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Photo-assisted degradation of 2,4,5-trichlorophenol by Electro-Fe(II)/Oxone® process using a sacrificial iron anode: Performance optimization and reaction mechanism

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HIGHLIGHTS

- Degradation of 2,4,5-TCP by Electro-Fe(II)/Oxone® with UV (EFOU) was explored.
- It was found that EFOU could be optimized by applying different current modes.
- The strategy of oxidant addition in optimizing probe degradation was investigated.
- Decay pathway of 2,4,5-TCP by EFOU were proposed based on LC–ESI/MS analysis.

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ABSTRACT

The degradation of chlorinated organic compound (2,4,5-trichlorophenol, 2,4,5-TCP) in Electro-Fe(II)/Oxone® system simultaneously exposed to UV (254 nm) irradiation (i.e., EFOU) was investigated in this study. In this oxidation process, once an electric current is applied between the anode (an iron sheet) and the cathode (a graphite bar), a predetermined amount of Oxone® is added to the reactor and UV light is simultaneously irradiated. It was found that an acidic condition is favorable to the process and over 92% removal of 0.2 mM 2,4,5-TCP in the pH range of 2.5–4.35 was rapidly obtained by the proposed EFOU process. Nevertheless, around 80% of 2,4,5-TCP was decayed at pH of 7.70 in 20 min suggesting that the proposed EFOU process is efficient even at neutral pH. Experimental results show that applied current of 1 mA results in the best performance, while the process is slightly inhibited at higher currents due to excessive generation of ferrous ions. The investigation on the mode of current-application shows that the EFOU process can be further optimized by controlling a proper electrolytic duration to reach a balance of Fe(II) generation and energy consumption. Additionally, it is found that tandem addition of Oxone® could minimize the scavenging effect between the radicals (from the first dose) and fresh Oxone® (from the second dose) and improve the overall performance of EFOU. Furthermore, aromatic intermediates such as 2,5-dichlorohydroquinone, 4,6-dichlororesorcinol, 2,4-chlorophenol, and many others are identified by using LC–ESI/MS analysis, based on which a possible decay pathway of 2,4,5-TCP by EFOU process is therefore proposed.

1. Introduction

2,4,5-Trichlorophenol (2,4,5-TCP) is an important representative of chlorinated organic compounds and has been widely used as disinfectants, fungicides, wood preservers and plant growth regulators over the past few decades. 2,4,5-TCP has also been used in the production of a variety of biocides. It is used as the precursor for the synthesis of the herbicide 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and of the bactericide, hexachlorophene [1]. Especially, it is formed as the primary intermediate upon the decay of 2,4,5-T by the advanced oxidation processes (AOPs) [2,3] or microbial activities [4]. 2,4,5-TCP is considered to have significant toxicological effects and potential carcinogenicity. 2,4,5-TCP has been included in the "persistent, bioaccumulative, and toxic chemical list" by the US EPA, imposing a serious threat to human health and natural ecosystems. It is resistant to biodegradation in aerobic and anaerobic systems [5], thereby tending to bioaccumulate in the environment. Moreover, 2,4,5-TCP is considered to be more resistant to biodegradation than other trichlorophenols [6]. As a result, it is listed as one of the priority pollutants by US EPA [7]. Although its use as a biocide has been banned in many countries, the application of

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