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Low-Cost Sustainable Dye Removal from Textile Wastewater Using Banana Husk-Derived Activated Carbon

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Abstract

The textile sector, particularly Sri Lanka's Batik industry, produces highly colored wastewater containing reactive dyes that are resistant to degradation and pose significant environmental risks. Small and medium enterprises (SMEs) in this sector often lack access to affordable treatment systems. This study developed a low-cost, sustainable dye removal technology using banana husk (*Musa* spp.) derived activated carbon and compared its performance with rice husk (*Oryza sativa*) based activated carbon. Both agricultural wastes were chemically activated with phosphoric acid and characterized using Fourier-Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM). Adsorption behavior was examined under batch and fixed-bed column conditions. The banana husk adsorbent achieved a maximum dye removal efficiency of 94.6% and a Langmuir adsorption capacity of 82.3 mg g^{-1}, surpassing rice husk (68.4% and 54.1 mgg^{-1}, respectively). The Langmuir model provided the best fit (R^2=0.982), confirming monolayer adsorption on a relatively homogeneous surface. Column studies revealed that a bed height of 22 cm and a flow rate of 1.16 mL min^{-1} produced the longest breakthrough time (175 minutes) and the highest overall removal efficiency, with an equilibrium dye concentration reduction exceeding 90%. FTIR analysis showed hydroxyl and carbonyl functional groups responsible for dye binding, while SEM confirmed enhanced porosity and uniform surface morphology after activation. A preliminary cost analysis revealed that the production cost of banana husk-derived activated carbon was approximately 65% lower than that of commercial activated carbon, mainly due to the use of locally available agricultural waste and low energy input during carbonization. This highlights its potential as an affordable and sustainable adsorbent for decentralized wastewater treatment applications. The results demonstrate that banana husk-derived activated carbon is a high-performance, locally available, and environmentally friendly adsorbent suitable for small-scale textile wastewater treatment. Future work should assess regeneration efficiency, long-term stability, and scalability to strengthen its practical application within Sri Lanka's Batik SMEs and similar industries globally.

Keywords: *Banana husk, Activated carbon, Textile wastewater, Adsorption, Batik industry*