

DEVELOPMENT OF BIOMASS BOILER ASH-BASED ADSORBENT FOR TEXTILE DYE REMOVAL

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The textile industry releases dye-contaminated effluents that pollute water and generate biomass boiler ash as solid waste, both of which demand sustainable management. This study investigated the use of biomass boiler ash generated from a rubber wood-fired boiler at an apparel factory in Colombo, Sri Lanka, as a low-cost adsorbent to remove Asahifix Red XP-3BF (Reactive Red 194 dye or AR dye), both sourced from the same factory. Two types of biomass boiler ash: Boiler Bed Ash (BBA) and Wet Bottom Ash (WBA), were collected, oven-dried, sieved, and tested for dye adsorption potential. Preliminary tests revealed that BBA achieved a higher removal efficiency (63.06%) of the AR dye compared to WBA (32.32%). Therefore, subsequent studies were performed using BBA. The effects of adsorbent dosage, shaking time, settling time, and dye concentration were evaluated under controlled laboratory conditions with 10 mg L⁻¹ initial dye concentration at an ambient temperature. Results indicated that the highest AR dye removal of 98.2% is achieved at 10 g L⁻¹ adsorbent dosage. However, 4.0 g L⁻¹ dosage, showing 54.3% was selected as the optimum dosage to compromise the adsorbent load for large effluent volumes, thereby balancing sustainable performance and material economy. Further, the optimal shaking and settling times were identified as 60 min and 20 min, respectively. Dye removal decreased with the increase in the initial dye concentration, from 82.1% at 5 mg L⁻¹ to 13.2% at 50 mg L⁻¹. X-ray fluorescence analysis of fresh and spent BBA adsorbent revealed the emergence of 12% potassium in the spent material, confirming successful adsorption of AR dye. Adsorption behavior fitted to the Langmuir isotherm model ($R^2 = 0.9681$), indicating monolayer adsorption on a homogeneous surface with a maximum adsorption capacity (Q_{\max}) of 1.72 mg g⁻¹. Separation factor (R_L) values ranging from 0.018 to 0.155 confirmed that the process was favorable. The study demonstrates a circular economy and sustainable practice through utilising waste from the same source, ensuring a cost-effective, eco-friendly, and reliable treatment approach.

Keywords: Adsorption isotherms, Biomass boiler ash, Circular economy, Textile dye removal, Wastewater treatment