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Impacts of COD and DCP loading rates on biological treatment of 2,4-dichlorophenol (DCP) containing wastewater in a perforated tubes biofilm reactor

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Abstract

Biofilm processes offer considerable advantages for biological treatment of chlorophenol containing wastewaters since such industrial effluents are difficult to treat by conventional activated sludge processes. A rotating perforated tubes biofilm reactor (RTBR) was developed and used for treatment of 2,4-dichlorophenol (DCP) containing synthetic wastewater. Effects of COD and DCP loading rates on COD, DCP and toxicity removals were investigated. Percent COD removal decreased and effluent COD increased with increasing COD and DCP loading rates due to toxic effects of high DCP content in the feed. DCP and toxicity removals showed similar trends. As the DCP loading rate increased the effluent DCP content increased yielding high toxicity levels in the effluent. COD and DCP loading rates should be below 90 g COD m^{-2} d^{-1} and 2.8 g DCP m^{-2} d^{-1} in order to obtain more than 90% DCP and toxicity removals. However, DCP loading rates lower than 1 g DCP m^{-2} d^{-1} are required to obtain more than 90% COD removal. Empirical equations were developed to estimate percent COD, DCP and toxicity removals as functions of COD and DCP loading rates. The coefficients of the empirical equations were determined by using the experimental data. Empirical model predictions for percent COD, DCP and toxicity removals were in good agreement with the experimental data.

Keywords: 2,4-Dichlorophenol (DCP); Organic loading rates; Rotating tubes biofilm reactor (RTBR)

1. Introduction

Effluents of some chemical industries such as petrochemicals, refineries, pesticides, pulp and paper contain toxic chlorophenol compounds which make biological treatment of such effluents difficult. Conventional activated sludge processes treating chlorophenol containing wastewaters usually yield low treatment efficiencies. Therefore, development of new bioprocesses is required for effective removal of chlorophenols from industrial wastewaters to reduce the toxicity of the effluents.

Among various methods developed for removal of chlorophenols, physico-chemical methods such as adsorption and ion exchange (Jung et al., 2001) are usually used to concentrate the chlorinated phenols on the solid phase which require further mineralization by chemical and biological oxidations. Chemical oxidation methods are fast, but may result in formation of undesirable by products and also may require expensive chemical agents such as ozone. Biodegradation of chlorophenols is more specific and relatively inexpensive. Aerobic and anaerobic treatment processes were developed by many investigators for removal of chlorophenols from wastewaters (Annachatre and Gheewala, 1996; Armenante et al., 1999; Atuanya et al., 2000; Bali and Sengul, 2002). The number and position of chlorine groups on the aromatic ring strongly affects biodegradability and toxicity of chlorinated compounds. Usually biodegradability decreases and toxicity of such compounds increase with increasing number of chlorine

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groups (Annachatre and Gheewala, 1996). Investigations on biodegradation of chlorophenols were mainly focused on suspended pure culture studies using different bacteria and fungi because of low activity of activated sludge bacteria in degradation of such compounds (Li et al., 1991; Dapaah and Hill, 1992; Hill et al., 1996; Yee and Wood, 1997; Steinle et al., 1998; Fahr et al., 1999; Kim and Hao, 1999; Wang and Loh, 1999; Wang et al., 2000; Farrell and Quilty, 2002). In some studies, biodegradation of chlorophenols was accomplished by using a carbohydrate substrate as the primary metabolite along with chlorophenols as the cometabolite (Hill et al., 1996; Kim and Hao, 1999; Wang and Loh, 1999). Limited number of studies was reported on biological treatment of chlorophenol containing wastewaters (Sahinkaya and Dilek, 2002; Kargi and Eker, 2006; Kargi et al., 2005). Pre-adaptation of the activated sludge cultures to the chlorophenols was reported to improve the rate and the extent of biodegradation of those compounds (Bali and Sengul, 2002; Sahinkaya and Dilek, 2002).

In order to overcome toxic effects of chlorophenols, immobilized cell or biofilm reactors were used recently (Shieh et al., 1990; Radwan and Ramanujam, 1996; Swaminathan and Ramanujam, 1998; Shin et al., 1999; Kim et al., 2002). Biofilm reactors are more resistant to high concentrations of chlorophenols because of high biomass concentrations and diffusion barriers within the biofilm for the toxic compounds. Packed column, rotating biodisc, fluidized bed and UASB reactors were used for aerobic and anaerobic treatment of chlorophenol containing wastewaters.

