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Editorial: Advanced technologies for industrial wastewater reclamation

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Editorial on the Research Topic
Advanced technologies for industrial wastewater reclamation

Humankind is facing the significant challenge of water scarcity (Martins et al., 2020). Since 1950, the world population has doubled, and global water consumption has increased by more than 600% (Martins et al., 2020). A report by the United Nations demonstrated that two-thirds of the world's population would face water stress by the year 2025 (Ahmed, 2006). A significant fraction of the increased water consumption was attributed to the rapid growth in the industrial developments (Sathya et al., 2022). Nearly all water consumed in industries ends up as industrial wastewater (IWW). The release of IWW into the environment may adversely affect the environment and pose a health threat to humans and our ecosystem (Martins et al., 2020).

Innovative solutions are therefore needed to provide adequate treatment of IWW to meet the increasingly stringent discharge standards and explore options to obtain sufficient water to support industrial developments (Cai et al., 2021). Treating and reclaiming treated industrial effluent can be an effective option to meet both challenges. Nonetheless, IWW is far more complex than domestic sewage, containing numerous organic and inorganic pollutants and exhibiting much greater variability in wastewater characteristics (Sathya et al., 2022). As a result, employing state-of-the-art biological treatment technologies alone is often inadequate for meeting stringent discharge standards, not to mention the ability to meet water reclamation requirements (Samaei et al., 2018; Sathya et al., 2022). Alternatives such as advanced oxidation processes (AOPs, e.g., ozonation (Deng et al., 2021a; Jothinathan et al., 2021), Fenton (Cai et al., 2020a; Cai et al., 2021; Sathya et al., 2022) and photocatalytic oxidation (Thiruvenkatachari et al., 2008; Autin et al., 2013) and separation processes (e.g., membrane filtration (Deng et al., 2021b; Liu et al., 2021) and adsorption (Ambaye et al., 2020) have been used for treating recalcitrant organics. However, AOPs typically require high energy (e.g., O_3-generation in the ozonation process and UV-irradiation in the photocatalytic process) and chemical (e.g., oxidants and catalysts in the Fenton process and persulphate-based oxidation process) consumptions and therefore are expensive options (Loh et al., 2021; Wu et al., 2021; Jothinathan et al., 2022). Separation processes, on the other hand, have been used for pollutant removal and resource recovery, but innovative strategies are still needed to reduce their costs (Ambaye et al., 2020; Liu et al., 2021). Thus, there is a need to develop innovative technologies and build upon our knowledge of existing technologies for IWW treatment and reclamation.

Beyond the development of innovative technologies, combinations of the existing technologies could also obtain considerable performance with reduced energy and chemical consumption. Deng et al. (2021b) combined catalytic ozonation processes with a membrane bioreactor (MBR) for the treatment of phenolic wastewater produced by the petrochemical industry. This combination achieved total organic carbon (TOC) and phenolic compounds removals of 98.0% and 99.4%, respectively, and decreased the membrane fouling rate of MBR by 88.2%. The pretreatment by catalytic ozonation in the combined process reduced the acute biotoxicity of the wastewater by 79.2% and increased the 5-day biochemical oxygen demand to chemical oxygen demand ratio (BOD_5/COD) by 2.45-folds, which significantly contributed to the performance enhancement and membrane fouling mitigation of MBR (Deng et al., 2021b). Tong et al. (2018) combined the adsorption processes by ligntie-activated coke (LAC-adsorption) and immobilized biological filter (IBF) in the treatment of heavy oil wastewater on a pilot-scale system. The combined process obtained a dissolved organic carbon (DOC) removal of 85.9%, where most biorefractory compounds were removed by the pre-LAC-adsorption process and benefitted the subsequent IBF, and the post-LAC-adsorption process contributed to amides removal (Tong et al., 2018). Cai et al. (2020b) combined the fluidized bed reactor-based Fenton processes (FBR-Fenton) with a biological activated carbon (BAC) system for the reclamation of reverse osmosis concentrate and obtained a COD removal of 69% with a low average effluent COD of 26 mg/L. In the combined process, the FBR-Fenton processes markedly contributed to the degradation of humic acid and fulvic acid and improved the BOD_5/COD ratio by 4.2-10.0 times, which strengthened the performance of the BAC system (Cai et al., 2020b).

