76th Annual Meeting

of the International Society of Electrochemistry

7 - 12 September 2025

Mainz, Germany

Electrochemistry –
From Basic Insights
to Sustainable Technologies

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Recycled alkaline battery derived-mixed metal oxide anodes for enhanced photoelectrochemical oxidation of venlafaxine

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The concept of a circular economy has been consolidated in the electrochemical field, driving research and the development of technologies for wastewater treatment through electrochemical processes [1]. The use of recyclable and low-cost materials has been a constant focus of studies in the development of mixed metal oxide (MMO) anodes. In this context, new eletrodic materials incorporating used alkaline battery waste are being studied to achieve high efficiency, low cost, and easy replicability for industrial-scale application [2]. In environmental electrochemistry, the production of electrocatalytic materials has gained increasing importance, especially for the elimination of recalcitrant organic compounds and the generation of high-value-added products from wastewater [3]. MMO anodes have proven to be efficient for water and wastewater treatment, standing out for their low cost, ease of fabrication, replicability, high stability at low oxygen potentials, and ability to generate hydroxyl radicals on the anode surface. This study investigated the effect of an anode material based on alkaline battery waste for the degradation of venlafaxine-contaminated water. Mg and Zn were recovered from a recycled alkaline battery and synthesized to form ZnO and Mn_2O_3 oxides. Then, three anodes (Ti/RuMn, Ti/RuZn, and Ti/RuMnZn) were fabricated using the polymeric precursor method (also known as Pechini) and evaluated based on their electrochemical and physical characterizations. Among anodes, the Ti/RuMnZn MMO was selected for its superior electrocatalytic properties, such as a larger active surface area and stability. The performance of this anode was evaluated for application in the degradation of venlafaxine hydrochloride (30 mg L^{-1}) in 0.5 M Na_2SO_4 by electrochemical (EO) and photoelectrochemical oxidation (PEC). Single photolysis was also conducted as control experiment. A 9 W UVC lamp was used in the PEC and photolysis experiments. During EO, current densities of 10, 20, and 30 mA cm^{-2} were applied, with the highest degradation (70%) achieved at 30 mA cm^{-2}. This current density was then selected for the PEC process, which increased the compound removal to approximately 80%. Additionally, a total organic carbon analysis indicated that the reduction of organic load was more efficient in the PEC process. The energy consumption study indicates that, although PEC treatment led to better results in terms of venlafaxine degradation, EO showed lower energy consumption. Finally, the formation of carboxylic acids was identified, confirming that the fabricated anodes align with the concept of a circular economy by enabling the generation of high-value-added products.

Acknowledgments
The authors acknowledge the funding received by the São Paulo Research Foundation (FAPESP– grants #2024/10972-4, #2020/02743-4, #2022/03386-6, #2022/12895-1).

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