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EDITORIAL

Unlocking the potential: scaling up advanced oxidation technologies

Selma Mededovic Thagard[1]

Advanced oxidation technologies (AOTs) have emerged as innovative and effective methods for water and wastewater treatment. These techniques involve the generation of hydroxyl radicals ($^{\cdot}$OH) to oxidize and degrade persistent organic pollutants and emerging contaminants, often rivaling the performance of established water treatment processes. The potential applications of AOTs for treating diverse source waters and oxidizing contaminants are extensive. In comparison with technologies like granular activated carbon and membranes, AOTs offer effective and cost-efficient treatment in three key areas: (1) micropollutant treatment, (2) addressing taste-and-odor compounds, and (3) treatment of recycled water. The advanced oxidation can serve as a final polishing stage for pre-treated effluents or can be employed as a primary or secondary treatment step to enhance subsequent biological processes and membrane separation.

The most common AOTs involve the utilization of ultraviolet (UV) radiation, metal ions (via the Fenton process), or ozone to catalyze the decomposition of hydrogen peroxide into hydroxyl radicals. Ultrasound-based techniques leverage the propagation of acoustic waves within the treated solution to achieve analogous outcomes. Additionally, both plasma and electrochemical methodologies rely on the application of electrical current to split water molecules into hydroxyl radicals which subsequently degrade and mineralize contaminants. These technologies share several common characteristics, such as operating under atmospheric pressure and often at room temperature. They exhibit versatility in treating water with varying organic loads and possess the ability to remove inorganic compounds and yield high-quality effluents. Despite these advantages, the upscaling of the majority of these technologies to an industrial scale has been challenging due to various technical, economic, and regulatory reasons. Addressing research questions at the bench scale has consistently been recognized as an initial and essential step toward enabling successful scaling of AOTs to the industrial level. These questions encompass issues such as potential scavenging effects, and concerns regarding incomplete degradation and the generation of harmful byproducts. However, considering that answering these research questions will most likely be system- and matrix-dependent, and that these factors may vary when transitioning to full-scale processes, it becomes dubious whether these questions are indeed definitive obstacles impeding the scale-up of AOTs. What often goes unaddressed but is equally, if not more crucial, is the absence of scaling laws for the upscaling of many AOT treatment systems. For some processes, this effort includes more than just increasing the size of the reactor vessel; it also requires designing and building larger and more powerful power supply sources.

The bench-scale experiments often lack the complexity and heterogeneity of real-world scenarios, making it challenging to predict performance accurately when transitioning to larger scales. Replicating the bench-scale conditions in full-scale systems, which involve higher volumes and flowrates, requires innovative design modifications and comprehensive analysis of hydrodynamics, mass transfer rates, and the knowledge regarding the impacts of varying water quality parameters on process efficacy. Acquiring this knowledge requires collaborative efforts among researchers, engineers, policymakers, industry stakeholders, and the standardization of systems across different laboratories, as well as testing on semi-pilot and pilot units. Without implementing such a strategy, the likelihood of successful scale-up in the foreseeable future is minimal.

✉ Selma Mededovic Thagard
smededov@clarkson.edu

[1] Department of Chemical and Biomolecular Engineering, Clarkson University, Potsdam, USA