In addition to the IWW treatment and effluent reuse, the recovery of valuable resources is also essential under the global trends of the circular economy (Goglio et al., 2019; Soltangheisi et al., 2019; Cheng et al., 2022). Wastewater is a rich source of organic carbon, nutrients (e.g., nitrogen N) and phosphorus P) and metals (e.g., potassium K), copper (Cu) and silver (Ag). Concerning energy generation, Heidrich et al. precisely determined the energy content of domestic wastewater (DWW) through freeze-drying samples to minimize the loss of volatiles and organic matters. Their results indicated that DWW contains an energy generation potential of 7.6 kJ/L (Heidrich et al., 2011). Wang et al. also estimated that the energy content of DWW related to COD was 23 W *per capita* (Wang et al., 2017). Similar assessments on IWW are lacking, but a significant energy recovery potential of organic IWW can be estimated due to their normally much higher organic carbon concentration. In terms of nutrients, it has been estimated that more than 20% of consumed P from minerals is excreted by human activities (Cordell et al., 2009). Robles et al. estimated that the global resource recovery from waste streams could essentially retrieve 50% of the P consumed by humans. Additionally, an N to P mass ratio of over 3 has been widely observed in research done on various waste streams, which indicated that more N than P is lost during the wastewater treatment (Batstone et al., 2015; Robles et al., 2020). Some kinds of IWW contain extremely high concentrations of N and P compared to DWW (Bokun et al., 2020; Deng et al., 2022). For example, in coking wastewater, the ammonia concentration is usually in a high range of 500-2,000 mg N/L, and it could further research the range of 3,500-10,000 mg N/L in the semi-coking wastewater when the pyrolytic temperature of coal was reduced to 600°C-800°C (Ma et al., 2017; Bokun et al., 2020; Huang et al., 2021). P concentration is usually high in the waste streams, such as fertilizer production wastewater, paper pulping and making wastewater and some of the chemical industry wastewater (Bian et al., 2011; Hutnik et al., 2013; Gentili & Sveriges, 2014). Specifically, the P concentration in the wastewater from the phosphorus mineral fertilizers industry (Hutnik et al., 2013) and the wastewater from PolyTH production industry (Bian et al., 2011) could reach 445 mg P/L and 15,000-18,000 mg P/L, respectively. Metal ions are also rich in IWW, such as K and Mg are rich in dairy wastewater and manure wastewater (Goglio et al., 2019), and Ag and Cu are rich in deplating wastewater (Gu et al., 2020). Based on the abovementioned information, IWW is an abundant source of energy, nutrients and metals to be recovered and reused, which could significantly contribute to the circular economy. Furthermore, the worldwide increase in consumption and the gradual depletion of natural resources have emphasized the need for resource recovery from waste streams (Goglio et al., 2019; Soltangheisi et al., 2019). Therefore, instead of releasing resource-rich waste streams into the water bodies increasing the environmental risk, this resource recovery can lead to multiple benefits, such as generating valuable products, greatly improving wastewater treatment processes, reclaiming wastewater, maintaining the ecological balance of aquatic environments and reducing the carbon footprint in wastewater disposal. In order to fulfill this vision, novel technologies for resource recovery from IWW need to be developed by the research community.

This Research Topic focuses on novel technologies for IWW treatment for the purpose of resource reclamation. This includes the dissemination of knowledge generated from studies regarding the development, optimization, and applications of advanced technologies aiming at the treatment and resource recovery of IWW. It also aims to address an important aspect of sustainable water management with an emphasis on meeting the needs of the industrial sector from a global perspective.

We hope this Research Topic can contribute significantly to both the research and the engineering communities for managing IWW treatment and reclamation.

Author contributions

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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.

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