Decolorization of azo dye in a newly developed plug-flow baffled bioelectrocatalyzed reactor

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Abstract：

In this study, we designed a membrane-free, continuous plug-flow baffled bio-electrocatalyzed reactor (PFB-BER) to enhance the degradation of azo dye containing wastewater. The efficiency of decolorizition of alizarin yellow R (AYR) was tested in such a bioelctrochemical system with acetate as carbon source. The influent containing AYR (100mg·L^{-1}) and acetate (1000mg·L^{-1}, 25mM PBS) was flowed into the PFB-BER continuously under an external power source of 0.5V. The decolorizaiton of AYR increased from ~70% to 90% at HRT of 24h. The decolorization of AYR reduced from 80% at 12h to 70% at 8h and to 45% at 4h. While, the decolorization enhanced to 80% at 4h and to 96% at 8h with additional cathode electrode volume rate up to 20% being introduced to the system.

Keywords：

plug-flow baffled bioelectrochemcatalyzed reactor (PFB-BER); bioelectrochemical systems (BESs) ; alizarin yellow R; decoloration; HRT

INTRODUCTION

Azo dyes are extensively used in the textile processing. Azo dyes should be removed from wastewater before they were discharged into the environment, since most of azo dyes and their metabolic products are mutagenic to human and toxic to aquatic life. Bioelectrochemical system (BES) as one of anaerobic biological processes has emerged as a potential wastewater treatment approach for azo dye removal because of its significant advantages including high efficiency and cost-effective. In this work, a plug-flow baffled reactor (PFB-BER) was developed to enhance the decolorizationof azo dyes. Key operational parameters, HRT and cathode electrons volume rate, were investigated to evaluate the performance of the PFB-BER.

MATERIALS AND METHODS

Establishment of PFB-BER. A newly designed plug-flow baffled bioelectrocatalyzed reactor (PFB-BER) was constructed with 3 corridors (length 20 cm , depth 5 cm, , width for each corridor 5 cm) and with a total empty volume (TV) of 1.50 L and an effective liquid volume of 1.25 L. Graphite granular (ID from 3.0 mm to 5.0 mm) filling in titanium baskets (Length 45 mm, height 30mm, width 45mm) were adopted

as cathode and anode. The volume ratio of cathode to anode was 2:1. The electrode volume was 15% of the effective liquid volume.

Set up. Four reactors were set up as replicates. Two reactors were operated without applied voltage (open circuit PFB-BER), and the left two reactors were running under applied voltage of 0.5V with external resistance 20 ohm (closed circuit PFB-BER). All the reactors were inoculated with active sludge collected from Taiping wastewater treatment plant (Harbin, China.). Continuous flow tests were conducted with increasing AYR concentration gradually. A successful start-up was received when the anode potential reduced to below -300mVmV. And a stable operation was received when AYR decolorization changed little at a fixed concentration of 100mg·L^{-1} for almost a month.

Calculation. AYR decolorization efficiency (DE) was calculated according to the following equation: $DE = \frac{C_{in-AYR} - C_{ef-AYR}}{C_{in-AYR}} \times 100\%$

where $C_{in\text{-}AYR}$ is influent AYR concentration, mg·L^{-1}. $C_{ef\text{-}AYR}$ is effluent AYR concentration, mg·L^{-1}.

RESULTS AND DISCUSSIONS

In the open circuit PFB-BER, the efficiency of AYR decolorization was 73.65±2.88% at HRT of 24h as shown in Fig. 1 and AYR was mainly decolorized via biological reduction. In the closed circuit PFB-BER, the efficiency of AYR decolorization was enhanced to 93.35±1.43%, which was probably attributed to the electrochemical reduction. When HRT was shortened to 12h, the decolorization efficiency of open circuit PFB-BER decreased to 68 % and the chromaticity of effluent was higher than 80 times, which could not meet the textile wastewater discharge standard in China. While the decolorization efficiency of closed circuit PFB-BER was as high as 90% at HRT of 12h, which presented an ideal performance. Therefore, in the following experiments, the PFB-BER all operated in closed circuit to investigate the effect of HRT on the performance of PFB-BERs.

Efficiency of AYR decolorization under different HRTs

For PFB-BER, the AYR loading was gradually increased from 106.23g·$m^{-3}$$TVd^{-1}$ to 637.40 g·$m^{-3}$$TVd^{-1}$ via shortening the HRT from 24h to 4h. The efficiency of decoloration decreased from 93.35±1.43% at HRT of 24h to 46.46±2.65% at HRT of 4h (Fig. 2). Correspondingly, the cathode potential raised, from -850mV (HRT ≥ 8h)

to -750mV (HRT=4h). The anode potential increased from -400mV (HRT ≥ 8h) to -270mV(HRT=4h). This implied that when HRT was shorter than 8h, the AYR loading rate was beyond of the treatment capability of cathode, the residual AYR in the water might seriously inhibit the anodic microbial activity, which resulted in the increase of potentials. Therefore, 8h was suggested as an appropriate HRT for the operation of PFB-BER.

