methods, which has been reported, is using polymers as flocculant agents.

In the Wet Process phosphoric acid manufacturing process, the final phosphate rock product from the beneficiation plant is ground, followed by acidulation using sulfuric acid in the so-called attack tanks. This results in a slurry of calcium sulfate crystals, known as phosphogypsum in the industry, and phosphoric acid. The slurry is filtered, usually using a pan filter. The phosphogypsum is washed two to three times and pumped to the disposal site. The filter acid typically contains 28-30% P₂O₅. More often than not, the filter acid is further concentrated to about 54% P₂O₅ by evaporation. During the evaporation process, insoluble solids of aluminum, iron, magnesium and calcium, as well as other salts, precipitate out of solution gradually as P₂O₅ increases. The concentrated phosphoric acid slurry containing the solid precipitates is treated by either centrifugal separation or settling to achieve solid-liquid separation. The resulting thick material is called phosphoric acid sludge. Based on studies by the FIPR Institute and others, the solids in phosphoric acid sludge contains the highest REE concentration among the various phosphate mining and processing streams. As can be seen from Table 1, total REE content in solid fraction of the Florida phosphoric acid sludge is generally over 2000 ppm.

Based on analysis of several sludges from a Florida operation, the phosphoric acid sludge slurry averages about 20 solids. This indicates that the phosphate value in this slurry is much higher than that of REEs based on the current prices. Therefore, any attempt to recover REE from the sludge must ensure maximum recovery of the P₂O₅ value in order to improve the overall economics, which requires separation of the acid from solids. Due to its high viscosity, the phosphoric acid sludge presents one of the most difficult solids-liquid separation challenges Sanders et al., 2013; Pillasi et al., 1993; Rey et al., 1993; Malito et al., 1993).

Polymers are attached simple monomers that are polymerized into high-molecular-weight substances with molecular weights in the range of 10⁴ to 10⁶ Da (Metcalf and Eddy, 1991). Polymers are differentiated based on their molecular weight, structure whether being linear or branched, amount and type of charge, and compositions (Wakema and Tarleton, 1999). Polymers used as flocculants bring together the coagulated particles into larger aggregates or flocs and prepare them for settling or enhanced filtration. Depending on the charge type, flocculants can be neutral, anionic or cationic.

The conditioning of sludge filter feed with high molecular weight polyacrylamide and acrylamide/sodium acrylate copolymer to improve filtration rates has been previously reported in the literature (Zhao et al., 2017; Symens et al., 1981; Bratby, 2006; Chen et al., 2016; Moody, 1992; Lee et al.,

Table 1. Rare earths concentration (ppm) in various phosphate mining and processing streams

<table>
<thead>
<tr>
<th>Sample</th>
<th>Clay</th>
<th>Amine Flotation Tails</th>
<th>Phosphogypsum</th>
<th>Phosphoric Acid</th>
<th>Sludge 1</th>
<th>Sludge 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total REE</td>
<td>287.62</td>
<td>199.48</td>
<td>153.75</td>
<td>71.66</td>
<td>2160.00</td>
<td>2211.88</td>
</tr>
</tbody>
</table>


Related Content

Study on Oxidation of Stainless Steels During Hot Rolling
www.igi-global.com/article/study-oxidation-stainless-steels-during/51373?camid=4v1a

Stochastic Methods Applied to Structural Mechanics: Reliability and Optimization Methods
www.igi-global.com/chapter/stochastic-methods-applied-to-structural-mechanics/203764?camid=4v1a
Al2O3 Nanobricks via an Organic Free Route Using Water as Solvent
www.igi-global.com/chapter/al2o3-nanobricks-via-organic-free/67790?camid=4v1a

Tribology of Thermally Sprayed Coatings in the Al2O3-Cr2O3-TiO2 System
www.igi-global.com/chapter/tribology-of-thermally-sprayed-coatings-in-the-al2o3-cr2o3-tio2-system/128076?camid=4v1a