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The optimization and comparison of a cerium salt-based phosphate filtration system to industry standard phosphate removal water filtration systems

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Phosphorus is one of the fundamental building blocks for biological molecules. Phosphorous removal from water is required at many wastewater treatment plants as phosphate helps encourage growth of industrial bacterial organisms. To adhere to federal regulation on phosphorous removal, most industrial wastewater treatment facilities rely on either aluminum or iron based systems to remove the excess phosphorous in the form of reacted phosphate. The main drawback of these traditional systems is that they require a large amount of coagulants to process their phosphorous-metal products. In this experiment our team evaluated the reactivity of the cerium chloride and phosphate ions in multiple conditions to optimize the yield and flocculation of cerium phosphate crystals.

\[ \text{CeCl}_3(aq) + \text{PO}_4^{3-}(aq) \rightarrow \text{CePO}_4(s) + 3\text{Cl}^- (aq) \]

**Background pH Analysis**

Concentration & Filtration Analysis

**Hypothesis**

The ideal reaction conditions for cerium phosphate generation would be at a 1:1 ratio in a basic environment at approximately 8 pH. Filtration can be avoided with the use of coagulants and flocculants.

**Aims**

- Identify the most significant reaction variables for cerium phosphate production.
- Evaluate the effect of reagent concentration, filtration and pH has on cerium phosphate production.
- Evaluate the success of coagulants and flocculants on cerium-phosphate crystals in lab-grade, municipal and industry waste water.
- Conduct a financial analysis on the cost of a cerium salt-based phosphate removal system to standard industry phosphate removal methods.

**Methods**

The concentration studies were conducted with the use of 1000 ppm solutions of CeCl₃ and Na₂HPO₄. The reactions were evaluated after mixing and a 10-20 minute settling time. The reacted solutions were analyzed through Inductive Coupled Plasma Mass Spectrometry (ICP-MS). The filtration experiments were conducted with the use of thermo Scientific syringe filters. Both the filtration and concentration studies utilized a Design of Experiment and JMP software to determine the best reaction parameters. Standard water treatment coagulants were tested on reacted cerium phosphate solutions to evaluate the settling properties of the produced flock.

**Concentration & Filtration Analysis**

**pH Analysis**

**Proposed Treatment Design**

**Figure 1:** The ratio of cerium chloride (ppm) to dissolved ortho-phosphate (ppm) was tested with a decreasing filter size.

**Figure 2:** The pH of a 1:1 molar reaction between cerium chloride and dissolved ortho-phosphate was increased with a decreasing filter size.

**Figure 3:** PO₄ percent removal from pure environment lab grade water

**Figure 4:** PO₄ percent removal in James River Water

**Figure 5:** PO₄ percent removal from Reservoir Water

**Figure 6:** PO₄ percent removal from ChemTreat customer water

**Figure 7:** Displays the designed process flow diagram of a cerium salt-based water treatment plan.

This process consists of evaluating the phosphate concentration of the flock in a clarifier. Additives will be dependent on water source.

**Next Steps**

For the continued development of the cerium salt phosphate removal system, the reaction flocking agents need to be continually analyzed with each different water source. To support this system, investigation into the recycling of cerium from cerium phosphate should be investigated.

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