Effect of the cathode electrode volume rate on AYR decolorization

To further improve the decoloration efficiency in PFB-BER, one more cathode was introduced. The decolorization efficiency at HRT of 8h was enhanced, to 96.4±2.58% (Table 1). When HRT was shortened to 4h, the decolorization efficiency still kept above 80% and the potentials of anode and cathode were -421.5±11.5mV and -889.2±14.3mV, respectively. This indicated that bigger cathode volume could improve the performance of PFB-BER. More AYR could be degraded in the cathode zone in a same duration period. Thus, higher decolorization efficiency was received at a shorter HRT (4h).

Outlook

The further work should investigate the position and pattern of the electrodes. In this study the electrode volume rate merely 15% of the efficient electrode, the use of other volume in the reactor is a question，more effective role as anaerobic, or adding more electrodes to arise the decolourization rate, the balance of this would be a good research point. A plurality of electrodes arranged in a large reactor is one of the key points in the practical application.

Table 1. Compare the number of electrodes for AYR decolorization, anode and cathode potential under different HRTs(8h, 4h)

HRT	4h		8h	
	One group	Two groups	One group	Two groups
DE (%)	44.87±2.04	83.10±4.71	70.02±3.80	96.4±2.58
AP (mV)	-269.2±26.5	-421.5±11.5	-405.1±12.5	-424.1±9.21
CP(mV)	-746.9±30.2	-889.2±14.3	-820.3±19.8	-897.1±12.6

DE: Decolorization Efficiency；AP：Anode Potential；CP：Cathode Potential

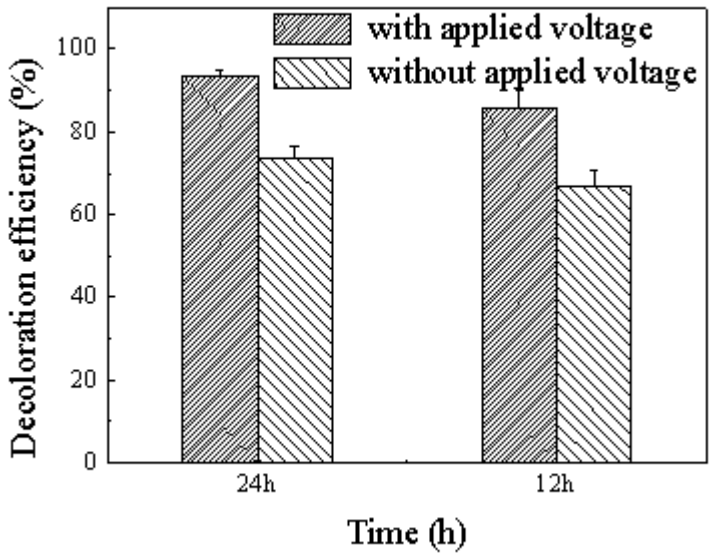

Figure 1. Decoloration efficiency of AYR with or without applied voltage.

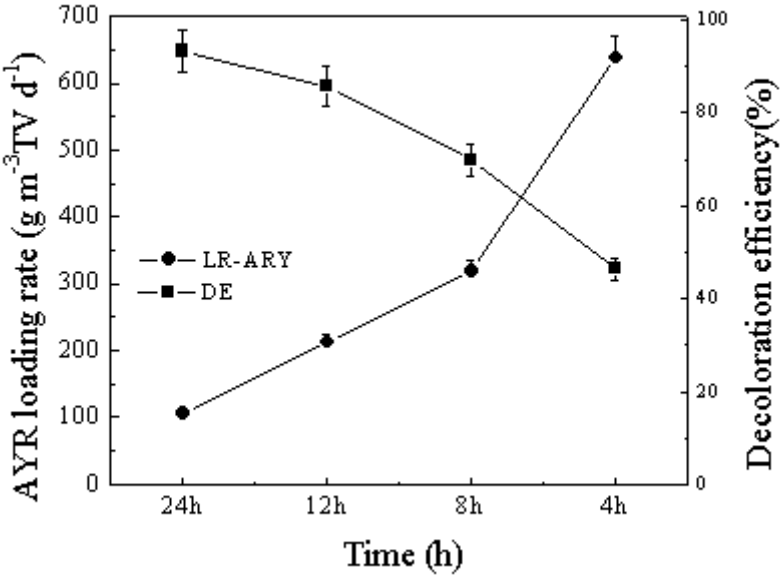

Figure 2. Variation of AYR concentration and decoloration efficiency under different HRTs.

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