Polishing of pretreated dye wastewater using novel sequencing batch reactors

K. S. Singh, M. M. LeBlanc and D. Bhattacharyya

ABSTRACT

Novel, aerobic sequencing batch reactor technology was tested as a polishing step for anaerobically treated textile wastewater containing dye. Operation cycle times of 6, 8 and 12 hours were studied using discrete phase periods. The SBRs were able to further remove influent dye concentration of as little as 5 mg/L, and remove highly variable loadings of COD and SS to effluent levels of 100 and 20 mg/L respectively.

Key words | aerobic, azo dyes, decolorization, post-treatment, sequencing batch reactor, textile dyeing

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INTRODUCTION

Background

Removal of color from textile wastewaters through biological processes has been under extensive study for the last couple of decades. Conventional aerobic biological processes used in the textile industry have been found unsuccessful in significantly removing dyes beyond the adsorbing capacity of the biomass; this is attributed to the bio-resistant design of the dyes (Bahorsky 1998). However, in anaerobic processes, decomposition of dye structure takes place through reductive cleavage of azo (−N═N−) bonds. Once the original structure is broken into fragments, intermediate products may be further degraded aerobically (Seshadri *et al.* 1994; Panswad *et al.* 2001; Sen & Demirer 2003; Albuquerque *et al.* 2005). An anaerobic-aerobic treatment has been recommended by several researchers (Seshadri *et al.* 1994; Talarposhti *et al.* 2001) for the removal of color from textile wastewaters.

Objectives

Aerobic polishing of an anaerobically degraded dye-wastewater was investigated in this study. Novel modified aerobic sequencing batch reactors have been used as polishing units. The objectives of the investigation were to monitor the removal of residual dyes, whose intermediates are suspected carcinogens (Panswad *et al.* 2001; Sen & Demirer 2003), and to monitor the ability of the system to consistently achieve Canadian wastewater effluent guidelines.

METHODS

The research was carried out using four aerobic sequencing batch reactors, operated as polishing units to anaerobically treated synthetic textile wastewater, containing a mixture of reactive dyes: Procion Red MX-8B, Red MX-5B and Orange MX-2R. Cycle times of 6, 8, and 12 hours were tested for a minimum of 40 cycles each. Four SBRs were operated simultaneously on four distinct anaerobically treated wastewaters (Figure 1). S1 processed a control wastewater, which had undergone primary treatment in an upflow anaerobic acid reactor (U1), and contained no dye.

The influent for S2 was a combined effluent from three, parallel, UAARs (U2, U3, U4), dosed with different dye concentrations; 25, 50, and 100 mg/L for U2, U3, and U4, respectively. This same effluent was further treated in an expanded granular sludge bed reactor (E1), acting as a methane reactor, and the effluent from the UAAR-EGSB

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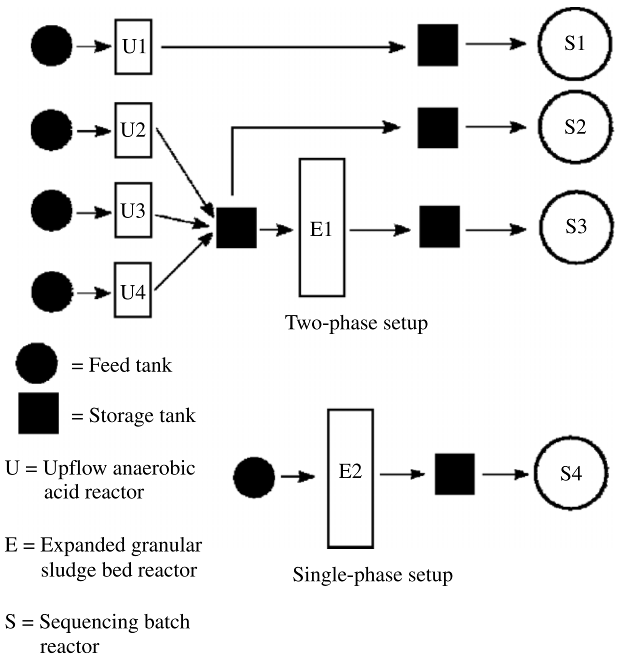

Figure 1 | Flow diagram of experimental setup.

series (two-phase system) was the influent for S3. S3 received a sucrose co-substrate in order to maintain the influent organic loading within a similar range to both S2 and S4. Approximately 10 mL of saturated sucrose solution was added to each 3 L fill. A fourth effluent was produced by a single EGSB reactor (E2), which acted as a combined acid and methane reactor, and was post-treated in S4.

The bottoms of each of the SBRs used were partitioned into eight equal sections. Each section contained a porous membrane floor, through which aeration took place. The entrance point for filling each SBR was located at the centre of the floor of the cylindrically shaped reactors. For each test cycle of 6, 8, or 12 hour duration, sludge was removed once from only one of the eight partitions, thereby maintaining a constant solids retention time of 8 days.

