Environmental Science and Pollution Research (2025) 32:8643–8669
https://doi.org/10.1007/s11356-025-36253-2

REVIEW ARTICLE

Emerging antibiotic pollution and its remedy by waste based biochar adsorbents: a review

Insha Hamid[1] · Mohsen Ahmadipour[2] · Muthanna J. Ahmed[3] · Masood Ahmad Rizvi[4] · Aabid H. Shalla[5] · Waheed Ahmad Khanday[1]

Received: 4 October 2024 / Accepted: 6 March 2025 / Published online: 14 March 2025

Abstract

One of the pollutants of emerging concern, antibiotics, have been reported in soil, water, sediment, animal manure, food, and even drinking water. Their partially metabolized forms reach wastewater treatment plants (WWTPs) and natural waters wherein the development of antibiotic resistant bacteria (ARB) and dissemination of antibiotic resistance genes (ARGs) have been reported to occur. Antimicrobial resistance (AMR) is projected to cause 10 million deaths annually across the world by 2050 in case stringent measures are not taken. In this study, various methods of adsorptive removal of antibiotics with their critical analysis and emphasis on the application of biochar (BC) and modified biochar derived from waste biomass have been comprehensively reviewed. Also, the antibiotic toxicity, preparation of biomass waste-derived BC adsorbents from cost-effective precursors to ensure sustainability, the adsorption kinetics, isotherm models and thermodynamic parameters have been discussed. It was inferred that biochars are quite efficient in terms of antibiotic removal in water owing to their large surface area, excellent surface characteristics and functionality, facile synthesis and the potential to be regenerated, while being cost-effective and sustainable in nature. This review aims to guide the expansion of research in the aforementioned area of interest and to provide a progressive push towards the development of a circular economy.

Keywords Adsorption · Biomass waste · Biochar · Emerging pollutants · Antibiotic pollution

Introduction

Antibiotics are medications which are used worldwide to combat infections in humans, animals and plants. In addition to their use in disease control and prevention, they are also employed as growth promoters by the livestock and poultry industries (Hellen et al. 2015; Hoslett et al. 2021; Krasucka et al. 2021); despite the fact that this approach of production is prohibited in many nations. The mechanism of action of these drugs is either the inhibition of microbial growth by obstructing multiplication (bacteriostatic antibiotics) or the complete killing off of microbes by interfering with the process of cell wall formation (bactericidal antibiotics) (Etebu and Arikekpar 2016; Krasucka et al. 2021). The ever-growing population and the prevalent spread of infections necessitates the enhanced use of antibiotics all over the world; leading to an increasing demand, and needless to say- magnified production (Zhang et al. 2023a, b). Globally, antibiotics used in animal husbandry account for nearly 70% of the consumption while approximately 30% is attributed to human consumption (Krasucka et al. 2021). A major component of antibiotics taken by an organism- about 30–90%- is excreted without being completely metabolized, leading to the introduction of antibiotics into various environmental components (Krasucka et al. 2021; Mangla et al. 2022; Zhang et al. 2024a, b). Major sources of antibiotic pollution

Responsible Editor: Guilherme Luiz Dotto.

✉ Waheed Ahmad Khanday
khanday.waheed@yahoo.com

[1] PG Department of Chemistry, Sri Pratap College, Jammu & Kashmir, 190001 Srinagar, India

[2] Institute of Power Engineering, Universiti Tenaga Nasional, Serdang, Malaysia

[3] Department of Chemical Engineering, College of Engineering, University of Baghdad, 10071 Baghdad, Iraq

[4] Department of Chemistry, University of Kashmir, Jammu & Kashmir, 190006 Hazratbal, India

[5] Soft Material Laboratory, Department of Chemistry, Islamic University of Science and Technology, Jammu & Kashmir, 192122 Awantipora, India