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Integration of Processes for Wastewater Treatment: Trend, Advances, and Future

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The growing scarcity of freshwater resources has shifted the goals of water and wastewater treatment from simple waste disposal to prioritizing waste minimization, water reuse, and resource recovery. This shift underscores the critical need for sustainable water management. At the same time, industrial and municipal wastewaters contain increasing amounts of toxic, persistent, and inhibitory compounds. Persistent contaminants resist natural degradation, while inhibitory substances disrupt biological treatments, posing significant environmental challenges if untreated. Stricter global regulations on wastewater discharge have heightened the need for advanced treatment technologies their combination that effectively degrade these pollutants while remaining cost-effective. This demand is driving innovation in water treatment, fostering new technologies that align with both environmental and economic goals. Advanced water and wastewater treatments are essential for sustainable development, as they ensure pollutant removal, protect water resources, and support public health. By promoting resource conservation and pollution prevention, these technologies play a vital role in the continued growth and resilience of societies. Biological processes are generally recognized as the most cost-effective treatment methods. However, various industrial effluents, including those from petrochemical, winery, pharmaceutical, slaughterhouse, textile, and soluble polymeric wastewaters, contain significant amounts of non-biodegradable, recalcitrant, and refractory organic compounds. These compounds are difficult to degrade through conventional treatment, making it challenging to meet standard regulations. As a solution, advanced oxidation processes (AOPs) are often employed to effectively break down resistant materials and mineralize stable, inhibitory, and toxic contaminants. Despite their effectiveness in treating organic compounds, AOPs face certain limitations that hinder their widespread commercial use, such as high requirements for oxidant and catalyst dosages, high energy consumption, and challenges in nutrient removal. Consequently, AOPs are typically recommended as complementary treatments, either before or after biological processes. Advanced wastewater treatment now emphasizes reducing operational and maintenance costs, making combined processes more appealing than traditional methods. Optimized integration of AOPs with biological treatments promotes cleaner production and a greener environment, delivering high-quality treated effluents with pollutant removal efficiencies exceeding 90%, allowing water recycling in industrial applications. This presentation will cover advancements, challenges, and future directions in process integration for wastewater treatment, along with recent findings.

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