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Bioelectro-Fenton: a sustainable process for the removal of pharmaceuticals residues from water

Water scarcity is one of the main environmental issues humanity is facing. This situation is aggravated by the constant release of refractory contaminants into water reservoirs due to the incessant growth of the industrial activity. These so called "emerging contaminants" include dye stuff, pesticides, pharmaceuticals, personal care products and industrial chemicals, among others. Their presence in environmental bodies has been well documented all around the world and several studies have evidenced their harmful effects. Pharmaceuticals have gained special attention because these substances are developed to induce a biological response. Numerous studies have pointed out that different classes of drugs and their metabolites inflict important toxicological damage on living organisms such as endocrine disruption, gene modification, antibiotic resistance, carcinogenicity, etc. Furthermore, there is a potential risk of bioaccumulation because of their persistent character. State-of-the-art wastewater treatment technologies do not have the capacity to remove these kinds of pollutants. In this view, it is a need of the upmost importance to develop efficient and sustainable wastewater treatment methods to ensure the supply of clean water to our future generations.

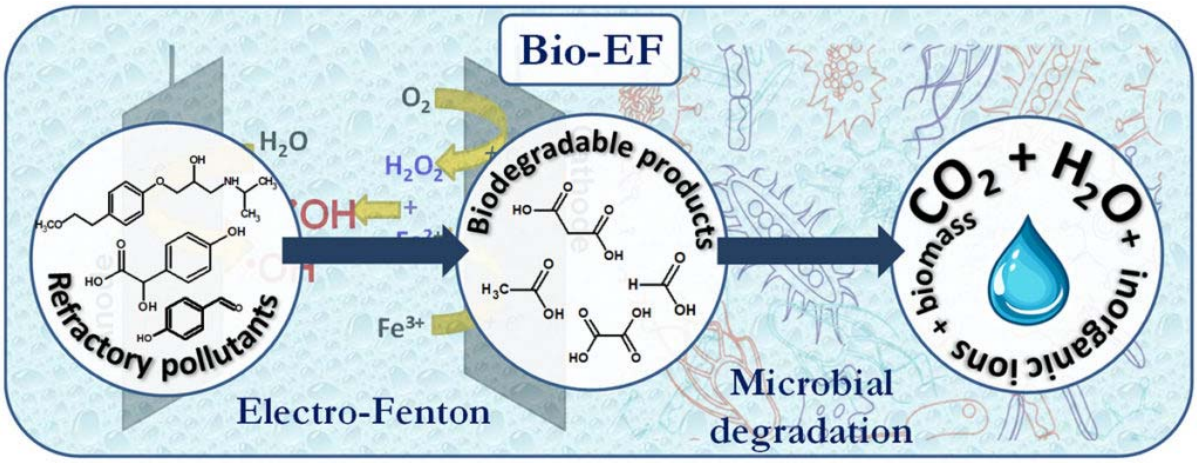

Fig. 1. Principle of coupling between electro-Fenton and biodegradation.

In this work, a coupled "Bioelectro-Fenton" process (Bio-EF, represented in Fig. 1) was proposed as an efficient and cost-effective sequential method for the treatment of synthetic solutions containing the β-blocker metoprolol (0.1 mM concentration). The first step of the treatment process consisted of the electro-Fenton (EF) degradation of the drug using an electrochemical cell equipped with a carbon-felt cathode and a boron-doped diamond (BDD) anode. It was found that following only 1 h of EF treatment, the drug was transformed into biodegradable compounds, mainly short-chain carboxylic acids like oxalic, acetic, malonic and formic acids (identified by HPLC/HPLC-MS analyses and reflected in the increase of biological oxygen demand, BOD_5), due to the efficient oxidative attack of the hydroxyl radicals ($^{\bullet}OH$) that were continuously formed in the solution via the electrochemically-assisted Fenton's reaction. The Fenton's reaction takes place between H_2O_2 that is electro-generated at the cathode and a catalytic amount of Fe^{2+} present in the solution, which is the

basis of the "environmentally friendly" EF process. Additionally, the BDD anode was another source of •OH contributing to the degradation/mineralization of the drug. When EF was performed during prolonged treatment times, energy consumption was importantly increased, which in turn resulted in a more costly process. Therefore, after 1 h of EF, where the solution's TOC had been reduced by 47% and the biodegradability had risen, the effluent was submitted to aerobic biological oxidation, during which a mixture of bacteria cultures were capable of metabolizing the remaining organics in the solution, resulting in almost complete mineralization (90% of TOC removal) following 4 d of incubation (Fig. 2). In this way, the treatment was finalized by a conventional biological method: biological processes are the most widespread and cost-effective wastewater treatment technologies.

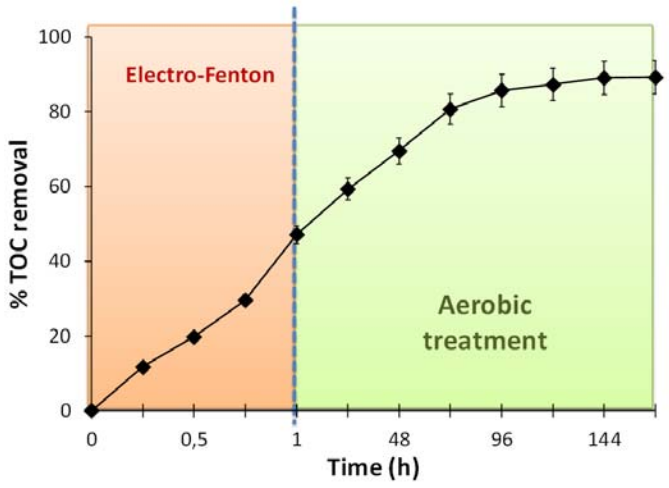

Fig. 2. Evolution of mineralization degree (in terms of TOC removal) of 0.1 mM metoprolol solution during coupled process Bioelectro-Fenton.

Overall, this integrated Bio-EF process was presented as an effective treatment alternative for the degradation of pharmaceutical pollutants in wastewater, in which the outstanding oxidation capability of the EF process and the cost-effectiveness of microbial degradation were capitalized in a joint treatment strategy.

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