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Electrochemical filtration process for simultaneous removal of refractory organic and particulate contaminants from wastewater effluents

Naresh Mameda [a], Hyeona Park [b], Kwang-Ho Choo [a, b, *]

[a] Advanced Institute of Water Industry, 80 Daehak-ro, Buk-gu, Daegu 41566, Republic of Korea
[b] Department of Environmental Engineering, 80 Daehak-ro, Buk-gu, Daegu 41566, Republic of Korea

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A B S T R A C T

Versatile electrochemical reactions are effective for removing a wide range of water contaminants. This study focuses on the development and testing of bifunctional electrocatalytic filter anodes as reactive and separating media for the simultaneous removal of refractory dissolved organic and particulate contaminants from real wastewater effluents. The results show that the TiO_2 particle interlayers formed between the Ti fiber support and the top composite metal oxide catalyst layers assist in reducing filter pores to an effective size range that enables removal of most particulates within the wastewater. The double-sheet design, which is a sandwich-structured module with an internal void space for permeate, prevents filter fouling, and transmembrane pressure can be maintained at a very low level of <5 kPa during batch and continuous flow reactor operations. Substantive and simultaneous removal of dissolved organics (e.g., chromophores, fluorophores, 1,4-dioxane, chemical oxygen demand, and total organic carbon) and particulate matter (i.e., turbidity) are achieved, although removal rates and efficacies differ depending on the electric current density applied. Decolorization and particulate rejection occur swiftly and immediately, but 1,4-dioxane degradation is relatively slow and quite time-dependent. Possible 1,4-dioxane degradation pathways during electrocatalysis are also proposed. Electrochemical filtration technology shows considerable promise for use in the next generation of advanced wastewater treatment solutions.

1. Introduction

The use of electrochemical processes for removing nonbiodegradable organic and inorganic contaminants (e.g., dyes, pharmaceuticals, hazardous substances, heavy metals) from various wastewater effluents has been the focus of many recent studies (Korshin and Yan, 2018; Martínez-Huitle et al., 2015; Muff, 2014; Särkkä et al., 2015; Singh and Mishra, 2017; Soriano et al., 2017). There are several different types of electrochemical reactions used to efficiently treat wastewater: electrocoagulation (Tian et al., 2018; Ya et al., 2018), electro-Fenton (Gunawan et al., 2017; Sandhwar and Prasad, 2017), electrooxidation (Moreira et al. 2015, 2017; Shi et al., 2017), and electroreduction (Chuang et al., 2018; Yan et al., 2018). In this respect, electrochemical technologies have several advantages over other physicochemical treatment methods as they use versatile direct/indirect reactions (Ammar et al., 2016; Cho et al., 2014; Labiadh et al., 2017; Zöllig et al., 2015), have compact modular configurations (Chen et al., 2017; Huang et al., 2016; Ling et al., 2016; Mukimin et al., 2015), involve easy operational processes (Brillas and Martínez-Huitle, 2015; Sirés et al., 2014), and provide in-site active chemical agent generation (Moreira et al., 2017; Ridruejo et al., 2018). However, the use of electrochemical methods alone is currently insufficient for coping with the wide range of contaminants present in water and wastewater streams.

Combined electrochemical processes provide synergistic effects for removing contaminants from wastewater. For instance, the addition of dolomite [$CaMg(CO_3)_2$] to an electrolytic system can accomplish the effective and simultaneous removal of ammonia and phosphate from swine wastewater (Huang et al., 2018), and coupling the electro-Fenton with biological

* Corresponding author. Department of Environmental Engineering, 80 Daehak-ro, Buk-gu, Daegu 41566, Republic of Korea.
E-mail address: chookh@knu.ac.kr (K.-H. Choo).

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