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Treatment of azo dye-containing synthetic textile dye effluent using sulfidogenic anaerobic baffled reactor

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HIGHLIGHTS

- Azo dye and sulfate could be reduced simultaneously.
- ABR provides favorable environments for different types of reactions.
- ABR performs well in terms of COD, sulfate, color, and aromatic amine removals.

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ABSTRACT

This study aims at investigating azo dye reduction performance of a sulfidogenic anaerobic baffled reactor (ABR) for around 400 days. ABR was operated at 30 °C in a temperature-controlled room and hydraulic retention time (HRT) was kept constant at 2 days. The robustness of ABR was assessed under varying azo dye loadings and COD/sulfate ratios. Additionally, oxygen was supplied (1–2 L air/m^3 reactor min) to the last compartment to investigate the removal of azo dye breakdown products. ABR performed well in terms of COD, sulfate and azo dye removals throughout the reactor operation. Maximum azo dye, COD and sulfate removals were 98%, 98% and 93%, respectively, at COD/sulfate ratio of 0.8. Aeration created different redox conditions in last compartment, which enhanced the removal of COD and breakdown products. The adverse effects of aeration on azo dye reduction were eliminated thanks to the compartmentalized structure of the ABR.

1. Introduction

Azo dyes, the major class of dyes, are produced economically and can be used in variety of sector; textile, food, paper and leather industries. Over 1 million-tone dye is produced per year, of which 50% are textile dyes (Singh and Arora, 2011). During textile dyeing process, applied dye to the fabric can be substantially lost in the wastewaters; which is around 98% for basic dyes and 50% for reactive dyes (O'Neill et al., 1999). The release of dye containing effluents into the environment is undesirable due to the serious potential environmental problems linked with the dyes and their breakdown products (Pandey et al., 2007). Color removal, especially from textile wastewaters, has been a big challenge over the last decades since there is no single and economically attractive technology for dye decolorization. In addition to color, a typical textile industry wastewater is characterized by chemical oxygen demand (COD), biochemical oxygen demand (BOD), pH, and salinity (Dos Santos et al., 2007). In dyeing process many chemicals such as heavy metal containing dyes (chromium, cadmium, zinc, etc.), nitrate and sulfate containing salts, surfactants, sulfide and formaldehyde may be added to improve dye fixation. It has been reported that sulfate is generally added to the dye baths for ionic strength adjustment or it may be formed by the oxidation of sulfur species used in dyeing processes, such as sulfide, hydrosulfide, and dithionite. It is estimated that sulfate concentration can reach up to 1706–2690 mg/L in the textile dyeing effluent (Bisschops and Spanjers, 2003).

Although different chemical, physical, and biological treatment alternatives have been studied to remove dyes from textile wastewaters biological methods are commonly considered to be the most effective and environmentally safe (van Der Zee and Villaverde, 2005). In general, complete azo dye mineralization requires both anaerobic and aerobic biological processes (Hu, 1998). Though anaerobic treatment removes color, aromatic amines resulting from decolorization process are not mineralized under anaerobic conditions and tend to accumulate to toxic levels (Carliell et al., 1998). This led to the development of two-stage

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sequencing anaerobic–aerobic biological processes, in which the reduced breakdown products are oxidized in the second aerobic stage. Although anaerobic–aerobic one stage processes (anaerobic and aerobic sequencing batch reactors) offers promising and economical decolorization way for textile dye effluent, the exposure of anaerobic sludge to alternating anaerobic–aerobic environment may decrease the anaerobic decolorization efficiency and COD removal (Bonakdarpour et al., 2011). Cinar et al. (2008) observed that the azo reductase activities gradually increased in anaerobic stage and decreased in aerobic stage due to the adverse effect of dissolved oxygen. Similarly, anaerobic environment decreased the activity of catechol 2,3-dioxygenase enzyme activity, which is an indicator of aromatic amine biodegradation. Hence, anaerobic–aerobic two separate stage processes may have higher decolorization potential compared with one stage anaerobic–aerobic processes.

So far, several anaerobic reactor types have been used for textile wastewaters; such as, fluidized bed reactors (Cirik et al., 2013), sequencing batch reactors (Cinar et al., 2008; Bonakdarpour et al., 2011), upflow anaerobic sludge blanket reactors and packed bed reactors (Isık and Sponza, 2008). However, few studies have examined the performance of anaerobic baffle reactors (ABRs) for the decolorization of textile wastewaters. ABRs are able to keep the biomass in the reactor for a long solids retention time (SRT) independent of HRT, which is in favor of azo dye degrading microorganism (Tawfik and El-Kamah, 2011). Additionally, one of the most significant advantages is its ability to separate processes longitudinally, allowing the reactor to behave as multiple-stage system without associated control problems and high costs. The reactor design is simple with no moving parts or mechanical mixing, making it relatively inexpensive to construct.

