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Article

Sustainable Activated Carbon Production from Water Filter Waste Carbon Cartridge: Insights into Adsorption Isotherms, Kinetics, And Mechanisms

Prachi P. Bote, Sneha V. Koparde, Omkar S. Nille, Dilip D. Anuse, Akanksha G. Kolekar, and Samadhan P. Pawar*

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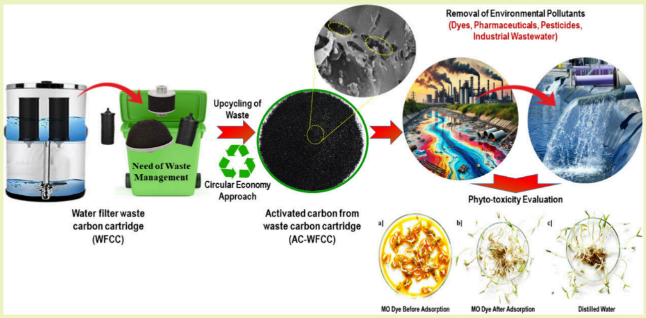

ABSTRACT: In this study, an efficient, sustainable, and environmental waste upcycling approach was employed for the one-step preparation of a chemically activated adsorbent using water filter carbon cartridges (AC-WFCC). The simple chemical activation method provides a straightforward and scalable approach, contributing to both waste management and environmental remediation. AC-WFCC was thoroughly examined using XRD, BET, SEM, HR-TEM, FT-IR, and Raman spectroscopy to confirm its structural integrity and high surface area (922.18 $m^2 \cdot g^{-1}$). It exhibited a maximum adsorption capacity of 306.22 $mg \cdot g^{-1}$ for the removal of methyl orange (MO). The detailed investigational study on the effects of pH, adsorbent dose, contact time, and concentration on adsorption performance was carried out. The adsorption process follows the Redlich−Peterson adsorption isotherm model (R^2 = 0.988) and pseudo-second-order kinetics (R^2 = 0.999). The thermodynamic parameters ΔG, ΔH, and ΔS revealed the spontaneous and exothermic nature of the adsorption of MO by AC-WFCC. Further, a phytotoxicity study on *Vigna Mungo* seeds was performed, and it demonstrates the nontoxic behavior of AC-WFCC with 80 to 100% seed germination in treated dye solution. AC-WFCC was regenerated and reused for up to five successive cycles. Finally, the applicability of the adsorbent was checked towards diverse environmental pollutants with excellent efficacy.

KEYWORDS: *waste upcycling, activated carbon, adsorption, kinetic, thermodynamic, environmental remediation, phytotoxicity*

1. INTRODUCTION

Water pollution due to physical, chemical, or biological factors is causing aesthetic and detrimental effects on aquatic life and human beings. In the last couple of decades, water pollution has become a significant global environmental concern due to the industrial revolution and population growth in developed countries.[1] The increase in population has led to the generation of tremendous amounts of waste, which is beyond the limit of the self-purification capacity of water, and hence accumulation of emerging pollutants into water sources results in various harmful effects. On the other hand, industrial activities also generate significant volumes of wastewater laden with diverse pollutants, posing severe environmental and public health risks. Wastewater generated from industries mainly contains high concentrations of dyes, organic content, heavy metal ions,[2] pharmaceuticals, micro- and nanoplastics,[3] as well as personal care products, etc.[4,5] Among many other industries, the dye industry is the major source of water pollution.[6] The disposal of dyes into effluents affects aquatic life and human beings. These dyes have different classifications on the basis of color, structure, solubility, etc., such as anionic, cationic, and nonionic.[7] The most widely used dyes in textile industries are methylene blue, crystal violet, malachite green, methyl orange, etc.[8−10]

Methyl orange (MO) is a water-soluble synthetic organic azo dye commonly employed as a pH indicator and as a coloring agent in many industries. Its discharge into aquatic ecosystems poses significant environmental and health risks. The vibrant color of MO can hinder light penetration into water bodies, affecting the natural process of photosynthesis and hence disrupting the aquatic food chain. Furthermore, the presence of MO in water causes respiratory tract irritation, skin irritation, gastrointestinal irritation, and eye irritation.[7,10] Hence, the removal of MO dye is essential to mitigate its adverse effects on the aquatic ecosystem, biodiversity, human

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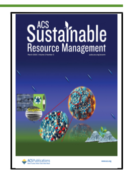

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