Different biological tests were used for toxicity assessment of individual chemicals or complex effluents (Liu, 1986; Brouwer, 1991; Farre and Barcelo, 2003). One of the recently developed toxicity assessment method is the 'Resazurin assay' which is relatively simple, inexpensive and rapid (Liu, 1986; Brouwer, 1991; Strotmann et al., 1993). The basic principle of the method is the measurement of percent inhibition on dehydrogenase activity of bacteria in the presence of toxic compounds. Toxicity values obtained with the Resazurin assay are comparable to those obtained with the more commonly used biological methods such as *Daphnia magna*, and Microtox TM (Farre and Barcelo, 2003).

The major objective of this study is to investigate the effects of COD and DCP loading rates on COD, DCP and toxicity removals from DCP containing synthetic wastewater in a rotating perforated tubes biofilm reactor (RTBR). The RTBR was developed by the authors and used for biological treatment of high strength wastewaters in recent studies (Kargi and Eker, 2001, 2002a,b, 2003). The reactor has large biofilm surface area and provides effective aeration of biofilm by direct contact with air during rotation. Resazurin assay was used for the assessment of the feed and effluent wastewater toxicity levels.

2. Materials and methods

2.1. Experimental system

Fig. 1 depicts a schematic diagram of the rotating perforated tubes biofilm reactor (RTBR). The experimental system consisted of a feed reservoir, wastewater tank containing rotating tubes, driving motor, shaft and a wastewater pump. The discs containing the tubes were rotated by using a motor and a shaft passing through the central hole on the discs. Rotational speed was 12 rpm (rev min^{-1}) throughout the study. Feed reservoir was placed in a deep refrigerator to keep the temperature below 5 °C in order to avoid any decomposition. The rotating tube system had two sections mounted on the same shaft each having 25 perforated tubes (total of 50 tubes) of length $L = 25$ cm made of PVC. Outer and inner diameter

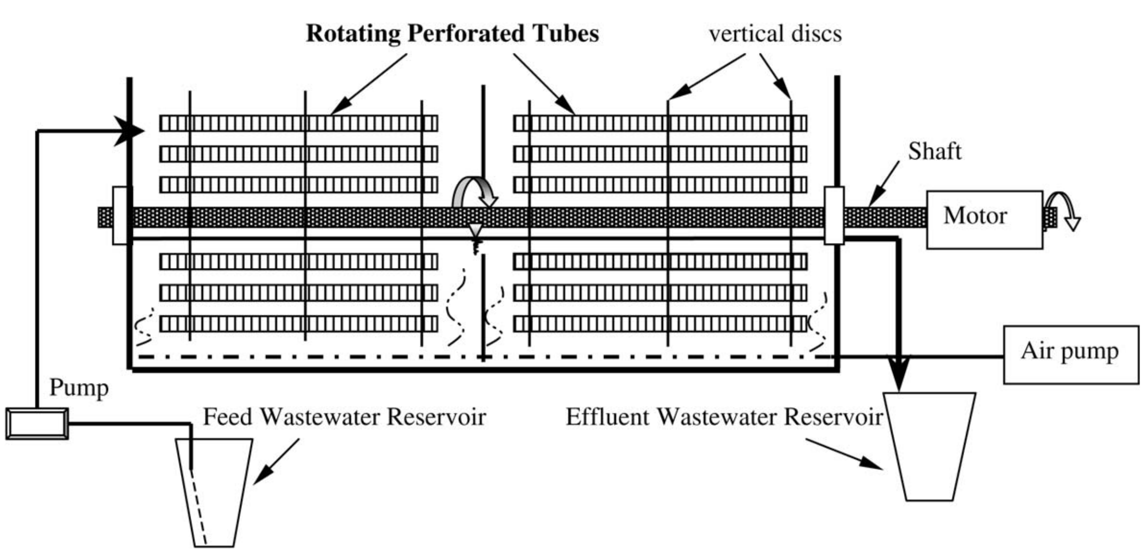

Fig. 1. Schematic diagram of the rotating perforated tubes biofilm reactor (RTBR).