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EFFECT OF DYE CONCENTRATION ON SEQUENCING BATCH REACTOR PERFORMANCE

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ABSTRACT

Reactive dyes have been identified as problematic compounds in textile industries wastewater as they are water soluble and cannot be easily removed by conventional aerobic biological treatment systems. The treatability of a reactive dye (Brill Blue KN-R) by sequencing batch reactor and the influence of the dye concentration on system performance were investigated in this study. Brill Blue KN-R is one of the main dyes that are used in textile industries in Iran. Four cylindrical Plexiglas reactors were run for 36 days (5 days for acclimatization of sludge and 31 days for normal operation) at different initial dye concentrations. The dye concentrations were adjusted to be 20, 25, 30 and 40 mg/L in the reactors R1, R2, R3 and R4, respectively. In all reactors, effective volume, influent wastewater flowrate and sludge retention time were 5.5 L, 3.0 L/d and 10 d, respectively. According to the obtained data, average dye removal efficiencies of R1, R2, R3 and R4 were 57% ± 2, 50.18% ± 3, 44.97% ± 3 and 30.98% ± 3, respectively. The average COD removal efficiencies of all reactors were 97% ± 1, 97.12% ± 1, 96.93% ± 1 and 97.22% ± 1, respectively. The dye removal efficiency was decreased by increasing the dye concentration with the correlation coefficient of 0.997.

Key words: Biological treatment, sequencing batch reactor, reactive dyes, Brill Blue KN-R

INTRODUCTION

The decolorization of wastewater is still a major environmental concern. Synthetic dyes used in textile industry, are difficult to be removed by conventional wastewater treatment systems based on adsorption and aerobic biodegradation. In spite of the low toxic effect on receiving bodies, the dyes constitute an aesthetic problem with great impact in the public opinion and color restricts the downstream use of the wastewater (Lourenco et al., 2001).

At present, several methods have been developed to treat dye wastewater. Physicochemical treatments such as coagulation/flocculation, flotation, membrane processes or activated carbon adsorption are common practices, but they are quite inefficient and result in a phase transfer of pollutants, leaving the problem unsolved. On the other hand, single biological treatments, the most economical and environmentally friendly ones, are not a suitable alternative when working with toxic and/or non-biodegradable wastewaters. In fact, most of disposed dyes are of non-biodegradable nature and standard biological treatment of their colored effluents is not effective (Montano et al., 2006a). Biological processes are considered to be highly useful and potentially advantageous compared to physicochemical methods for the treatment of toxic compounds due to their eco-friendly nature, energy saving and minimum usage of chemicals (Mohan et al., 2007).

The application of SBR to color removal is rather a new approach compared to anaerobic–aerobic sequential treatment (Kapdan and Ozturk. 2005). Sequencing batch reactor (SBR) as a modified activated sludge process has been used for many industrial wastewaters such as fiber and dyes wastewater. Main advantages of this system are low build cost, high flexibility and low required

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space (Ganjesh et al., 2006). Disadvantages of this system are high excess sludge production and high SVI index (Bernet et al., 2000; Kargi and Uygur. 2002).

Different researches have been carried out on reactive dyes removal by various processes (Panswad and Luangdilok , 2000; Lourenco et al., 2001; Sponza and Isik, 2002; Mass and Chaudhari., 2005; Alizadeh and Borgaie., 2006; Montano et al., 2006b; Petrinic et al., 2007 ; Alaton et al., 2008; Ju et al., 2008; Isik and Sponza, 2008). However, limited studies focused on the influence of reactive dye concentrations on the performance of biological processes. In this study, the treatability of a reactive dye (Reactive Brill Blue KN-R) using SBR system and the influence of the initial dye concentrations on system performance were investigated.

MATERIALS AND METHODS

The synthetic dye-containing wastewater was used in this study. The composition of the wastewater was powdered milk (1795 mg/L) as main carbon source, urea (198 mg/L) as nitrogen source, K_2HPO_4 (52 mg/L) and KH_2PO_4 (46 mg/L) as phosphorous sources.

Reactive Brill Blue KN-R (CI: Reactive Blue B-16) was used in different concentrations. The dye is one of the main dyes that are used in textile industries in Iran. The maximum absorbance (λ_{max}) of the dye with the background of deionized water was 594 nm, which was determined according to scanning pattern performed on HACH spectrophotometer DR/4000. During the experiments, λ_{max} was used for all the absorbance readings. The percentage of dye removal was calculated by the following equation:

Dye removal (%) = $[(C_r-C_t)/C_r] * 100$

Where C_r and C_t are the dye concentration in raw and treated solutions, respectively.

