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Editorial: Advances in nanotechnology for water treatment

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Editorial on the Research Topic
Advances in nanotechnology for water treatment

Despite its necessity, the sustainable use of nanotechnology for water remediation has continued to gain appreciable interests owing to the ill-fated consequences rendered by contaminated water to human health, aquatic lives, equipment, the ecosystem and environment. Water treatment techniques range from chemical to mechanical, physical and biological methods. However, despite the continuous attempts to address water pollution using existing technologies, water contamination remains a situation that is created by mankind as informed by the constant change in technological civilization, hence the need to develop improved techniques for providing safe water for use.

Concerted efforts in current research are often tailored towards the development of nontoxic, benign or green nanomaterials for the advanced treatment of contaminated/polluted water. In lieu of the fact that these efforts have been directed at stripping contaminants and pollutants such as heavy metals, bacteria, dyes, antibiotics, CO_2, and other hazardous/harmful constituents, the common goal still remains-ensuring the availability of safe water for use via the development of tunable nanostructures which in turn brings about a healthy environment while ensuring zero tolerance for toxins or contaminants which seem to threaten human/aquatic existence and wellbeing (Jin et al., 2023; Dutta et al., 2021; Steiger et al., 2023).

In all certainty, despite bearing in mind the impossibility of tendering all the most sophisticated recent and viable nanotechnology-approaches for water treatment in one Research Topic, the editors and authors of this Research Topic, worked assiduously to provide readers with a more realistic background/framework of nanotechnology applications in water treatment with case studies from an industrial perspective. It also provides a background that is entrenched in ensuring a good selection criteria for administering or ranking nanotechnologies for specific water treatment applications.

The opening paper of this Research Topic, by Olawade et al. is a review paper that addressed key aspects related to the use of nanoparticles for microbial control in contaminated water with insights into their applications, antimicrobial mechanisms and ecological implications. Commonly used nanoparticles such as Ag-, Cu-, TiO_2-NPs, and CNTs in water treatment applications were discussed. Issues related to cell membrane damage, the generation of reactive oxygen species (ROS) as well as NP-interactions with metabolic processes were also highlighted. In addition, the ecological implications of nanoparticles' release into the environment, their environmental persistence, toxicity to non-target organisms and some regulatory challenges were critiqued with insights into some future perspectives and challenges relating to NP-synthesis, stability as well as the development of sustainable treatment technologies integrated with conventional methods. The second article by Sanni et al. is a comprehensive review on the adoption of biogenic nanomaterials and photocalysts for water treatment. The idea conveyed several photocatalysts and engineered nanostructured components for the purification of water. A global policy framework for ensuring the safe use of nano-based products for wastewater remediation was proposed while providing advisory information on how to administer safety protocols towards ensuring apt toxicity assessment of these nanomaterials. The paper concluded with the provision of a few case studies with some pertinent challenges listed alongside viable pathways for curbing issues related to the scaling up of recent wastewater treatment technologies for commercialization and industrial application. The third paper by Olawade et al. reviewed some pertinent approaches for the treatment of wastewater bearing contaminants that alter the pH and quality of water. They focused on the research that bothered on the use of graphene oxide, CNTs, MOFs and other nanocomposites which possess high surface/tunable surface areas and excellent adsorptive properties, enhanced with carboxyl, thiol and amino groups, that are highly selective towards some heavy metals which have detrimental effects on human and aquatic lives when ingested or consumed through contaminated sources. Successful strategies including chemical desorption, electrochemical and photocatalytic regeneration were highlighted as proven methods for improving the reusability and costeffectiveness of nanomaterials. Although NP-scalability and stability were mentioned as critical issues, green continuous-flow synthetic NPs were offered as promising solutions for large-scale applications whereas, challenges related to their stability and longevity could be tackled via surface modification, development of hybrid nanocomposites and combined treatment technologies (membrane filtration and electrochemical methods) for high remediation efficiencies. The closing article by Chennam et al. is an experimental technique that entails the use of carefully formulated polyacrylonitrile-sourced carbon-fibre (CF) composites comprising TiO_2 nanoparticles for the treatment of wastewater. The synthetic CFs were decorated with TiO_2 NPs sourced from tailored soaking protocol of 0.025–0.2 M concentrations of $TiCl_4$ solution. The authors highlighted the essential properties of the novel adsorbent which were tailored towards the photodegradation of methylene blue dye in solution. The approach adopted in this study provided some essential insights into the use of the new synthetic adsorbent for the degradation of MB, where the highest photocatalytic degradation rates were recorded for the lowest nano TiO_2-coated CF composite. The authors alluded that the synergistic interaction between the CF and TiO_2 NPs bearing uniform morphology alongside a well-defined crystalline anatase structure, is the key reason for the remarkable performance of the CF-composite.

New methods for tackling wastewater pollution challenges range from data-centric intelligent systems for water pollution control, machine learning approaches for optimizing the best material characteristics for selective contaminant removal, the use of nano-modified, polymeric materials (Ajith et al., 2021), zeolites, metal organic frame works, metal organic gels, hydrogels, aerogels, to facile and bottom-up design strategies for the fabrication of biocomposite materials with functionally tailored properties (Khdair et al., 2025; Saeed et al., 2024) which are constantly being developed and tried as emerging techniques with great potentials for redeeming wastewater for safe use.

Finally, the editors are appreciative of the privilege granted by Frontiers in nanotechnology and Frontiers in Chemical Engineering to unveil the discourses which have contributed immensely to current literature on the subject. It is also believed that the thoughts provided in all the published articles will pave the way forward for future research in addressing the emerging toxins and contaminants that are seemingly recalcitrant to existing nanotechnologies adopted in wastewater treatment applications.

Author contributions

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References

Ajith, M. P., Aswathi, M., Priyadarshini, E., and Rajamani, P. (2021). Recent innovations of nanotechnology in water treatment: a comprehensive review. *Bioresour. Technol.* 342, 126000. doi:10.1016/j.biortech.2021.126000

Dutta, D., Arya, S., and Kumar, S. (2021). Industrial wastewater treatment: current trends, bottlenecks, and best practices, *Chemosphere*. 285, 131245. doi:10.1016/j.chemosphere.2021.131245

Jin, X., Sun, H., Ren, H. H., and Huang, H. (2023). Biological filtration for wastewater treatment in the 21st century: a data-driven analysis of hotspots, challenges and prospects. *Sci. Total Environ.* 855, 158951. doi:10.1016/j.scitotenv.2022.158951

Khdair, A. I., Aburumman, G. A., Gholipour, S., and Afrand, M. (2025). Nanoparticles in water purification: multifunctional roles, challenges, and sustainable applications. *Environ. Sci. Nano*. doi:10.1039/d5en00268k

Saeed, F., Arundhathi, B., Sridhar, S., and Sahu, N. (2024). "Nanotechnology in water purification and treatment: current outlook and future perspectives" in *Futuristic Trends in Chemical, Material Sciences and Nanotechnology, vol. 3. Book 1*, eds. V. Kumar, S. Banerjee, G. S. Devi, and A. Shruti. (Iterative International Publishers (IIP), Selfypage Developers Pvt Ltd.).

Steiger, B. G. K., Zhou, Z., Anisimov, Y. A., Evitts, R. W., and Wilson, L. D. (2023). Valorization of agro-waste biomass as composite adsorbents for sustainable wastewater treatment. *Industrial Crops and Prod.* 191, 115913. doi:10.1016/j.indcrop.2022.115913