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ORIGINAL PAPER

Investigating the removal efficiency of different textile dye classes from wastewater by electrocoagulation using aluminum electrodes

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Abstract
Textile production is one of the largest sectors in the manufacturing industry; however, the textile dyeing process produces a voluminous amount of highly colored wastewater. The dyes used are organic compounds of different dye classes that are stable in an aquatic environment with low decomposition rates. This study investigated the removal efficiency of five textile dyes of different dye classes (Disperse Orange 30, Acid Blue 324, Basic Yellow 28, Reactive Black 5, Vat Brown 1) from wastewater by electrocoagulation (EC) process that was equipped with aluminum electrodes. EC process achieved 91.98, 98.13, 47.46, 92.55, and 82.60% removal efficiencies for AB324, BY28, VBI, and RB5, respectively, at a current density of 0.83 mA/cm^2. The energy consumption for dyestuff removal was in the following order: DO30 < VB1 < RB5 < AB324 < BY 28. The total operating cost per kilogram of dyestuff removed in 15 min at 0.0502 mA/cm^2 was determined as 0.250, 0.274, 0.550, 0.647, and 0.764 $/kg for DO30, VB1, RB5, AB324, and BY28, respectively. The removal mechanism was well fitted to the pseudo-first-order kinetic model with R^2 above 0.94 for AB324, BY28, and RB5 dyes. However, the removals for DO30 and VBI dyes were exponential and neither fitted the first-order kinetic nor second-order kinetic model. The overall removal trend was as follows: DO30 > VB1 > AB324 > RB5 > BY28. Therefore, the use of dyes that can easily be removed from wastewater should be encouraged to preserve the quality of water in the receiving environments and to reduce the cost of wastewater treatment.

Keywords Electrocoagulation · Aluminum electrodes · Textile dyes · Operating cost

Introduction

The textile and dye manufacturing industry is a major producer of wastewater, responsible for over 20% of global wastewater production (Brar et al. 2019; Velusamy et al. 2021). More than 10,000 dyestuffs are used in the textile industry, and over 280,000 tons of dye is discharged to the receiving environments annually (Maas and Chaudhari 2005). Textile industries use different classes of dyes, which are often composed of large aromatic molecules with many linked rings. Three common dye classifications are: (1) reactive dyes; (2) disperse dyes; and (3) acid dyes (Chicatto et al. 2018).

Reactive dyes are anionic and soluble in water, form covalent bonds with fibers, and are mainly applied to rayon and cotton. The acid dyes are water-soluble anionic compounds, which attach to fibers via ionic bonding, van der Waals forces, and hydrogen bonding. The acid dyes are mainly applied to wool and nylon in an acidic medium. On the other hand, disperse dyes are a dispersion of finely ground powders applied to oleophilic fibers and polyesters. Most of the dyes are complex organic molecules that are thermodynamically stable and resist degradation by oxidizing agents and microbes (Gupta et al. 2014; Dai et al. 2018). The wastewater discharge from the textile industry is highly colored even in very small dye concentrations (Suresh et al. 2014). Highly colored wastewater obstructs light penetration into the water bodies, hence reducing photosynthesis, and causing oxygen depletion. Besides, wastewater from the textile industry contains toxic heavy

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