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A novel synergistic bioleaching approach to phosphor powder recycling

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Abstract: Efficient scalable rare earth separation processes are a topic of great importance as technologies such as renewable energy and electrical vehicles begin to take root. To assist in the amelioration of this issue this paper reports a method by which low pH and high pH leaching are used synergistically to separate rare earth elements from phosphor powders.

Keywords: Phosphor Powder, *A. chroococcum*, *At. ferrooxidans*, Yttrium.

1. Introduction

The rare earth elements are a group of 17 D and F block metals characterized by their highly similar levels of reactivity, coexistence in ore and ubiquity in many industrial fields ranging from glass and ceramics manufacturing to lighting to nuclear reactor cladding. Presently there is little recycling of these materials necessitating the constant refinement and production of replacement materials sent to landfill. The current industrial best practices for the refinement and separation of rare earth metals from ore rely on solvent extraction and froth filtration. While effective these methods leave much to be desired. Owing to their high levels of water consumption and potential to leach acidic and corrosive substances into the environment. As such there is a great impetus to develop novel methods for the separation of rare earth metals from previously underutilized feedstocks (Owusu-Fordjour and Yang, 2023).

Currently approximately 10% of the worlds REE waste is produced from waste phosphor powder tubes. These tubes contain a high quantity of the relatively scarce and expensive metal Yttrium along with lower concentrations of Europium and Terbium

Azotobacter chroococcum is a non-symbiotic nitrogen fixing soil dwelling bacterium. Nitrogen is a key nutrient which is vital for plants to thrive, due to the nitrogen fixation of this bacteria as ammonium hydroxide been used in recent studies assessing viability for improved plant health in the agriculture industry (Wani et al 2013).

As a result of our labs capability to leverage acidophile and nitrogen fixing bacteria divalent leaching methodology was created with the intention of identifying differential leaching effectiveness. Previous research has identified the ease with which rare earth oxides can be solubilized using iron catalyzed acidic leaching however the previously mentioned aluminates and phosphates represent a challenge to conventional acidic leaching. Furthermore, while acidic leaching can separate industrially relevant and useful metals such as Yttrium and Europium there is a marked problem with dissolution and precipitation of base metals. Consequently, any pretreatment step utilizing ammonia capable of solubilizing previously coprecipitated base metal contaminants would represent an effective pretreatment to allow for a higher quality of biological rare earth product to be created. With this aim this paper demonstrates a novel two stage leaching method to separate aluminium from rare earth aluminates prior to leaching with the aim of increasing rare earth yield.

2. Methodology

Acidophilic bacteria were cultured according to Duffield-Healy and Farnaud, (2023). Ammonia producing bacteria were cultured in ATCC media 964 according to ATCC protocol. 1% solid mass of phosphor powder waste was added to the media in two stages. First the high pH ammonia leach then a second low pH acid leach. The same powder was carried over during this process. Each leach lasted 48H at 160RPM and 30oC. Leachate metal composition was measured using an ICP-MS.

3. Results

Figure 1 represents the recorded metal concentrations following 48 hours of leaching under both high and low pH conditions

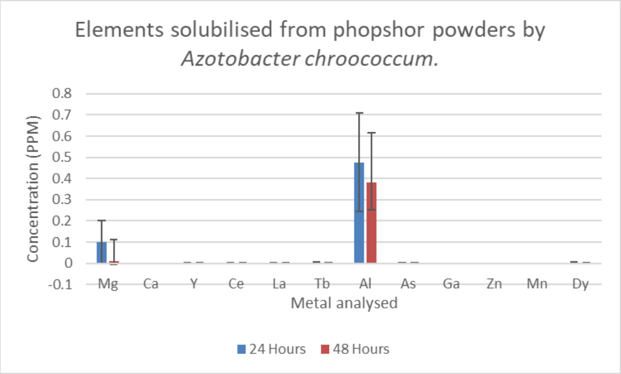
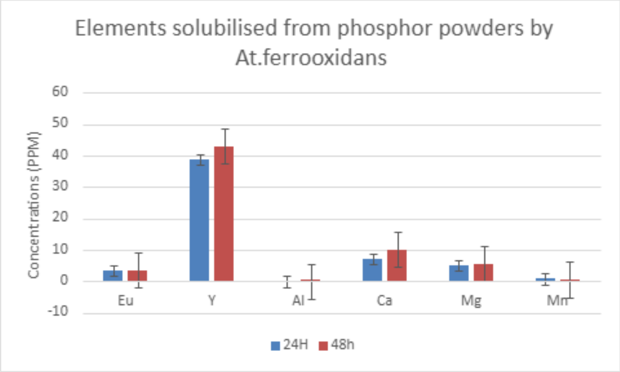


Figure 1. concentration of metals solubilized during 48 hours of leaching under high pH biogenic ammonia leaching

As seen in figure one high pH leaching did not solubilise a large amount of material. Instead, only a small quantity of aluminium was solubilised from the feedstock. The quantity of material was unchanged between 24H and 48H. Following high pH leaching an additional round of low pH leaching was performed using low pH biologically produced sulfuric acid in the presence of 30mM of trivalent iron. Figure 2 displays the quantity of material recovered



As seen in figure two low pH leaching of the phosphor powder material yielded a wider array of elements solubilized including large quantities of Europium and Yttrium as reported previous publications. Additionally small concentrations of Aluminium, Calcium magnesium and manganese were detected. No statistically significant shift in metal concentration was recorded between the two timepoints measured.

4. Discussion

As displayed in figure one, due to the comparably high pH nature of the *Azotobacter* media and ammonium hydroxide produced by the bacteria, metals present in the substrate likely precipitated out of solution except for small concentrations Al and Mg. After the first 24 hours pH was around 9 and the concentration of Al was 4.7g/L, after the subsequent 24 hours the concentration of ammonia in solution increased and the value of Al decreased, showing precipitation of the metal. The low pH solubilisation of the phosphor powder in iron catalysed biogenic sulphuric acid resulted in the rapid solubilisation of the main metal oxides present in the power, namely Calcium Europium and Yttrium. Further analysis may benefit from the comparison of the yield calculated in this paper and from phosphor powder solubilisations performed without a pre-treatment step.

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