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Editorial: Sustainable adsorbents and photosensitizers for the removal and (photo)degradation of emerging organic pollutants from water

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Editorial on the Research Topic
Sustainable adsorbents and photosensitizers for the removal and (photo) degradation of emerging organic pollutants from water

Emerging organic pollutants (EOPs) include a wide array of newly synthesized compounds of various classes such as pesticides, flame retardants, pharmaceutical drugs, personal care products, food additives, dyes, and micro/nanoplastics (Otálora et al., 2021; Tang et al., 2019). A wide range of EOPs are now being detected in surface water and groundwater resources due to recent and historical anthropogenic activities (Vashistha, 2022). These pollutants enter the environment through several pathways such as industrial effluent discharge, agricultural runoff, wastewater treatment plants (WWTPs) effluent discharge and improper waste disposal (Kuchangi et al., 2023; Shah, 2021). Due to their discharge into the environment, EOPs can harm wildlife, ecosystems, and possibly humans (Zhou et al., 2024). Thus, a wide variety of methods have been reported for the removal and treatment of EOPs, particularly using adsorptive removal methods and photocatalytic degradation utilizing a variety of nanomaterials (Mashile et al., 2023; Paumo et al., 2021).

This Frontiers in Chemical Engineering Research Topic aimed to highlight the development of effective degradation or removal technologies of EOPs, as well as the application of bio-based sorbents for monitoring the occurrence of EOPs in water systems. A total of four papers are contained herewith including two comprehensive reviews and two research articles related to adsorbents and photosensitizers for the treatment of EOPs in water. The collected work represented contributions from leading research groups worldwide offering insights into the direction of the treatment of EOPs in water using various adsorbents and photocatalysts. The papers address critical challenges in adsorption and photocatalysis technologies, as well as critical aspects that can be incorporated to ensure

that the drawbacks experienced are counteracted. For instance, in their comprehensive review titled "Harnessing visible light: enhancing TiO_2 photocatalysis with photosensitizers for sustainable and efficient environmental solutions", (Chauke et al.) aimed to comprehensively outline the role of photosensitizers on photocatalysis using TiO_2 for applications in environmental remediation and energy generation. The authors outlined different photosensitizers and their advantages and disadvantages in the mentioned applications. These include the use of thiazine dyes such as methylene blue, rhodamine B, and azure A, amongst others. Different studies were cited to highlight the potential of dye photosensitizers used to modify TiO_2. The descriptions and properties of different thiazine dyes as well as the application of these dyes, the mechanisms for sensitization as well as their advantages and disadvantages-due to their toxicity as a result of their properties. The % efficiency of different photosensitizers showed that dye sensitizers can efficiently harness light energy for enhanced charge carrier generation for photocatalysis and sustainable environmental technologies. This response addresses TiO_2's limited performance due to its sensitivity to visible light. The authors also discuss potential strategies to address the drawbacks of TiO_2-based thiazine dye photosensitizers, which include tuning dye compositions, optimizing the morphology of TiO_2, and integrating co-catalysts, among others. In this review, the potential of thiazine dyes coupled to TiO_2 were shown to be effective photosensitizers with potential applications in wastewater treatment as well as solar energy conversion.

Due to the highlighted potential applications of TiO_2, (Mkhohlakali et al.), prepared Titanium dioxide (TiO_2) nano-powder using a sol-gel process with a typical non-ionic surfactant (Triton X-100) and compared their photocatalytic activity with TiO_2 prepared without a surfactant. It is noteworthy that the lack of visible region absorption of the bare TiO_2 nanoparticles, among other issues, is a bottleneck of the photocatalytic degradation process leading to low degradation rates and high energy consumption. Interestingly, the UV-Vis spectrophotometric results demonstrated that light absorption was dominant in the visible region (438–450 nm) leading to the redshift, thus enabling the reduction of bandgap from 3.12 to 2.98 eV when the surfactant was incorporated into the TiO_2 nanoparticles. This was coupled with the photoluminescence (PL) results that indicated that the surfactant-incorporated TiO_2 exhibited enhanced oxygen vacancies and surface defects resulting in the reduction in the direct electron-photon (e/h^+) pair recombination. As a proof of concept, a modelled methylene blue dye was degraded using both the surfactant-incorporated TiO_2 nanoparticles and the bare TiO_2 nanoparticles. The studied mechanism for the degradation of MB showed that the TiO_2 photocatalysts produce holes in the valence band when they are exposed to UV light. The electrons and holes induce the formation of superoxide and hydroxyl radicals that can oxidize and degrade methylene blue dye pollutants adsorbed on their surface. Thus, compared to the bare TiO_2 with 75% degradation of MB in 60 min, the surfactant-incorporated TiO_2 demonstrated higher photocatalytic dye degradation reaching 97% degradation of MB under 60 min. The study suggested that MB was completely mineralized to H_2O and CO_2, however, further evidence using LCMS could be necessary to support these findings. Nonetheless, the surfactant-incorporated TiO_2 is a promising photocatalyst for the degradation and mineralization of methylene blue dye pollutants in water and could be applied to degrade other organic pollutants in water.

