Electrochemical Technologies for Wastewater Treatment with a bright future in the forthcoming years to benefit of our society

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Editorial

Climate change and growth of population are forecast to cause severe shortage of resources such as energy, food and water, although this is expected to be dissimilar throughout the world [1] having a higher impact in developing countries. Therefore, there is a critical need to design and develop affordable solutions that ensure the access to critical resources by understanding the nexus sectors. In the case of water security, this concept compresses interrelated tasks and highlights water's centrality for achieving a sense of security, development, sustainability and human well-being, at all levels [2]. In this sense, the development of technologies and smart water solutions will play a key role in achieving the Sustainable Development Goal 6 (SDG6), since it represents a substantial opportunity if its implementation is carried out in order to guarantee sustainability and increase competence in water management (to treat and distribute water for human use) [3,4]. To do that, the integration of the technologies developed until now in the water sector will represent a clear benefit for our society, offering a coherent vision for the future. This integration must arise from a consensus through a collaborative multidisciplinary process in the different water security areas, which should be coordinated by different organizations, foundations, research centers, universities and industries, in agreement with national/international guidelines and standards. In addition, all eco-friendly water solutions should also have an appropriate contribution in the food and energy sectors [2]. However, this strategy needs significant efforts in order to properly identify the main priorities, contribute to implement efficient water management, bring major improvements for smart water solutions, as well as highly contribute to develop efficient technologies for water decontamination and sanitation [2,3].

The present water crisis will probably worsen in the coming decades, stimulating the science and technology fields to identify innovative, robust, safe, eco-friendly (in the spirit of green chemistry) and energy-cost-efficient water treatment solutions [2]. Nowadays, conventional water technologies can acceptably solve several water security problems; but some of them are chemically, energetically, and/or operationally intensive. In contrast, recent water treatment technologies have shown promising advances for environmental remediation, demonstrating great progress and capabilities for the abatement of persistent pollutants, as well as cost-competitiveness as compared to existing technologies. Among them, the electrocatalytic and electrochemically-driven approaches have emerged as environment-friendly methods and sustainable technologies that offer different water security solutions to fulfill SDG6 (i.e., depollution of water, sanitation, disinfection, water treatment as well as their specialized use for monitoring pollutants) [4,5]. The use of the electron, which is a clean, inexpensive and suitable driver for decontamination, avoiding conventional chemical oxidants or reductants, allows reaching significant technical impacts in the form of versatile, efficient, cost-effective, easy-to-automatize and easy-to-upscale small portable devices [5].

Over the last two years, a close interdisciplinary collaboration between several scientists has led to significant advances, from fundamentals to applications of the electrochemical technologies, either for monitoring pollutants or treating different water matrices. Therefore, this special section was aimed to cover the most recent development of these technologies, emphasizing the fundamentals and new approaches developed, as well as providing an overview of state-of-the-art, advances and challenges to translate these environment-friendly processes from laboratory to full-scale industrial/commercial devices. Consequently, the core of this special section, which has been entitled "*Electrochemical Technologies for Wastewater Treatment (2021)*", counts on contributions mainly focused on water, soil and volatile/odorous substances treatments. Overall, 25 articles from experts located in different countries have been published in this collection. All of them underwent a robust peer review screening, according to the expected high standards of the *Current Opinion in Electrochemistry* journal.

Papers focusing on electrocatalytic materials (anodic and cathodic electrodes), as the key components of the electrochemical cell, have considered the nature of the materials and their oxidation performance (active versus non-active) as well as the advances on the synthesis and preparation approaches [6–8]. In particular, the progress in anode fabrication by different modifications and preparation strategies has been highlighted, as critically discussed by Hu eta al. [6], Salazar-Banda et al. [7] and Malpass et al. [8], including boron-doped diamond (BDD), PbO_2, SnO_2, mixed-metal oxides and Ti-based anodes (e.g., Ti_4O_7, blue titanium oxide), as well as carbon-based materials

The knowledge associated to the identification and the production of reactive oxidizing species has progressively advanced with the improvement of the instrumental techniques [9], which has contributed to the understanding of the type, nature, quantity and mechanisms of production of oxidants, as well as of the influence of experimental factors on their generation in electrochemical advanced oxidation processes (EAOPs). Special attention was given to the current knowledge on mechanisms and models used [10], highlighting different methods for the oxidants identification and reactivity [10] and their applications in wastewater treatment and water disinfection (i.e., hydroxyl radicals, active chlorine, peroxocompounds, ferrate, chlorine dioxide, hydrogen peroxide, ozone) [11–16].

Reports regarding the recent advances in EAOPs for the sustainable treatment of slaughterhouse and dairy wastewater [17], antibiotics [18], pesticides [19], petrochemical wastewater [20] and textile effluents [21], as well as for electrodisinfection [13,15,16], have also been pointed out. Given the extensive scientific evidences, it seems obvious that important public benefits could be achieved by using electrochemical SDG6-solutions as an alternative to remove a great number of pollutants and waterborne agents from different water matrices, operating with different parameters. On the other hand, the original applicability of hybrid electrochemical technologies (electrochemically-driven approaches coupled with biological treatments or membrane filtration) may also constitute real water-security solutions because of the underlying concepts, such as pollutant accumulation and preconcentration, oxidation effectiveness and techno-economic advantages [22,23], which overcome those of single electrochemical processes. Also of special importance are the advances on solid polymer electrolyte reactors and the microfluidic cells [24] that reduce the ohmic resistances and increase the mass transport of the pollutants towards the electrode surface.

The synergism between photo- and electrochemical processes has strongly stimulated several researches in the last years towards new systems, materials and reactors as green and sustainable alternatives in water disinfection, wastewater reclamation, H_2 production and CO_2 reduction [25–27]. On the other hand, although cathodic H_2O_2 production and acidic pH conditions play a key role in the decontamination effectiveness of Fenton-based processes, Sirés and Brillas [28] have discussed in detail the trends in the use of novel electrocatalysts, cathode configurations and reactor design, as well as the progress in iron-based catalysts, with the main purpose of expanding the application to a much wider pH range.

Special attention was also paid to the use of electrochemical gas treatment solutions, as promising alternatives for treating gases polluted with volatile organic compounds and odorous substances [29,30], and to the most recent developments, gaps, challenges, and trends in integrated electrokinetic systems for decontamination of soil polluted with organic contaminants [30]. Strategies like electrokinetic soil washing, electrokinetics coupled with permeable reactive barriers, electrokinetic-advanced oxidation processes, and bioelectrokinetic remediation are described. Probably, the last topics could be considered out of scope of our special section; however, when wastewater and soils are decontaminated, highly contaminated gases and more polluted effluents are secondarily generated, which require subsequent treatments. For this reason, these innovative electrochemical technologies have been also summarized and discussed by experts in the field.

Based on the wide range of subjects considered in the special section, it should be of interest for chemists, electrochemists, environmental and chemical engineers and biotechnologists, as well as for students who are interested in environmental treatment technologies. Finally, we take this opportunity to thank all authors for their original contributions and, in particular, the reviewers, whose comments and suggestions were extremely important to achieve high-quality papers. A special thanks goes to the Journal Editors, Prof. Richard G. Compton, Prof. Hasuck Kim and Patricia Hudson, for their great support since the acceptance of our proposal.

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Conflicts of Interest

The authors declare no conflict of interest.

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