Chapter 2

Valorization of Biochar for Efficient Removal of Anionic Dyes From Wastewater:

A Sustainable Approach to Environmental Depollution

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ABSTRACT

This chapter presents an investigation into the valorization of biochar derived from the pyrolysis of Cistus seeds (BS) and shells (BSh) for the removal of AO-52 dye from aqueous solutions. The study explores the influence of factors such as pH, adsorbent dosage, initial dye concentration, and contact time on the adsorption efficiency of BS and BSh biochars. The authors applied various kinetic and isotherm models, including pseudo-first-order, pseudo-second-order, Freundlich, and Langmuir, to analyze the adsorption mechanisms. The results indicate that the adsorption process follows pseudo-second-order kinetics, with the Langmuir model best describing the isotherms. Maximum adsorption capacities of 500 mg g^{-1} and 358.47 mg g^{-1} were observed for BSh and BS, respectively. The findings highlight the potential of biochar from Cistus seeds and shells as an effective, sustainable material for dye removal in wastewater treatment, offering an eco-friendly solution for addressing water pollution in the textile industry.

1. INTRODUCTION

Industrial processes determine the nature of liquid discharges, such as dyes and heavy metals, which have significant impacts on the environment and public health. Current treatments for aqueous effluents include both biological treatments and physicochemical treatments, such as carbon and polymer adsorption (Hwang & Chen, 1993). Morocco, with its extensive forested areas, has a substantial annual biomass production that serves various purposes, including timber (Venkat S. Mane, 2011), firewood (Mazzone et al., 2021), charcoal (El Farissi et al., 2017; Ioannou et al., 2013; Lüddeke et al., 2015), and paper pulp

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production (Sánchez-Gutiérrez et al., 2020). However, the seeds and shells of certain wild biomasses remain largely unexploited, aside from limited use in essential oil production (Haddou et al., 2023).

In this chapter, we present an overview of adsorption phenomena, general information on dyes, and activated carbon, and a study of the adsorption efficiency of biomass (seeds and shells of *Cistus ladaniferus*) and their activated carbons synthesized from forest residues for purifying dye-contaminated aqueous solutions (Acid Orange 52 (AO-52)) (Yahia et al., 2012). Initially, we examined the influence of various parameters on adsorption capacity, including contact time, adsorbate concentration, solution pH, and adsorbent dose(El Farissi et al., 2020, 2023). Subsequently, we applied different kinetic models, such as pseudo-first-order, pseudo-second-order, Elovich rate equations, and the intraparticle diffusion model, to simulate the experimental dye adsorption kinetics data. Finally, we studied the adsorption isotherms, whose parameters reveal the surface properties and adsorbent affinity. Adsorption isotherms can be generated based on several theoretical models, including the Temkin, Dubinin-Radushkevich, Langmuir, and Freundlich models, with the latter two being the most widely used."

2. MATERIALS AND METHODS

2.1. Adsorbate and adsorbent

Adsorption is a surface-based process where gas or liquid molecules bind to solid adsorbents, driven by the tendency to reduce surface tension, which also accelerates many chemical reactions. The process is more effective with heavier molecules and smaller adsorbent particles, as these factors enhance the adherence strength. In practical applications, adsorption captures unwanted molecules in fluids or retrieves valuable elements like soluble gold from solutions. For the removal of the anionic dye Acid Orange 52 (AO-52), two specific biochar, BS and BSh, were created through pyrolysis under tailored conditions: BS was formed at 450°C with a heating rate of 21 °C min^{-1} and particle sizes of 0.3 to 0.6 mm (H. El Farissi, R. Lakhmiri, H. El Fargani, 2017), while BSh was produced with larger particles (2–3 mm) at a heating rate of 40 °C min^{-1} (Farissi et al., 2017). Afterward, the biochar was ground to finer particle sizes (0.1– 0.2 mm) to optimize their adsorptive properties. The dye solution for experimentation was prepared by dissolving 0.4 g of AO-52 in 1 liter of distilled water and then diluted as needed to achieve specific concentrations.

Table 1. Physicochemical characteristics of the AO-52 dye

Usual name	**Acid Orange 52 (AO-52)**
Chemical formula	$C_{14}H_{14}N_3S\ O_3Na$
Molecular weight	327.334 $g.mol^{-1}$
Solubility in water	High
λ_{max} (nm)	464

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