frontiers | Frontiers in Environmental Chemistry

TYPE Editorial
PUBLISHED 04 July 2025
DOI 10.3389/fenvc.2025.1651836

OPEN ACCESS

EDITED AND REVIEWED BY
Bin Gao,
Rensselaer Polytechnic Institute, United States

*CORRESPONDENCE
Victor O. Shikuku,
vshikuku@kafu.ac.ke

RECEIVED 22 June 2025
ACCEPTED 27 June 2025
PUBLISHED 04 July 2025

CITATION
Shikuku VO, Otieno B, Vunain E, Biswick T and Kowenje C (2025) Editorial: Advances in the synthesis and utilization of waste-derived materials for water purification.
Front. Environ. Chem. 6:1651836.
doi: 10.3389/fenvc.2025.1651836

Editorial: Advances in the synthesis and utilization of waste-derived materials for water purification

Victor O. Shikuku[1]*, Benton Otieno[2,3], Ephraim Vunain[4], Timothy Biswick[4] and Chrispin Kowenje[5]

[1]Department of Physical Sciences, Kaimosi Friends University, Kaimosi, Kenya, [2]Department of Chemistry, Vaal University of Technology, Vanderbijlpark, South Africa, [3]Water, Sanitation and Hygiene Research and Development Centre (WASH R&D Centre), Howard College, University of KwaZulu-Natal, Durban, South Africa, [4]Department of Chemistry and Chemical Engineering, University of Malawi, Zomba, Malawi, [5]Department of Chemistry, Maseno University, Maseno, Kenya

KEYWORDS

waste materials, water treatment, adsorption, photocatalysis, circular economy

Editorial on the Research Topic
Advances in the synthesis and utilization of waste-derived materials for water purification

Introduction

Access to clean water remains a challenge to many communities globally. This situation is exacerbated by the mounting crisis of water pollution in both developed and developing nations. Industrial discharges, agricultural runoff, and unscientific and *ad hoc* waste management approaches continue to introduce a broad spectrum of contaminants—ranging from heavy metals to the chemicals of emerging concern (CEC)—into water bodies, threatening aquatic life and human health. At the same time, the ever-increasing volume of solid and agricultural wastes imposes immense pressure on landfills, contributing to secondary pollution through leachates, greenhouse gas emissions, odours and resource wastages.

In this context, the convergence of waste management and water purification practices offers a promising avenue for sustainable development. The innovative valorization of waste materials into functional adsorbents or catalysts for water treatment not only diverts waste from landfills but also provides cost-effective tools for environmental remediation and contributes to the circular economy. Adsorption by sustainably produced biochar and activated carbon adsorbents from low-cost biomass, mainly agricultural waste, has attracted considerable attention over the years for the remediation of organic and inorganic pollutants due to their multifunctional properties (Vedenyapina et al., 2020; Ambaye et al., 2021; Samghouli et al., 2024). The Research Topic, "*Advances in the Synthesis and Utilization of Waste-Derived Materials for Water Purification*," focusses on these synergies, advancing scientific understanding while addressing pressing environmental challenges.

Aims and objectives

The core objectives of this Research Topic are:

- To explore novel routes for transforming waste materials—both organic and inorganic—into functional adsorbents and catalysts for water decontamination.
- To assess the efficacy, selectivity, and regeneration capability of these waste-derived materials against varied water pollutants.
- To foster interdisciplinary exchanges that bridge chemical engineering, material science, environmental chemistry, and waste management for holistic solutions.
- To set a research agenda for future commercialization and policy support for sustainable materials in water purification.

This editorial integrates and contextualizes the contributions of two Original Research and two comprehensive Review articles, which exemplify the range and depth of advances in this critical field.

In the comprehensive review, Nyairo et al., the authors critically assess the potential of agricultural and food waste biomasses—abundant and underutilized raw materials for low-cost and renewable adsorbents for the remediation of toxic heavy metals such as lead, zinc, nickel and cadmium. The waste biomasses considered include bones, rice husks, sugarcane bagasse, potato peels, egg shells, and chitosan. The review details various pretreatment and modification strategies (e.g., physical activation, chemical functionalization) that enhance the adsorption efficiency of the different waste biomass types of materials. This work situates itself at the intersection of waste valorization and sustainable water purification, underscoring the dual benefits of waste minimization and pollutant remediation. The review also identifies key adsorption mechanisms, limitations in scalability and potential for secondary pollution, and opportunities for future research, such as life cycle assessments (LCA), standardizing waste-derived materials and optimization of recoverability of the adsorbents, and integration into modular water treatment technologies.

