CHAPTER

6

RESIN-BASED ACTIVATED CARBONS FOR DYE REMOVAL

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6.1 INTRODUCTION

Resin, specifically that is derived from formaldehyde, is a widely utilized industrial adhesive, particularly in the production of exterior-grade plywood, oriented strand board panels and particleboards (Qiao et al., 2016). It is synthesized through polymerization of phenol and formaldehyde in the presence of alkaline catalyst. During the process, electrophilic aromatic substitution at the ortho and para positions of phenol brings about the formation of polymeric chains. Known for its exceptional resistance to water, heat and degradation, it also possesses significant mechanical strength, so preventing delamination in bonded materials.

Despite its valuable properties, formaldehyde resin raises environmental and health concerns. The primary hazard stems from formaldehyde emissions and hydrolytic decomposition of cured resin. Formaldehyde is a volatile, colourless gas associated with adverse health effects, including skin and eye irritation, respiratory distress, migraines and carcinogenic risks. Recognizing its potential harm, the World Health Organization (WHO) classifies formaldehyde as a carcinogen, while the United State Occupational Safety and Health Administration enforces strict exposure limits (Sarika et al., 2020).

The global production of formaldehyde resin exceeds 1 million metric tons annually, generating substantial amounts of resin waste worldwide. While the demand of wood-based products keeps growing, the accumulation of resin waste has become a great challenge to the environment and sustainability (Ren et al., 2022). Many nations have designated formaldehyde resin discards as hazardous (scheduled) due to their slow degradation and difficulty in recycling (Zhong et al., 2017). Conventional disposal methods such as landfilling and incineration are expensive, not sustainable and worst, can result in secondary pollutions. Therefore, efforts have been directed towards repurposing the waste into valuable materials. Alternative strategies such as thermal treatment and pyrolysis have been explored to convert the resin residues into activated carbon for environmental applications.

Activated carbon is recognized as an effective adsorbent because of its high porosity and large surface area, rendering it suitable for various adsorption applications, including water purification, solvent recovery, air filtration, catalysis and precious metal recovery. Typically, activated carbon is produced from carbonaceous materials such as fruit stones (e.g., cherry and apricot stones, grape seeds) and hard shells (e.g., pistachio, almond, and pecan shells) through high-temperature activation (Heidarinejad et al., 2020). Additionally, it can be synthesized through condensation and polymerization of organic molecules (Civioc et al., 2020). Studies have demonstrated that urea-formaldehyde resin can be transformed into activated carbon that exhibits superior methanol adsorption at 915.3 mg/g, attributed to its high microporosity (Su et al., 2020). Formaldehyde resin residues can be repurposed into activated carbon for wastewater treatment applications (Ren et al., 2022). This approach reduces the pollution loads and contributes to environmental sustainability by preventing water and land pollution.

6.2 RESIN-BASED ACTIVATED CARBON

Resin-based activated carbon has gained increasing attention as a promising adsorbent due to its unique physicochemical properties and vast applications in environmental remediation. Derived from synthetic resin, this class of activated carbon offers high surface area and rich surface chemistry, making it suitable for the removal of water pollutants. The valorization of resin residues into activated carbon aligns with sustainable waste management practices, as it mitigates the environmental burden of resin disposal and produces potent material for adsorption applications.

6.2.1 Material Selection and Activation Process

Selection of feedstock is a fundamental step in the production of activated carbon. Typically, activated carbon is manufactured from coconut shells, rice husks, fruit peels, sludges, etc. Often, they are classified as carbonaceous materials. Formaldehyde resin residue (FRR) can be also utilized because of their high carbon content and inherent cross-linked structures. The features provide a strong ground to develop pore networks upon activation.

The activation process, through physical or chemical, is imperative in tailoring the physicochemical properties of activated carbon. Physical activation employs oxidizing gases such as steam and carbon dioxide at elevated temperatures (700°C to 1000°C) to decorate the porosity. In contrast, chemical activation uses dehydrating agents such as potassium hydroxide, zinc chloride, and phosphoric acid at relatively lower processing temperatures (400°C to 700°C) to promote pore formation and introduce functional groups. The choice of activation method affects the yield, specific area and surface chemistry, all of which determine the performance of activated carbon for specific adsorption applications.

When compared with conventional carbon-rich feedstocks, FRR exhibits better structural uniformity and mechanical strength to yield consistent pore development. While the former may introduce heterogeneity due to variations in natural composition, FRR provides a predictable carbon framework for reproducible performance. Accordingly, FRR-activated carbons can achieve greater surface area