In this study, four cylindrical plexiglas reactors with 14 cm diameter and 46 cm height were used (Fig.1). The working volume and influent flowrate were 5.5 L and 3.0 L/d , respectively. Four air pumps and four mixers were used for continuous aeration and mixing. The speed of impeller was adjusted at 70 rpm.

The Sludge was provided from Zarghande wastewater treatment plant, in Tehran. Operation cycle of reactors was 24 hours including 2 min for filling, 22.5 hours for aeration, 1 hour for settling, 2 min for discharging and 25 min for idle phase. After acclimatization period, dye concentration was adjusted 20, 25, 30 and 40 mg/L in reactors R1, R2, R3 and R4, respectively. Reactors were studied for 36 days (5 days for acclimatization and 31 days for normal operation). Organic

Fig. 1: Four SBR reactors used in this study

loading rate (OLR), sludge retention time (SRT) and hydraulic retention time (HRT) were similar in all reactors.

The chemical oxygen demand (COD), dye absorbance ratio, mixed liquor suspended solids (MLSS), mixed liquor volatile solids (MLVSS), total suspended solids (TSS), turbidity, dissolved oxygen (DO), pH and sludge volume index (SVI) of samples were determined using standard methods for examination of water and wastewater (APHA, AWWA and WPCF, 1992).

RESULTS

Dye removal efficiency

The variation of dye removal efficiencies of all reactors are shown in Fig. 2. The minimum dye removal efficiency was obtained in R4 with the dye concentration of 40 mg/L. Maximum dye removal efficiency was obtained in R1 with dye concentration of 20 mg/L. Fig. 3 shows the influence of initial dye concentration on dye removal efficiency in SBR system. As shown, by increasing the dye concentration from 20 to 40 mg/L, the dye removal efficiency decreased from 57 to 31 percent. Correlation coefficient between initial dye concentration and dye removal efficiency was 0.997.

COD removal efficiency and effluent characteristics

Table 1 summarizes the operation data of SBRs including COD removal efficiency, effluent turbidity, and effluent TSS. The variation of COD removal efficiencies are shown in Fig. 4. The average removal efficiencies were almost in the same range of 97 percent and COD removal efficiencies increased from 95% to 98% during the normal operation period in all reactors. Maximum COD removal efficiency was obtained in the reactor 4 with the dye concentration of 40 mg/L. No significant influence on COD removal efficiency was observed by altering the dye concentration.

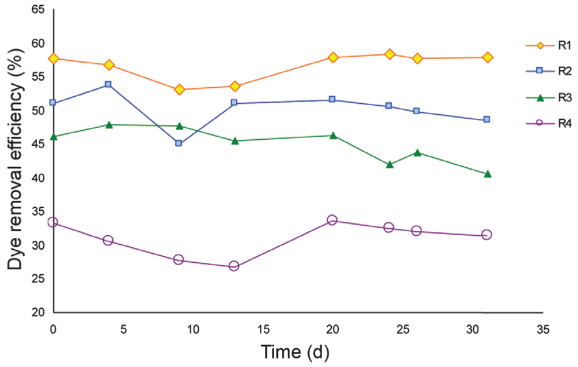

Fig. 2: Variation of dye removal efficiency in the SBR reactors

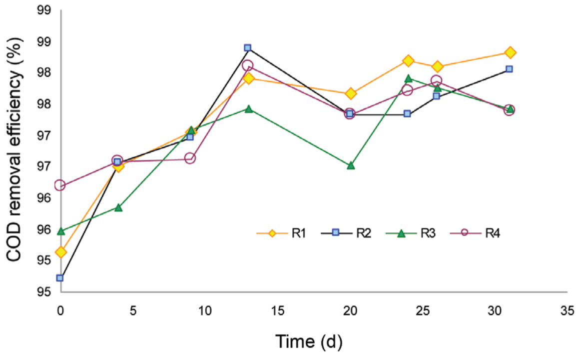

Fig. 4: The variation of COD removal efficiencies of SBRs

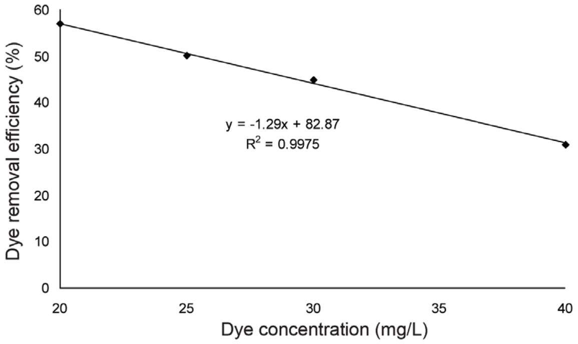

Fig. 3: The influence of initial dye concentration on dye removal efficiency in SBR system