In the second review article, the environmental legacy of chromated copper arsenate (CCA), a wood preservative that leaches carcinogenic elements (Cr, Cu, As) into soil and water is investigated by Atiang et al. The review outlines the emerging strategies for the removal and stabilization of CCA pollutants—including adsorptive and reductive technologies using waste-derived materials. By expanding the scope from water to interconnected environmental compartments (wood waste, soil), this work concisely exemplifies the importance of system-based approaches in environmental chemistry. The discussion extends to regulatory implications and the challenges in treating mixed-contaminant matrices, emphasizing the urgency of multi-pollutant remediation solutions in the context of circular economy principles.

The third article, original research by Suter et al., focusses on the synthesis of advanced nanocomposite adsorbents that couple high permeability, magnetic recoverability, and environmental compatibility. In the article, the authors demonstrate the fabrication and detailed characterization of a biodegradable ferromagnetic polymer nanocomposite for targeted removal of hexavalent chromium (Cr(VI))—a notoriously recalcitrant water pollutant. The study provides insights into adsorption kinetics, isotherms, and thermodynamics, highlighting not only superior removal efficiency but also the practical advantages of rapid and complete adsorbent recovery using external magnetic fields. This research is emblematic of the next-generation design of functional materials at the interface of nanotechnology and green chemistry.

Finally, the original research article by Ndongmo et al., addresses the Research Topic of synthetic dyes in industrial effluents by exploring the conversion of peanut shells—a common agricultural waste—into a ferromagnetic activated carbon. By leveraging this engineered adsorbent as a catalyst in the Fenton process, the authors report efficient degradation of methyl orange, a model azo dye. This study not only demonstrates the feasibility of upcycling agricultural residue for advanced oxidation processes but also highlights the synergistic benefits of combining adsorption and catalytic degradation. The magnetic feature further facilitates catalyst recovery and reusability, aligning with sustainable process design.

Broader context and future directions

The research contributions form an integrated framework for sustainable water purification, moving from waste source characterization through material synthesis and application to pollutant removal and resource recovery.

The advances showcased here hold broad implications for:

- Waste Management: Turning liabilities into assets by giving waste a second life.
- Water Treatment: Developing affordable and scalable solutions for rural and industrial applications.
- Circular Economy: Closing material and resource loops to minimize environmental footprints.

Future research initiatives should include the following areas:

- Scale up laboratory successes to field- and industry-level implementations with associated LCA and techno-economic studies.
- Address the mitigation of emerging contaminants (e.g., hormones, antibiotics, nanoplastics) with waste-derived materials.
- Integrate water purification, energy recovery, and nutrients reclamation for comprehensive solutions.
- Targeted evidence based science policies to address waste water managements.

Conclusion

The synthesis and deployment of waste-derived materials in water purification is no longer a conceptual aspiration but an advancing field with tangible societal benefits. The articles in this Research Topic not only extend the scientific frontiers but also inspire cross-sector partnerships crucial for achieving global water security and environmental sustainability.

Author contributions

VS: Writing – original draft, Writing – review and editing. BO: Writing – review and editing. EV: Writing – review and editing. TB: Writing – review and editing. CK: Writing – review and editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Acknowledgments

We heartily thank all the authors and reviewers who have participated in this Research Topic.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

References

Ambaye, T. G., Vaccari, M., van Hullebusch, E. D., Amrane, A., and Rtimi, S. (2021). Mechanisms and adsorption capacities of biochar for the removal of organic and inorganic pollutants from industrial wastewater. *Int. J. Environ. Sci. Technol.* 18, 3273–3294. doi:10.1007/s13762-020-03060-w

Samghouli, N., Bencheikh, I., Azoulay, K., El Hajjaji, S., and Labjar, N. (2024). Optimisation of Olea europaea stone – activated carbon preparation using response surface methodology for thiamphenicol removal in fixed bed column. *Ecol. Eng. Environ. Technol.* 25, 37–53. doi:10.12912/27197050/190084

Vedenyapina, M. D., Kurmysheva, A. Y., Rakishev, A. K., and Kryazhev, Y. G. (2020). Activated carbon as Sorbents for treatment of oharmaceutical wastewater. *Solid Fuel Chem.* 53:6 53, 382–2019394. doi:10.3103/S0361521919070061