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Biodegradation of textile dyeing industry wastewater using modified anaerobic sequential batch reactor – Start-up, parameter optimization and performance analysis

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A B S T R A C T

In this study a novel modified anaerobic sequential batch reactor (MASBR) was employed to treat the textile dyeing industry wastewater. The anaerobic sequential batch reactor (ASBR) was modified by the addition of a sorbent (ground nut shell powder) and plastic media. The start-up phase of the MASBR was observed over a period of 80 days. Statistical based experiments were performed in order to optimize the parameters viz., sorbent dosage and particle loading, and to study the interactive effects using response surface method (RSM). At the optimized conditions, experiments were performed at various organic loading rates by varying initial textile dye wastewater concentration and hydraulic retention time (HRT). The anaerobic biodegradation of textile dyeing wastewater in the MASBR was analyzed in terms of decolorization, COD reduction, biogas production, volatile fatty acids (VFA) at different organic loading rate (OLR) between 0.110 and 0.650 kgCOD/m^3 d. A maximum decolorization of 94.8% and COD reduction of 97.1% were obtained in the MASBR. The novel sorbent utilized in the study was characterized using FTIR and SEM analysis.

1. Introduction

Textile dyeing industry is one of the leading water consuming industries and produces large volume of wastewater from different steps during dyeing processes. Wastewater from various sections of textile dyeing unit is rich in color and contains dye residues, chemicals, etc. Depending on the type of textile manufactured and the chemicals used, the characteristics of textile dye industry effluent varies. The textile effluent comprises of high amounts of suspended and dissolved solids, biological oxygen demand (BOD), chemical oxygen demand (COD), chemicals, odour and color agents causing damage to both the environment and human health. It also contains trace metals like Chromium (Cr), Arsenic (As), Copper (Cu) and Zinc (Zn), which are harmful to the environment [1]. Physical and chemical treatment methods like coagulation, ozonation, membrane process, filtration with coagulation, ozonation with coagulation and adsorption [2–6] are effective for decolorization but utilize more energy and chemicals. Also these methods concentrate the pollutants into solid or liquid side streams and require additional treatment methods for disposal. Biological treatment methods can completely mineralize pollutants and are usually cheaper [7].

Anaerobic sequential batch reactor (ASBR) offers a potential alternative reactor to treat various industrial effluents, domestic wastewater, landfill leachate, biological phosphorus and nitrogen removal, etc. ASBR has the following advantages in a small-scale system: flexibility in operation, low construction and maintenance cost and simultaneous removal of nitrogen and phosphorus [8]. Several works were carried out on the applicability of this promising process in wastewater treatment [8–15]. Sequencing batch biofilm reactor process is the combination of biofilm process in the sequencing batch operation mode [12,16–22]. Support materials were added to ASBR to enhance the biofilm formation and to overcome the difficulties in growth and maintenance of activated sludge flocs [23].

Textile dye industry effluent is a high strength effluent, which contain biodegradable substrates and inhibitory constituents. Biological treatment methods alone may not be sufficient to handle the non-biodegradable substrate present in the textile dyeing industry wastewater. Hence to enhance the performance of the conventional SBR system in treating the textile dye wastewater,

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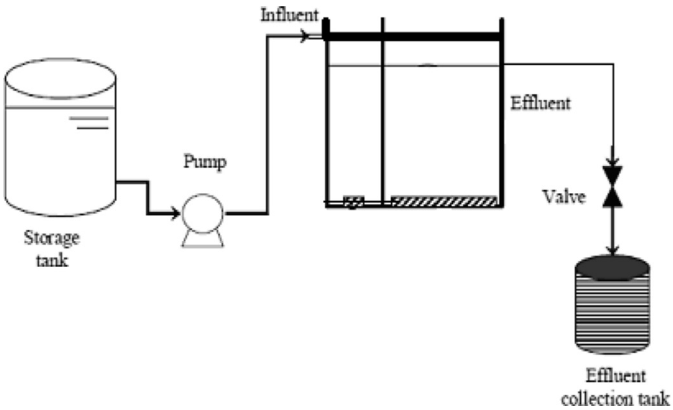

Fig. 1. Schematic diagram of ASBR set up.

adsorbent have been added in this study. Ground nut shell powder is an agro waste and it is available in plenty. Preliminary study shows that ground nut shell powder gives better results for the decolorization of dyes [24]. Hence, it is selected as a sorbent in this work. The MASBR employed in this work, involves simultaneous biodegradation and adsorption processes as two co-existing phenomena. So far, upto our knowledge, no work is available on the anaerobic degradation of textile dyeing industry wastewater in an ASBR along with the addition of ground nut shell powder as sorbent. The objective of this study was to analyze the performance of a modified anaerobic sequential batch reactor for the treatment of textile dyeing industry wastewater. Process parameter optimization and interactive effects are studied through response surface methodology (RSM).

