Electrochemical Reactor For Effluent Treatment: Removal Of Contaminants Of Emerging Concern And *Escherichia Coli*

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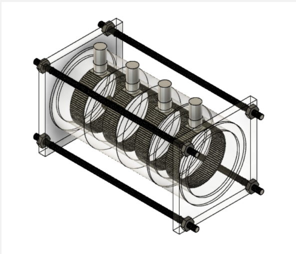

In. this study, we investigated the electrochemical oxidation (EO) technology for removing contaminants of emerging concern (CECs) and *Escherichia coli* from wastewater. Two electrode materials, platinized titanium (Pt/Ti) and dimensionally stable anodes (DSA, RuO_2–IrO_2/Ti) with different shapes were tested. The results showed that DSA with a circular mesh shape as both anode and cathode removed CECs and *E. coli* with efficiencies greater than 90%. Electrode surface area played a crucial role in enhancing the removal efficiency, with an increase of 20-50%. On the other hand, the current intensity had a negligible impact on the yield of CECs removal. EO is eco-friendly and costs only 1.1 €/m^3.

Introduction

Effluent from wastewater treatment plants (WWTPs) is a potential solution to address water scarcity and inadequate wastewater management. Effluent reuse is supported by legislation and policies like the Circular Economy, Sustainable Development Goals (SDG6), and the EU Green Deal. The European Commission has adopted quality requirements to safely reuse treated wastewater from urban WWTPs. The EU Regulation 2020/741 on minimum requirements for water reuse aims to ensure that reclaimed water is safe for agricultural irrigation. WWTPs remove pathogens, organic and inorganic matter, phosphorus, and nitrogen, but not contaminants of emerging concern (CECs) like active pharmaceuticals and personal care products, which pose an eco-toxicological threat [1,2]. Upgrading WWTPs is essential to remove CECs and ensure that reclaimed wastewater meets the required standards.

Electrochemical oxidation (EO) is a promising technology for removing persistent and recalcitrant organic contaminants in wastewater [3]. It is eco-friendly, as no additional chemicals are required. The mechanism of the EO process depends on various factors, such as electrode type, electrocatalyst material, wastewater composition, pH, applied current, and voltage levels [4].

This study [5] focuses on developing a cost-efficient electrochemical reactor to upgrade wastewater treatment plants, ensuring safe effluent reuse. The study evaluates the influence of electrode material and shape on the EO of contaminants and bacteria in real wastewater. The innovation of this work lies in the operational and potential industrial application of the electro-reactor for the simultaneous removal of different classes of contaminants and *Escherichia coli* in wastewater.

Material and Methods

Effluent samples were collected at a wastewater treatment plant in the Greater Lisbon area. The plant can treat 19,300 m^3/day of urban wastewater, which corresponds to about 94,000 equivalent inhabitants. The EO research and development were performed in four phases: (i-iii) development and optimisation and (iv) scale-up feasibility testing [5].

Five commonly used pharmaceuticals (sulfamethoxazole, SMX; Carbamazepine, CBZ; 17β-estradiol, E2; 17α-ethynylestradiol, EE2; diclofenac, DCF) were added to the effluent during phases I to III. The treatment was carried out in an undivided cylindrical-shaped reactor with a capacity of 0.45 L of effluent.

In phase IV, 9 CECs were studied (the previous 5 plus caffeine, CAF; bisphenol A, BPA; oxybenzone, OXY; triclosan, TCS). DSA/Ti material with a circular mesh shape was the best-performing anode and cathode, and a two-fold scaled-up sequence of four electrodes (anode-cathode, DSA circular mesh) was used interchangeably (Graphical Abstract). Experiments were carried out in an electrochemical reactor with a capacity to treat 0.9 L of effluent.

Different effluent samples were collected and used in the different phases, and the detailed characterization can be found in Ferreira et al., 2023 [5].

Results and Discussion

The results of the optimised electrochemical reactor experiment have indicated its potential to eliminate CECs and *E. coli* from a real secondary effluent [5]. The effectiveness and performance of each electrode used in the electrochemical oxidation process were different (Table 1), highlighting the complexity of the mechanisms involved. The cost-efficiency results of the process were influenced by the type of electrode material (Pt/Ti and DSA, RuO_2-IrO_2/Ti) and surface area/shape (bar, plate mesh, and circular mesh). The best outcomes were achieved for DSA/Ti with a circular mesh shape as anode and cathode, with removals ranging from 90% to below the detection limit for the CECs under study, mainly attributed to indirect oxidation mechanism. The degradation curves of all the compounds follow a pseudo first-order kinetics, and the obtained rate constant (k) for each of the nine compounds ranged between 0.0047 (CAF) and 0.0147 (EE2). The CECs can be divided into three main categories according to their pseudo first-order kinetics rate constant: rapid ($k>0.0103$), moderate ($0.0076<k<0.0103$), and persistent ($k<0.0076$). The differences obtained for the different CECs can be explained by their chemical structure and/or physicochemical properties, which influence their susceptibility to suffering EO [5].

The results show a potential for microorganisms' inactivation in effluent by EO. It is hypothesised that the *E. coli* inactivation is due to the formation of chloride species such as hypochlorite, chloride ions, chlorine, and chlorate [5].

The DSA circular mesh electrode had a higher real surface area in the electrochemical reactor, which proved to be advantageous in reducing cell potential (voltage) compared to the other anodes, resulting in lower energy consumption [5].

Table 1. Removal (%) of the target five CECs testing different anode materials (DSA/Ti and Pt/Ti) and shapes (bar, mesh plate and circular mesh) (adapted from [5]).

Electrode	SMX	CBZ	E2	EE2	DCF
DSA bar	47	8	44	42	40
Pt/Ti bar	69	31	44	54	88
Pt/Ti mesh plate	38	10	19	13	28
DSA mesh plate	52	5	30	31	52
DSA circular mesh	91	24	85	85	90

Conclusions

This study aimed to develop a cost-efficient electrochemical reactor to upgrade wastewater treatment plants for safe effluent reuse. DSA/Ti material with a circular mesh shape was found to be the best-performing anode and cathode, achieving high removal rates of up to 90% for the nine contaminants under study. The designed reactor also showed potential to inactivate *E. coli*. The DSA circular mesh electrode reduced cell potential compared to other anodes, resulting in lower energy consumption. This study contributes to the development of an eco-friendly technology for upgrading wastewater treatment plants and ensuring safe effluent reuse.

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