The role of sulfate reducing bacteria (SRB) on azo dye reduction may be important since textile finishing wastewater usually contains sulfate (Cirik et al., 2013). The effect of sulfate reduction on anaerobic color removal efficiency differs greatly in literature. Color removal may either be stimulated or suppressed since it competes with azo dye as an electron acceptor (Carliell et al., 1998; Albuquerque et al., 2005). So far, few researches have been conducted on the use of SRB for textile wastewater treatment (Yoo et al., 2001; van der Zee and Villaverde, 2005; Pandey et al., 2007; Cirik et al., 2013). This study aims at evaluating the performance of a four-stage sulfidogenic ABR for the treatment of synthetic azo dye-containing textile wastewater under different operational conditions.

2. Methods

2.1. Anaerobic baffled reactor (ABR) set-up

The ABR was consisted of four equal compartments separated by vertical baffles. The working volume of the reactor was 19 L (wide: 20 cm, long: 80 cm, deep: 20 cm), the active volume of each compartment was 4.75 L. Each compartment was further divided into two by slanted edge (45°) baffles to encourage mixing within each compartment (Fig. 1). ABR was operated in a temperature controlled chamber at 30 °C. The synthetic wastewater was continuously pumped into the reactor using a peristaltic pump to keep HRT constant at 2 days throughout the study. The effluent MLSS was measured daily and the results showed leakage of the anaerobic culture was negligible, which led to SRT close to infinity.

The ABR was inoculated from a full-scale anaerobic digester located at Gaziantep, Turkey and acclimatized to the described basal media for 98 days. The performance of the ethanol-fed sulfidogenic ABR was evaluated for 400 days with eight different periods (Table 1). The operational conditions were changed after observing steady state measurements in COD, sulfate and azo dye concentrations in all compartments.

Firstly, the reactor was fed with synthetic media containing 2000 mg/L sulfate without dye supplementation (period I, days 0–98) to enrich ethanol oxidizing sulfate reducing bacteria. Then, the reactor performance was evaluated at different dye loadings and COD/sulfate ratios (Table 1). Additionally, the last compartment of the ABR was aerated at two aeration rates in order to improve the degradation of aromatic amines produced during the cleavage of the azo dye under anaerobic conditions (Table 1). The impacts of the aeration of the last compartment on anaerobic cleavage of the azo dye and the fate of sulfide generated due to sulfate reduction were also investigated. The reactor was sampled 3 times a week for performance evaluation.

2.2. Simulated textile wastewater

The ABR was fed with synthetic wastewater containing 2567 mg/L $MgSO_4 \cdot 7H_2O$, 740 mg/L Na_2SO_4, 56 mg/L KH_2PO_4, 110 mg/L NH_4Cl, 11 mg/L Ascorbic acid, 50 mg/L yeast extract and 1340 or 1600 mg COD/L ethanol at a rate of 9.5 L/day (Table 1). The synthetic wastewater was prepared daily. Sulfate in synthetic

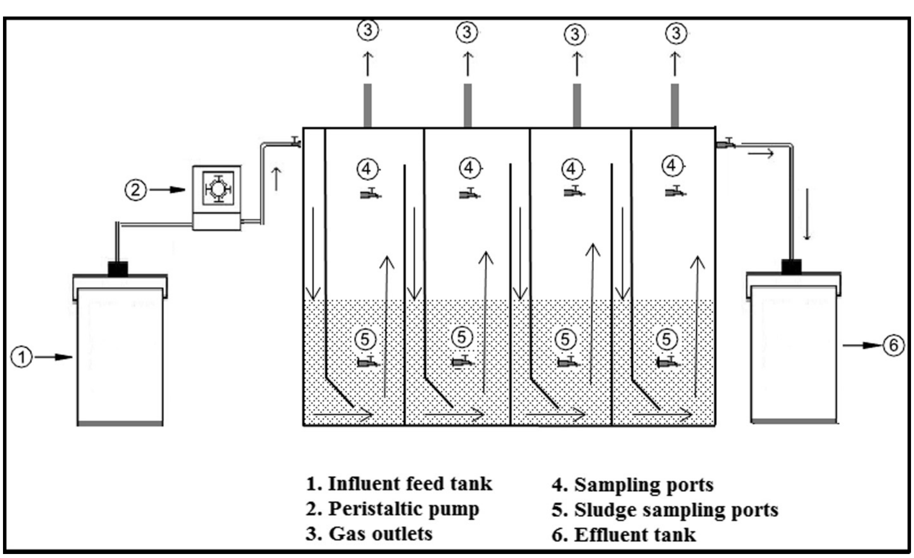

Fig. 1. Schematic of the ABR system.