Fluoride Ions Removal from Photovoltaic Industry Wastewater by FAU Zeolite Synthesized from Coal Fly Ash

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Keywords: fly ash, zeolite, wastewater treatment, solid waste management.
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Introduction

Water pollution is one of the most important ecological challenges that humanity faces, since clean water sources are scarce and current levels of pollution are not sustainable. Being aware of the fact, strict environmental regulations regarding wastewater management are being introduced by policymakers to the industries. In wastewater contamination, one of the most significant pollutants is hydrofluoric acid (HF), which is extensively utilized in many industries, such as feldspar processing, aluminum finishing, and PV manufacturing (S. Sengupta et al.2021). A typical wastewater sample from a local PV manufacturer contains fluoride concentrations ranging from 400 to 2000 mg/L. The presence of fluoride in certain aquatic systems raises health concerns globally. Because of its high toxicity, industrial wastewater with fluoride content is subject to strict regulations. The accepted discharge standard in Turkey is 20 mg/L from wastewater treatment plants.

There are many efforts for the removal of fluoride by various porous adsorbents (S. Sengupta et al. 2021). Among them, zeolites have a large surface area, and also, due to the presence of pores in their structure, they tend to have high sorption efficiency when used as adsorbents. Additionally, zeolites have positively charged ions such as Na^+, K^+, and Ca^{2+} inside their pores, which can help increase the adsorption of anions like fluoride. Although some natural zeolites have been extensively studied in the literature, there are few attempts to use synthetic zeolites for wastewater treatment due to high costs.

Coal fly ash is a waste generated from coal combustion in thermal power plants, and it consists of fine, powdery particles rich in various oxides, such as silica (SiO_2), alumina (Al_2O_3), hematite (Fe_2O_3), and lime (CaO). Being a byproduct of a mainstream electricity production process, its abundance poses significant environmental challenges due to the sheer volume generated and the potential for environmental contamination. However, fly ash also presents a valuable opportunity for resource utilization, as it contains precious components that can be harnessed for beneficial applications. Fly ash can be utilized in construction as a low-cost adsorbent for removing organic compounds, flue gas and metals, lightweight aggregate, mine backfill, road sub-base, and zeolite synthesis (Ahmaruzzaman et al. 2010). With the unique properties of zeolites and their wide-ranging applications, the integration of fly ash into zeolite production has garnered significant attention.

In this study, FAU-type zeolite was synthesized from fly ash, which is waste from coal combustion from a thermal power plant in Turkey.

Methodology

Fly ash samples were mixed with 5M HCl solution at a solid-liquid ratio of 1:5 and stirred under 90°C for 2 hours. Then, samples were washed with DI water and dried at 60°C overnight. Acidified fly ash samples were mixed with ground NaOH at 1:1.2 mass ratio and then placed in ceramic crucibles and fused at 750 °C for 2 hours with a heating rate of 10 °C/min to activate zeolite precursors. For zeolite synthesis, fusion products were stirred with water in HDPE bottles at room temperature for 12h. The reactions were performed in HDPE bottles in a preheated oven at 95 °C for 12 hours. The reaction products were washed with DDW and dried in the oven at 60 °C.

100 mg of prepared FAU-type zeolite and commercially modified natural zeolite purchased from ZEOCELL was mixed with the 100 mL wastewater containing an initial fluoride concentration of 424 mg/L and stirred for 30 minutes at room temperature. Then, the wastewater was separated by vacuum filtration, and the fluoride amount was analyzed using a Hach DR3900 Laboratory VIS Spectrophotometer.

Results

FAU-type zeolite synthesized from fly ash and commercially modified natural clinoptilolite zeolite was used for the removal of fluorine ions in the prepared wastewater. The same amount of adsorbent types are added to the same amount of wastewater. Fluorine removal efficiencies are calculated by,

$$Efficiency\ (\%) = \frac{Initial\ \ Fluorine\ Content\ -\ Final\ Fluorine\ Content}{Initial\ Fluorine\ Content}$$

The preliminary results given in Figure.1 showed that the fluorine removal efficiency of FA-type zeolite synthesized from fly ash was significantly higher than that of commercially modified natural zeolite.

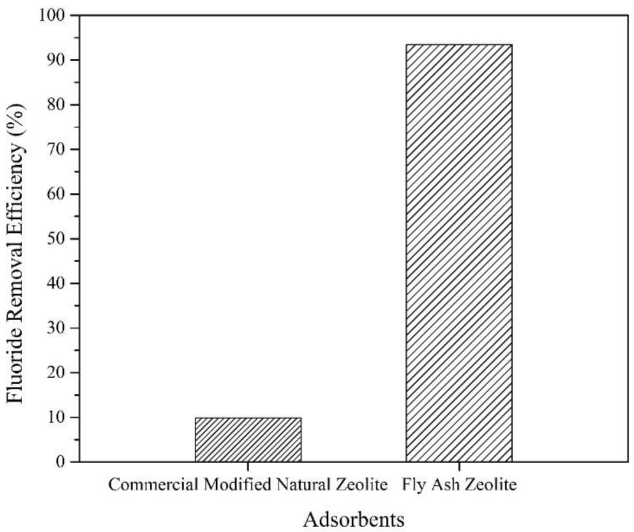

Figure.1. Benchmark study made between zeolite synthesized from Fly Ash and commercial sample. Fly Ash zeolite synthesized performed with 93% efficiency for pollutants removal.

Conclusion

Zeolite sample produced using fly ash have shown promising performance for wastewater treatment. Using fly ash as a source of zeolite production leads to a sustainable process since fly ash is a polluter byproduct of coal power plants. By removing water pollutants using an air polluter, inexpensive, circular, and environmentally friendly practices can be achieved in industry. Moreover, producing fly ash zeolites for specific pollutant removal processes is more straightforward than modifying natural zeolites since post-treatment of natural zeolites is a more complicated and expensive process.

Solar-assisted fly ash zeolite wastewater treatment can be further implemented to speed up the pollutant removal process, allowing a larger-scale removal process in real-life industrial implementations.

References

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