This study resonated with a comprehensive review (Mapukata et al.) discussing the advances in the fabrication, modification and application of electrospun TiO_2 and ZnO nanofibers for the treatment of organic pollutants in wastewater. The review highlighted that the high surface-area-to-volume ratio, high porosity, superior mechanical strength, electrospun titanium dioxide (TiO_2) and zinc oxide (ZnO) nanofibers have been proposed for the photocatalytic treatment of EOPs. However, their lower thermal stability and larger band gap for anatase TiO_2 of 3.2 eV and ZnO wurtzite phase of 3.3 eV raises a challenge, particularly with the sunlight reaching the Earth's surface containing only about 5%–10% UV light, thereby limiting the real-life applications of these nanofibers as the shift to the visible region is critical. To mitigate these challenges, modification strategies such as doping, dye photosensitization and the integration of other materials have been proposed to fine-tune and enhance their physical properties and promote versatility in their applications, leading to enhanced photocatalytic degradation. Fe-doping, S-doping and Cu-doping were reported to enhance the light absorption properties of the TiO_2 and ZnO nanofibers, resulting in visible-light active nanofibers capable of degrading a variety of organic pollutants. Dye photosensitization using porphyrins and metallophthalocyanines has been reported for the modification of TiO_2 and ZnO nanofibers for visible-light-driven photocatalysis, with the modified fibers demonstrating a shift to the visible region for higher visible light photocatalytic activity than the unmodified materials. Compositing TiO_2 and ZnO nanofibers have also been reported, with synergistic interaction between the individual semiconductor components providing enhanced physical and chemical properties, allowing visible light shifts for enhanced photocatalysis. The review also demonstrated the photocatalytic decomposition of wastewater contaminants, such as pesticides, pharmaceuticals, dyes and other pollutants. Interestingly, aside from the photocatalytic decomposition of wastewater contaminants, TiO_2 nanofibers have also been applied for oil-water separation.

On the other hand, (Toran et al.) reported the use of ultrafiltration (UF)+ reverse osmosis and ozone + coagulation microfiltration + RO membranes to compare the quality of their permeates. The polymeric UF membrane was more susceptible to fouling, requiring increased filtration intervals and more CIPs. The ceramic MF membrane could be operated at high fluxes with more frequent backwashing of the membrane and enough coagulant dosage. The ozone did not have any effect on coagulation and ceramic membrane fouling propensity. Both MF and UF membranes produced treated water within good standards recommended by national regulatory frameworks (RD 1620/2007). The UF membrane showed high elimination of dissolved salts, high turbidity and nitrates removal. The MF showed high salt rejection, suspended solids, and organic matter, yet it showed poor nitrate rejection which could be from high nitrogen-rich waste. The MF system had water permeate that meets the requirements of agricultural irrigation when it comes to suspended solids but does not comply with the *E. coli* limits 10 CFU/100 mL. This faecal contaminant is not related to influent quality rather it is due to the contamination of the membrane in the permeate zone. The coupling of both ceramic MF and polymeric UF resulted in enhanced treated water quality.

We hope that this Research Topic will be impactful to emerging researchers and scientists venturing into the field of adsorption and photocatalysis utilizing a wide array of nanomaterials. We thank the colleagues who contributed to this Research Topic for sharing insights into various materials and strategies on how to improve materials for photocatalysis in visible light and modifying adsorption properties.

Author contributions

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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.

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References

Kuchangi, S. N., Mruthunjayappa, M. H., and Kotrappanavar, N. S. (2023). An overview of water pollutants in present scenario. *3D Print. Technol. Water Treat. Appl.*, 83–105. doi:10.1016/b978-0-323-99861-1.00001-1

Mashile, P. P., Munonde, T. S., and Nomngongo, P. N. (2023). Occurrence and adsorptive removal of sulfonamides and β-blockers in African and Asian water matrices: A comprehensive review. *Environ. Adv.* 13, 100435, doi:10.1016/j.envadv.2023.100435

Otálora, A., Lerma, T. A., Arrieta-Urango, Y., and Palencia, M. (2021). Emerging organic pollutants in aqueousenvironments: Detection, monitoring, andremoval techniques. *J. Sci. Educ. Technol.* 10, 92–153. doi:10.34294/j.jsta.21.10.68

Paumo, H. K., Dalhatou, S., Katata-Seru, L. M., Kamdem, B. P., Tijani, J. O., Vishwanathan, V., et al. (2021). TiO2 assisted photocatalysts for degradation of emerging organic pollutants in water and wastewater. *J. Mol. Liq.* 331, 115458, doi:10.1016/j.molliq.2021.115458

Shah, M. P., 2021. *Removal of refractory pollutants from wastewater treatment plants.* Routledge: CRC Press. doi:10.1201/9781003204442

Tang, Y., Yin, M., Yang, W., Li, H., Zhong, Y., Mo, L., et al. (2019). Emerging pollutants in water environment: occurrence, monitoring, fate, and risk assessment. *Water Environ. Res.* 91, 984–991. doi:10.1002/wer.1163

Vashistha, V. K. (2022). Detection and remediation of chiral pharmaceuticals from wastewater: a review. *Chirality* 34, 833–847. doi:10.1002/chir.23437

Zhou, P., Wang, F., Shen, Y., Duan, X., Zhao, S., Chen, X., et al. (2024). Removal of emerging organic pollutants by zeolite mineral (clinoptilolite) composite photocatalysts in drinking water and watershed water. *Catalysts* 14, 216, doi:10.3390/catal14040216