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ORIGINAL PAPER

Comparative evaluation of classical and response surface methodologies approaches for 4-nitroaniline adsorption onto flamboyant seed carbon

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Abstract

The flamboyant seed's activated carbon (FSAC) was carefully studied as a promising adsorbent for removing 4-nitroaniline (4-NA) from an aqueous solution. The comparison between classical methods and response surface methodology (RSM) on operating conditions, including initial 4-NA concentration, pH level, adsorbent dose, and adsorption time, was conducted with great care and attention to detail. In the classical approach, the four operating parameters affected the adsorption capacity of FSAC, which increased with higher initial 4-NA concentrations and longer contact times. Adsorption was enhanced at low pH levels, with equilibrium reached at 120 min. In RSM, the amount of 4-NA adsorbed increased as concentrations rose, pH decreased, and adsorbent dosage was reduced. The quadratic model successfully described the relationship between adsorption and the operating parameters ($R^2 = 0.929$). The optimal adsorption capacity of 40.4 mg/g was achieved at 300 mg/L 4-NA concentration, pH 2, 0.1 g of adsorbent, and an adsorption time of 362.5 min. The Freundlich isotherm and pseudo-second-order kinetic models best explain the adsorption process, confirming the thoroughness and reliability of this research.

Keywords 4-nitroaniline · Adsorption · Isotherm · Kinetics · Activated carbon · Pollutant

Introduction

The increased pollution caused by industrial wastewater has rapidly destroyed ecological systems and freshwater sources worldwide (Lai et al. 2018). 4-nitroaniline (4-NA), a by-product of aniline (Fig. 1), is a common toxic pollutant in wastewater from various industries, such as petrochemical sectors, oil refineries, and manufacturers of dyes, pesticides, and glue (Malakootian et al. 2019). This compound serves as an important intermediate in the production of organic compounds like antioxidants, disinfectants, azo dyes, phenylenediamine, corrosion inhibitors, and poultry medicine. It is also used in the purification and synthesis of pharmaceutical drugs. Wastewater from these industries poses a significant pollution concern that demands urgent attention. The United States Environmental Protection Agency (USEPA) has classified 4-NA as one of the top water pollutants, given its carcinogenic, mutagenic, and toxic nature. The threshold limit value (TLV) of 4-NA is 10^{-3} kg/m^3, indicating high toxicity and hazard (Li et al. 2010). It is extremely harmful to humans and aquatic life, causing various health issues such as cyanosis, confusion, and unconsciousness, thereby representing a serious environmental threat (Azeez and Adekola 2016; Malakootian et al. 2019). Therefore, it is crucial to remove 4-NA from wastewater before discharging it into the environment. Several methods employed to remove 4-NA and other organics from aqueous solutions include chemical oxidation (Pacheco et al. 2007), ion exchange (Inamuddin et al. 2019), membrane filtration (Van Der Bruggen and Vandecasteele 2003), and advanced oxidation processes (Sun et al. 2008). However, these methods often suffer from limitations such as low effectiveness, high costs,

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