The cycle times were tested of 6, 8 and 12 hour duration consisting of five discrete periods: fill, aerate or react, settle, supernatant decant, and sludge decant (Table 1).

The specific parameters evaluated for both the influent and effluent of the SBRs were: chemical oxygen demand (total and filtered), total suspended solids, volatile suspended solids, color and dye concentration. A second set of trials were also completed in which BOD_5 and nutrient

Table 1 | SBR cycle phase durations

	Fill (h)	React (h)	Settle (h)	Decant (liquid/sludge) h
6 hour cycle	1.5	3	0.75	0.38/0.38
8 hour cycle	2	4	4	0.5/0.5
12 hour cycle	3	6	1.5	0.75/0.75

removal were also examined, but are not shown in this paper. Standard Methods (2005) were used for the collection of all wastewater data and nutrient data were determined by using commercially prepared Hach testing kits. Color and dye determinations were made using a Spectronic GENESYS 6 UV-Visual Scanning Spectrophotometer.

RESULTS AND DISCUSSION

Dye

The results show that effluent dye concentration was dependent on influent dye concentration during each of the

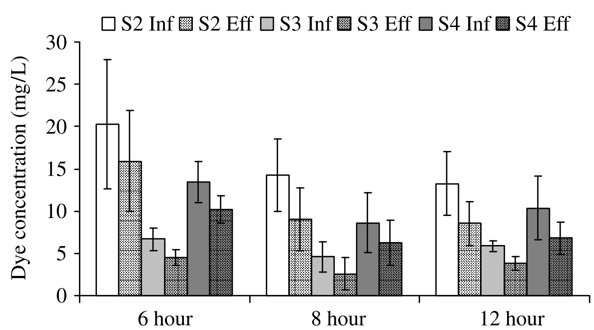

Figure 2 | Influent and effluent dye concentrations.

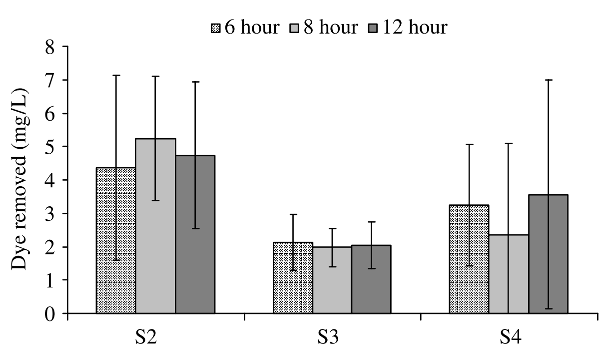

Figure 3 | Dye removed.

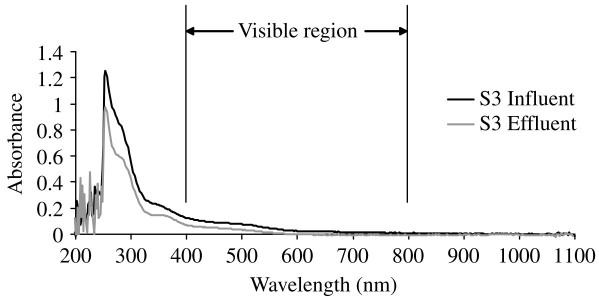

Figure 4 | Absorbance results for influent and effluent of S3.

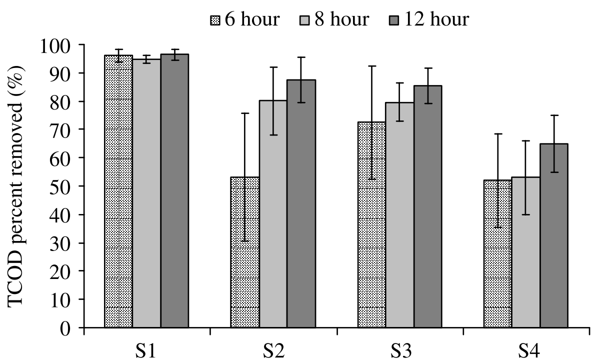

Figure 5 | Total chemical oxygen demand percent removed.

three cycle times tested (Figure 2); however, a decrease in dye concentration was observed in all three reactors containing dye, regardless of the influent dye concentration.

Figure 3 shows the actual dye amounts removed by each of the reactors and cycle times. No difference exists between the amounts of dye removed in each reactor over the three cycle times tested. This means that the 6, 8, and 12 hour cycle treatments are all capable of achieving the same amount of dye removal, and that the dye was being further removed by the aerobic post treatment independently of the cycle time.

