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Advanced treatment of wet-spun acrylic fiber manufacturing wastewater using three-dimensional electrochemical oxidation

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A B S T R A C T

A three-dimensional electrochemical oxidation (3D-EC) reactor with introduction of activated carbon (AC) as particle micro-electrodes was applied for the advanced treatment of secondary wastewater effluent of a wet-spun acrylic fiber manufacturing plant. Under the optimized conditions (current density of 500 A/m^2, circulation rate of 5 mL/min, AC dosage of 50 g, and chloride concentration of 1.0 g/L), the average removal efficiencies of chemical oxygen demand (COD_{cr}), NH_3–N, total organic carbon (TOC), and ultraviolet absorption at 254 nm (UV_{254}) of the 3D-EC reactor were 64.5%, 60.8%, 46.4%, and 64.8%, respectively; while the corresponding effluent concentrations of COD_{cr}, NH_3–N, TOC, and UV_{254} were 76.6, 20.1, and 42.5 mg/L, and 0.08 Abs/cm, respectively. The effluent concentration of COD_{cr} was less than 100 mg/L, which showed that the treated wastewater satisfied the demand of the integrated wastewater discharge standard (GB 8978-1996). The 3D-EC process remarkably improved the treatment efficiencies with synergistic effects for COD_{cr}, NH_3–N, TOC, and UV_{254} during the stable stage of 44.5%, 38.8%, 27.2%, and 10.9%, respectively, as compared with the sum of the efficiencies of a two-dimensional electrochemical oxidation (2D-EC) reactor and an AC adsorption process, which was ascribed to the numerous micro-electrodes of AC in the 3D-EC reactor. Gas chromatography mass spectrometry (GC–MS) analysis revealed that electrochemical treatment did not generate more toxic organics, and it was proved that the increase in acute biotoxicity was caused primarily by the production of free chlorine.

Introduction

The acrylic fiber manufacturing industry is dominant in Asia as a result of the large demand of the global market. China is the country that produces the largest amount of acrylic fiber, with a yield of nearly 0.7 tons of acrylic fiber every year (Zheng et al., 2015a). The wastewater from production of acrylic fiber contains complex, highly toxic, and poor biodegradable compounds, such as organic nitriles, alkanes, and aromatic organic compounds (Zheng et al., 2015b). Millions of tons of wastewater are generated during the process, which is a concern because the effluent is resistant to degradation by conventional biological treatment technologies. Therefore, it is essential to search for efficient treatment methods to

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Table 1 – Characteristics of the acrylic fiber wastewater.

Parameters	COD_{cr} (mg/L)	BOD_5 (mg/L)	NH_3–N (mg/L)	TOC (mg/L)	UV_{254} (Abs/cm)	BOD_5/COD_{cr}	pH
Range of values	203–240	18–30	44–63	60–103	0.18–0.26	0.09–0.13	7.0–8.4
Mean value ± S.D.	215.8 ± 10.3	24 ± 4	51.2 ± 4.8	79.3 ± 13.4	0.23 ± 0.02	0.11 ± 0.01	7.9 ± 0.4

S.D. is the abbreviation of standard deviation.
BOD_5: biochemical oxygen demand after 5 days.

eliminate the pollution risks of discharging acrylic fiber wastewater into sewer systems.

Presently, treatment techniques for acrylic fiber wastewater include electro-coagulation (Gong et al., 2014), the electro-Fenton process (Sun et al., 2015a), microelectrolysis (Lai et al., 2012), a novel biological treatment with an upflow anaerobic sludge blanket (UASB) (Li et al., 2011, 2012), sequencing bioreactor (SBR) (Li et al., 2013), ANAMMOX process (An et al., 2013) and hybrid anoxic/oxic membrane bioreactor (A/O-MBR) (Tian et al., 2015). However, there is no fully mature technology that is able to achieve the desired removal efficiency to meet discharge standards. Thus, it is increasingly urgent to find efficient techniques to reduce the amounts of contaminants in the wastewater. Three-dimensional electrochemical oxidation (3D-EC) technology with introduction of particle electrodes leads to higher specific surface area and shorter distance of mass transfer. The technique has been widely used in refractory wastewater treatment, including dyeing wastewater (Wang et al., 2005), landfill leachate (Zhang et al., 2010), CI acid orange 7 containing wastewater (Xu et al., 2008), paper mill wastewater (Wang et al., 2007), and heavy oil refinery wastewater (Wei et al., 2010). It has been considered as an effective and promising method for wastewater treatment (Zhang et al., 2013). However, there are few studies on the treatment of acrylic fiber wastewater using the 3D-EC process.

In this study, a 3D-EC reactor, with activated carbon (AC) introduced as particle electrodes, was utilized for advanced treatment of the secondary effluent of wastewater from the acrylic fiber manufacturing industry. The reactor parameters, including current density, circulation rate, AC dosage, and chloride concentration, were optimized, and then the removal rates of the contaminants were investigated under the optimized treatment conditions. The synergistic effect of the 3D-EC reactor was also explored to interpret its enhancement of the degradation of organics. Moreover, the biodegradability and acute biotoxicity of the wastewater were assessed to evaluate the environmental risk and industrial feasibility of the 3D-EC system.

1. Experimental

1.1. Wastewater

The experimental wastewater was the secondary effluent of an acrylic fiber manufacturing plant in Northern China. The wastewater was stored at 4°C. Physical and chemical properties of the raw wastewater are shown in Table 1. The raw wastewater is characterized by complicated components, high toxicity, and low biodegradability.

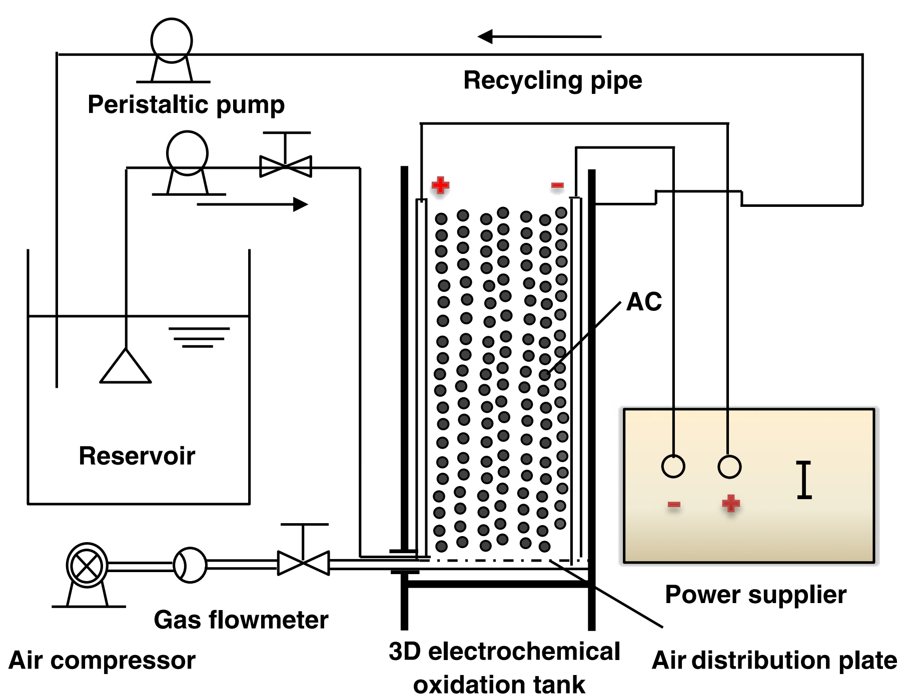

Fig. 1 – Schematic diagram of the experimental setup.