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# Impact of reactor configuration on treatment performance and microbial diversity in treating high-strength dyeing wastewater: Anaerobic flat-sheet ceramic membrane bioreactor versus upflow anaerobic sludge blanket reactor

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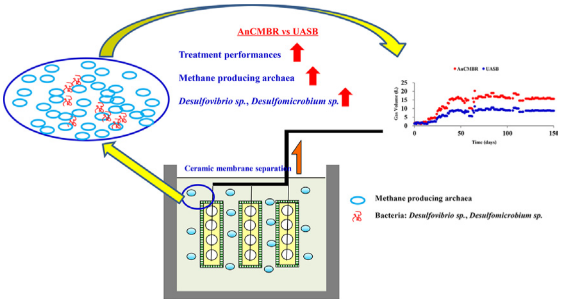
## GRAPHICAL ABSTRACT



## ARTICLE INFO

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## ABSTRACT

In this study, an anaerobic flat-sheet ceramic membrane bioreactor (AnCMBR) was used to treat high-strength dyeing wastewater, and compared with an upflow anaerobic sludge blanket (UASB) reactor. The start-up phases of the AnCMBR and UASB reactor were accomplished within 60 d by using cultivated seed sludge. The results showed that the AnCMBR had better COD, TN, and TP removal rates than the UASB reactor. The $CH_4$ production of the AnCMBR was higher than that of the UASB reactor. The AnCMBR was operated with low energy consumption due to good water permeability of the flat-sheet ceramic membrane. The AnCMBR and UASB reactor had similar $CH_4$-producing Archaea; *Methanosaeta*, *Methanosarcina*, and *Methanomassiliicoccus* were the most abundant. The AnCMBR had a higher proportion of *Desulfovibrio* sp. and *Desulfomicrobium* sp., which are reported to have the potential to degrade reactive dyes. A large number of sulfate-reducing enzymes were deduced to contribute to the sulfate-reducing pathway.

## 1. Introduction

Compared with physical-chemical methods, biological methods are widely applied in dyeing wastewater treatment due to low operating cost (Wenjie et al., 2018). The biological treatment process can be divided into anaerobic biological treatment and aerobic biological

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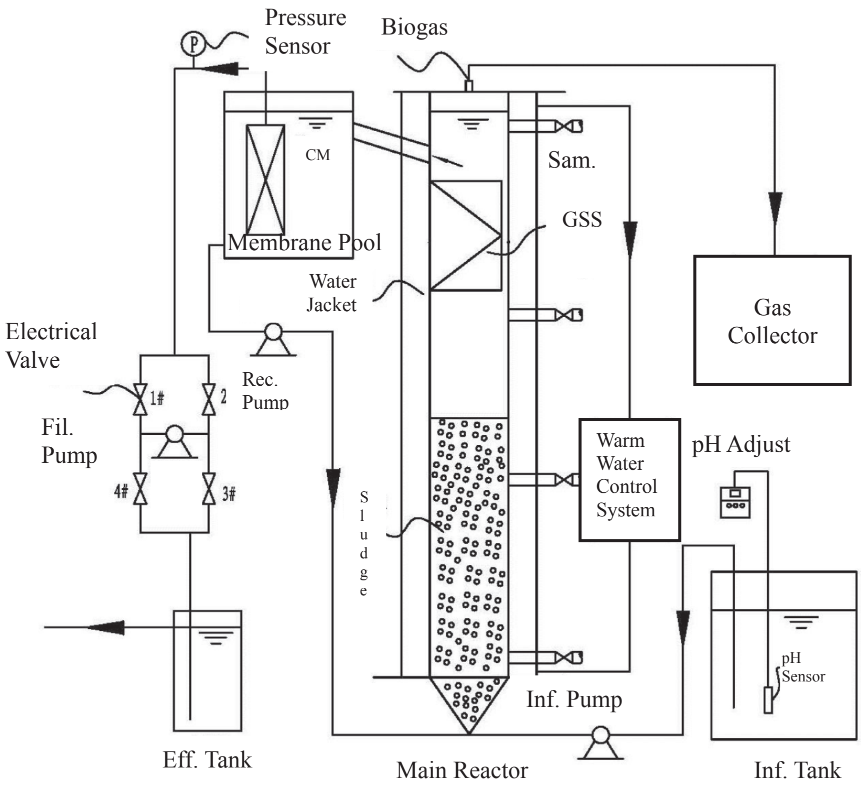