Influent and effluent samples were also scanned over the 190 to 1100 nm wavelengths. Figure 4 shows a sample result for S3 during the 6 hour cycle tests. Similar graphs were obtained for other reactors and cycles. A clear peak reduction exists between 190 and 390 nm indicating that aerobic post-treatment was able to partly remove dye intermediates, but the close relation of the rest of the curve shows that only a slight reduction was made to the actual residual dye that contains the color causing agents.

Although some reduction of dye intermediates is evident, the consistency of dye removals experienced in each reactor could be due to sorption processes onto the biomass. Influent dye concentrations of less than 5 mg/L were able to be further polished by the aerobic post-treatment, and the similarity of the results during the 6, 8, or 12 hour cycle testing periods suggest that such dye removal efficiencies could be reached using aeration periods of less than three hours.

COD

At all cycle times tested, significant and consistent removals of TCOD (Figure 5) were achieved for all the reactors, regardless of the influent concentrations which varied widely throughout the testing period. S1 removed COD by over 90% for all three cycle times. COD removals of 80–90% were achieved by S2 for the 12 hour cycle time, and both the 6 and 8 hour cycles showed larger variation in the results achieving average removals of 53% for the 6 hour cycle and 80% for the 8 hour cycle. The COD results for S3 showed average removals of 72, 80, and 85% for the 6, 8, and 12 hour cycles respectively.

Average COD values for S4 were 52, 53, and 58%, for the 6, 8, and 12 hour cycles; the 12 hour cycle time appears to have produced the highest level of removal efficiency, with the least amount of variation in each of the four reactors.

S1, S2, and S3 were able to meet a COD discharge concentration of 100 mg/L or less, showing the lowest values of effluent COD during the 12 hour cycle (Figure 6). S4 also returned the lowest effluent COD concentration values during the 12 hour cycle time as well, but stayed within the range of 100 to 200 mg/L. The SBRs showed stable performance in terms of organic matter removal measured as COD.

S2, S3, and S4 received similar COD concentrations into the SBR system, but S4 appears to have been less capable of removing COD compared to the other two reactors. Partially degraded dyes from the single-phase reactor E2 may have had an inhibitory impact on aerobic polishing bacteria in S4. A separate batch experiment is underway to quantify the inhibitory effects of dyes and their intermediates on aerobic bacteria.

Total suspended solids

Figure 7 shows that there appears to be no relationship between the influent TSS concentration and the effluent TSS

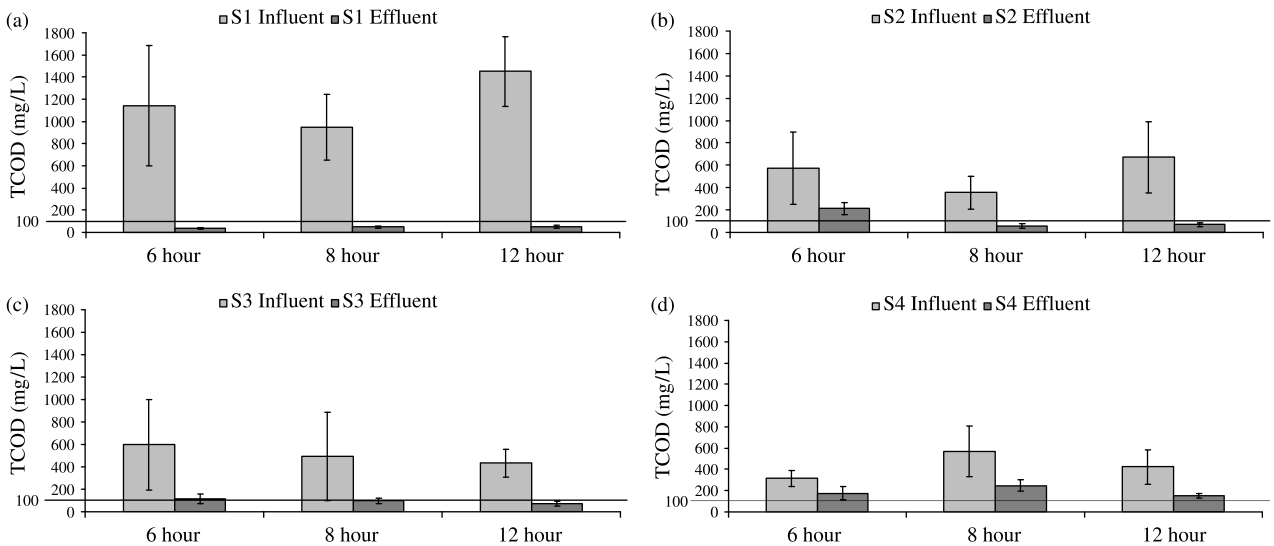

Figure 6 | Influent and effluent TCOD results for—(a) S1, (b) S2, (c) S3, (d) S4.

