

Treatment of Real Textile Wastewater Using Activated Carbon-Modified and Hydrogen Peroxide-Foamed Fly Ash-Based Geopolymer Adsorbents: Optimization of Operating Parameters

Murat Kasaplar

Institute of Graduate Studies, Environmental Sciences, Eskisehir Technical University, Eskisehir, Türkiye

Umrhan Tezcan Un

Faculty of Engineering, Department of Environmental Engineering, Eskisehir Technical University, Eskisehir, Türkiye

Evren Arioç

Faculty of Engineering, Department of Chemical Engineering, Eskisehir Technical University, Eskisehir, Türkiye

Abstract

This study investigates the synthesis and adsorption performance of novel fly ash-based geopolymer adsorbents modified with activated carbon (AC) and hydrogen peroxide (H_2O_2) as a foaming agent for the treatment of textile industry wastewater. In line with sustainable waste valorization principles, waste fly ash obtained from the Çatalağzı Thermal Power Plant in Zonguldak, Türkiye, was reutilized to produce five geopolymer formulations with systematically varied porosity and additive compositions. The formulations, designated as 2H20AC, 3H20AC, 4H20AC, 4H30AC, and 4H40AC, were synthesized by varying the hydrogen peroxide (H_2O_2) content (2–4 g) and activated carbon (AC) loading (20–40 wt%).

The adsorption performance of the synthesized materials was evaluated using real textile effluent collected from a textile manufacturing facility located in Bursa, Türkiye. The removal efficiencies of chemical oxygen demand (COD) and color were assessed under different operational conditions, with particular emphasis on the optimization of solution pH and adsorbent dosage to elucidate their roles in the adsorption mechanism. The results demonstrated that color removal efficiencies remained consistently high (>90%) across a broad pH range (3–9), indicating strong structural stability and surface functionality of the geopolymers. In contrast, COD removal exhibited a pronounced dependence on pH, reaching its maximum efficiency under mildly acidic conditions (pH 5).

Adsorbent dosage optimization revealed that increasing the dosage from 0.50 g to 1.50 g significantly improved removal performance, attributable to the increased availability of active adsorption sites, particularly within the highly porous 4H-series formulations. Among the tested materials, 4H40AC exhibited the highest performance, achieving 97.58% color removal and 89.02% COD removal at a dosage of 1.50 g.

The findings demonstrate that AC-modified, highly porous geopolymer adsorbents derived from industrial waste materials offer a cost-effective, sustainable, and efficient approach for the removal of organic contaminants and dyes from complex textile wastewater matrices, particularly under controlled mildly acidic conditions.

Keywords

Geopolymers, fly ash, activated carbon, textile wastewater, adsorption, COD removal.