**Fig. 1.** Diagram of AnCMBR and UASB system. CM: flat-sheet ceramic membrane; Fil. Pump: filtrate pump; Rec. Pump: recycling pump; Sam.: sampling port; Inf. Pump: influent pump; Inf. Tank: influent tank; Eff.: effluent tank.

treatment. According to the type of dyeing wastewater, the anaerobic process and aerobic process have their respective pertinence.

As far as biodegradable dyeing wastewater is concerned, aerobic processes are recommended, and treatment efficiency can reach more than 80%. Nevertheless, the removal rate of color is low. The main reason for this is that it is difficult to biodegrade the dye in dyeing wastewater, which has a low biochemical oxygen demand/chemical oxygen demand ($BOD_5$/COD) ratio. Self-oxidation is another reason for poor decolorization. Kudlich et al. (1999) studied the self-oxidation of hydroxy aniline, and found that the intermediate products of azo dye could be oxidized into naphthone or macromolecule polymers in the presence of $O_2$, and that chromaticity was restored. Ten aromatic amines appeared in the anaerobic degradation process (Tan et al., 2005); the results showed that only 1/5 of the aromatic amines were degraded in the aerobic environment. It can be concluded that the treatment of dyeing wastewater by aerobic biological processes is not thorough, especially for refractory, toxic, and harmful substances. Aerobic biological processes have a higher removal rate of $BOD_5$, but the removal rate of complex macromolecular material is poor. Therefore, aerobic biological processes are not ideal for the removal of substances that are difficult to degrade in dyeing wastewater.

Most of the current dyestuffs have characteristics of anti-photolysis, antioxidation, and biodegradability, which are contradictory to the conditions needed for aerobic biological processes. Anaerobic biological processes can adapt to the effect of such substances, and can effectively increase the biodegradability of the wastewater. The effect of an upflow anaerobic sludge bed (UASB) reactor on the treatment of dyeing wastewater was studied by Somasiri et al. (2008). The results showed that the removal efficiency of COD reached 90% with good removal rate of color. However, the anaerobic microorganisms were easily lost from the reactor, thereby resulting in a decrease in the treatment performance of the reactor. In order to maintain high concentrations of microorganisms in the reactor, microbial fixation is usually conducted by means of granular sludge or by adding biocarriers (Yue et al., 2016). The anaerobic membrane bioreactor (AnMBR) is a wastewater treatment technology that has been developed in recent years; it can achieve high load and good removal efficiency through efficient separation of microorganisms (Padmasiri et al., 2007; Lew et al., 2009; Ho and Sung, 2010). AnMBRs are expected to perform well in dyeing wastewater treatment due to the aforementioned advantages. Nevertheless, there are no reports on the use of AnMBRs in treating dyeing wastewater. The impacts of reactor configuration on treatment performance, especially changes in microbial populations, in treating dyeing wastewater using an AnMBR versus a UASB reactor need to be investigated.

The present study employed a flat ceramic sheet as the membrane module in an anaerobic flat-sheet ceramic membrane bioreactor (AnCMBR) that was developed for treating dyeing wastewater. The flat-sheet ceramic membrane can be used as the recycling membrane module of the membrane bioreactor in the treatment of industrial and municipal wastewater (Xue et al., 2016; Zhang et al., 2017a; Niwa et al., 2016). Treatment performances of the AnCMBR and UASB reactor using real dyeing wastewater were investigated. 16S rRNA was employed to characterize changes in the microbial populations within the anaerobic sludge. The results might provide theoretical guidance and a reference for engineering applications.

## 2. Materials and methods

### 2.1. *Wastewater composition*

The wastewater sample used in this study was obtained from a dyeing company (China) that produces disperse, reactive, and acid dyes. The compositions of the wastewater included COD concentration of 17,000–19,000 mg/L, five-day biological oxygen demand ($BOD_5$) of 680–760 mg/L, $SO_4^{2-}$ concentration of 100–150 mg/L, suspended