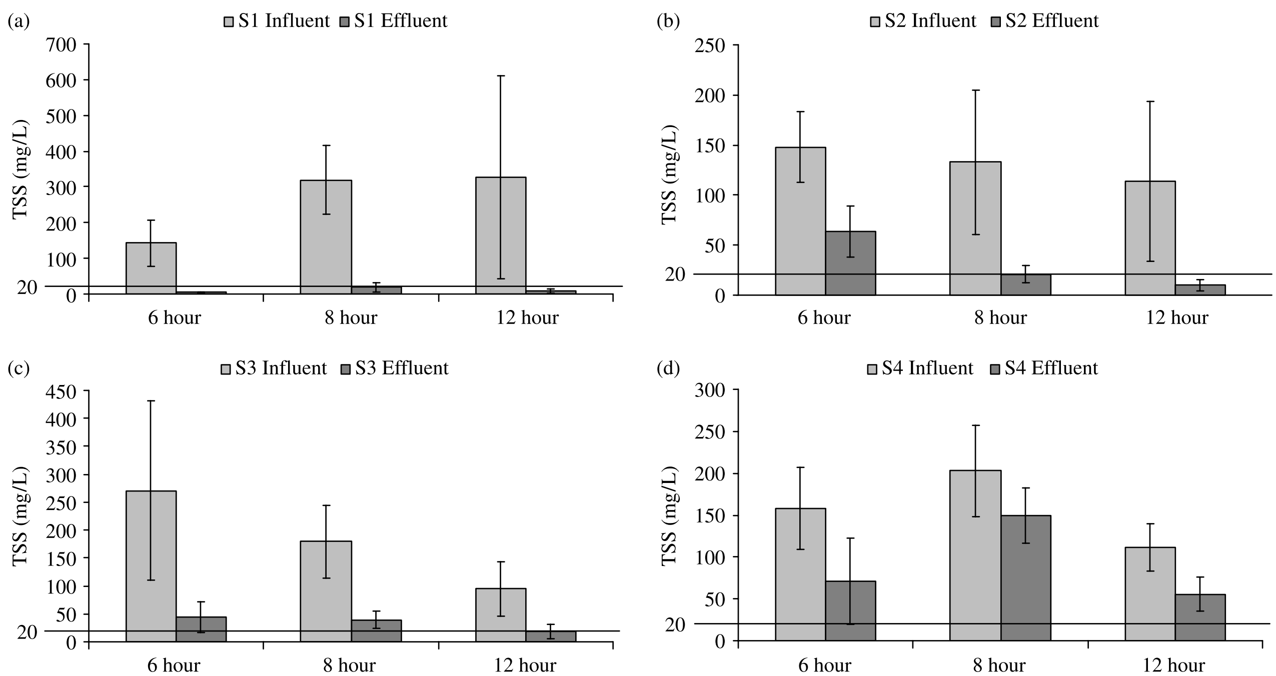

Figure 7 | Influent and effluent TSS results for—(a) S1, (b) S2, (c) S3, (d) S4.

concentration for S1, S2, and S3. However, the effluent values found for S4 seemed to be dependent on the influent values.

The highest quality effluent in all four reactors was produced during the 12 hour cycle time testing, and S1, S2, and S3 were able to consistently meet an effluent concentration of 20 mg/L or less.

CONCLUSIONS

The following points are clear from the results of this study.

- The wastewater received by S4 was more resistant to aerobic biological post-treatment than the other three wastewaters; however, a separate toxicity test is currently underway.

- S3, with the aid of a sucrose co-substrate, was able to successfully polish the wastewaters of the two-phase systems to a consistent and high quality effluent that does not require further treatment. In industrial practice, municipal wastewater as a co-substrate has the potential to increase the organic loading for this wastewater stream.
- The SBRs demonstrated the ability to handle highly variable COD and SS loadings.
- For dye removal, there is no benefit to an extended aeration period; however, to reach other effluent concentration requirements, the 12 hour cycle time is the most capable of producing a high quality effluent of the three cycle times studied.
- The aerobic SBR technology used as a post treatment for anaerobically treated textile wastewater has the ability to further remove the dyes, intermediate dye compounds, visible color, total COD, and other organic pollutants from the wastestream. The dye concentration in the aerobically treated wastestream was further reduced by aerobic polishing regardless of low levels of influent concentration (~ 5 mg/L). Overall, the 12 hour cycle time was most capable of meeting the regulatory limits for COD and SS in each of the four reactors.
- The two-phase treatment of the combined effluent from three UAARs further treated by E1 and then polished by S3 returned the lowest values for dye effluent concentration of the three systems containing dye. This system required a co-substrate to increase the organic loading before it could be successfully polished by the aerobic SBR, and was then able to successfully remove COD and SS as well as dye. In practice, the co-substrate requirement could be met by a municipal wastewater supplement.

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