Table 1: Effluent quality and removal efficiency of aerobic SBRs

Reactors	Influent OLR ($gCOD/m^3.d$)	HRT (d)	COD			Turbidity (NTU)	Effluent TSS (mg/L)
			Influent (mg/L)	Effluent (mg/L)	Removal (%)		
R_1	1067 ± 145	1.83	1958.6	55 ± 21	97 ± 1.09	5.83 ± 2	25 ± 14
R_2	1078 ± 117	1.83	1977.6	59 ± 23	97.12 ±1.13	5.14 ± 1	24 ± 13
R_3	1083 ± 134	1.83	1986.4	63 ± 18	96.93 ± 0.90	5.54 ± 3	23 ± 18
R_4	1119 ± 266	1.83	2052.8	58 ± 13	97.22 ± 0.69	4.80 ± 1	26 ± 13

Sludge properties

Main bio-sludge properties of the reactors are summarized in Table 2. These values were obtained in period of 31 days normal operation. Maximum MLSS concentration was observed in reactor 3 and minimum was in the reactor 4. The maximum average of SVI was in reactor 4 and minimum was in reactor 1. As it shown, by altering the dye concentration from 20 to 40 mg/L, there were no significant variations in sludge properties of SBR system.

Table 2: Sludge properties of SBR reactors (31 days of normal operation)

Parameter	Reactor 1	Reactor 2	Reactor 3	Reactor 4
Influent dye conc. (mg/L)	20	25	30	40
MLSS (mg/L)	3241 ± 448	3467 ± 642	3555 ± 447	3049 ± 614
MLVSS (mg/L)	2770 ± 401	2932 ± 546	3010 ± 365	2556 ± 480
MLSS/MLVSS (%)	85 ± 1	85 ± 2	85 ± 2	84 ± 1
F/M (1/d)	0.33 ± 0.04	0.31 ± 0.03	0.37 ± 0.04	0.37 ± 0.04
SRT (d)	10	10	10	10
SVI (mL/g)	37 ± 14.09	41.13 ± 12.89	45.25 ± 15.02	48.75 ± 17.25

DISCUSSION

In this study, dye removal efficiency was in the range of 31 to 57 percent and SBR system showed low removal efficiency for the reactive dye. According to the study that carried out by T. Panswad, color reduction of three different reactive dyes (Reactive Black 5, Reactive Blue 19 and Reactive Blue 5) in an aerobic/anaerobic SBR was 63, 64, and 66 percent. Moreover, more color removal efficiency achieved in anaerobic phase than aerobic phase (Panswad and Luangdilok, 2000). In a different study by Sponza, the removal efficiency of Reactive Blue 5 in an aerobic/anaerobic sequential process was 92 and 87 percent in an UASB reactor and CSTR (completely stirred tank reactor) (Sponza and Isik, 2002). Additionally in other study by Mass, the removal efficiency of Reactive Red 2 in a semi continues bioreactors were above 76% (Mass and Chaudhari, 2005).

COD removal efficiency of 97% was obtained in our study in SBR reactors under similar organic loading rate. No significance influence of dye on COD removal was observed. In the study by Ghoreishi and Haghighi, the COD removal efficiencies were in the range of 76 – 83 in a combined biological-reduction process (Ghoreishi and Haghighi, 2003). In another study that carried out by Sponza, the COD removal efficiencies under the HRT of 19.17 and 1.22 were 97% and 84% in combined aerobic/anaerobic system (Sponza and Isik, 2002). In the other study by Mass and Chaudhari, COD removal efficiency of the semi-continues bioreactors were 80 percent (Mass and Chaudhari, 2005). In aerobic/anaerobic SBR system, the COD removal efficiency was in the range of 90-99% (Panswad and Luangdilok, 2000).

Sludge properties were almost same in all reactors and no significance influence was observed by altering the dye concentration from 20 to 40 mg/L. SVI of all reactors was in the range of 37-49 mL/g. Average of SVI in all reactors was in the acceptable range 50 - 80 mL/g (Sirianuntapiboon and Srisornsak ,2007).

It can be concluded that the maximum and minimum dye removal efficiency was observed in R1 (dye concentration of 40 mg/L) and R4 (dye concentration of 40 mg/L), with the values of 57% ± 2, and 30.98% ± 3, respectively. However, SBR shows acceptable COD removal efficiency of 97%. Effluent turbidity and TSS of SBR system were lower than Iranian emission standard. The initial dye concentration has no significant influence on sludge properties. This study showed that the conventional SBR system did not show acceptable removal efficiency for selected reactive dye at the selected operational conditions. For increasing the dye removal efficiency, several options can be checked. For example, increasing the HRT, using a combination of aerobic/ anaerobic systems, or another combined systems (adsorption/biological process) can be considered.

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