2. Materials and methods

2.1. Materials

The textile dye industry effluent was collected from a small-scale textile dye industry located at Tirupur, Tamilnadu, India and stored at 5 °C in a freezer. The characteristic of the wastewater was analyzed and it is reported in earlier study [25]. Mixed anaerobes employed in this study were collected from a textile dyeing industry treatment plant. The sludge was collected in plastic container and sealed tightly and stored at 5 °C in a freezer. In the present study ground nut shell powder was used as an adsorbent. Groundnut shell was separated and soaked in water to remove the dirt particles. Then it was dried in an oven (REMI, India) at 70 °C for an hour. After that, it was crushed and sieved to mesh size range of 100 µm.

2.2. Modified anaerobic sequential batch reactor (MASBR) set up

The descriptive schematic of the MASBR was shown in Fig. 1. The reactors were constructed using 12 mm thick Plexiglas and were cylindrical in shape. The total volume of the reactor was 1.5 L of which 1 L was used as working volume. Tubes were inserted into the reactors to ensure the filling and withdrawal of the effluent using peristaltic pumps (Miclins, India). The mixing was achieved using a mechanical stirrer at the speed of 10 rpm at frequent interval during the reaction time.

2.3. MASBR inoculation and start-up

MASBR was filled with the textile dye industry effluent. The reactor was inoculated with the mixed culture along with the biomass support made of Fujino spirals. The selected sorbent (ground nut shell powder) was also added. The operating temperature was maintained at 32 ± 1 °C. The setup was left for 80 days in order to acclimatize the microorganisms. The textile dye industry wastewater was pumped into the reactor regularly and the COD reduction, mixed liquor volatile suspended solids (MLVSS) concentration and biogas production were monitored regularly in the MASBR.

Table 1
Operating conditions of MASBR.

Substrate concentration, mg COD/L	HRT, d	OLR, kgCOD/m^3 d
880	8	0.110
	6	0.147
	4	0.220
1720	8	0.215
	6	0.287
	4	0.430
2600	8	0.325
	6	0.433
	4	0.650

2.4. Experimental procedure for optimization studies in MASBR's

After the start-up period, parameter optimization experiments were performed based on the central composite design (CCD) in MASBR. Sorbent dosage (5, 10 and 15 g/L) and biomass support (10, 20 and 30% (v/v)) were optimized in MASBR. Initially in the MASBR, the biomass support is kept at 30% (v/v) by adding the required quantity of fujino spirals. Then the required quantity of sorbent is added as per the design given in Table 1. The hydraulic retention time (HRT) was maintained as 8 days. pH in the reactor is maintained as 7 ± 0.2 by the addition of HCl or NaOH as required. These parameters were optimized using RSM. The operating procedure of MASBR was given as follows: Fill – 1 h, React – 32 h, Settle – 2 h, With drawl – 1 h. During the fill period, textile dye wastewater was fed into the reactor. The anaerobic digestion was carried out for specified time as shown in Table 1. Then sludge is allowed to settle. After the bio-sludge is fully settled, the supernatant was removed during the withdrawal time. After that, fresh textile dye wastewater was introduced into the reactor and the above operation was repeated. To control the stable bio-sludge concentration in the ASBR, the excess bio-sludge was removed from the bottom of the MASBR.

At the optimized conditions, experiments were carried out in MASBR at various organic loading rates (OLR). OLR was varied by changing the influent wastewater concentration (880, 1720 and 2600 mg/L) and HRT (8, 6 and 4 d). The operating conditions were given in Table 1. During the experimentation period, decolorization, COD reduction, mixed liquor volatile suspended solids (MLVSS), sludge volume index (SVI) and gas production were measured regularly at frequent intervals. Volatile fatty acids (VFA) and food to microorganism (F/M) ratio were measured at the end of operation. All the analyses were carried out according to standard methods of analysis [26].

2.5. Analysis

Dye concentration was measured using Bio-spectrophotometer (Model: BL-200, ELICO, India) at a wavelength of 395 nm. The percentage COD reduction was calculated by

$$\%COD_{reduction} = \frac{COD_{Initial} - COD_{Final}}{COD_{Initial}} \times 100 \quad (1)$$

The percentage decolorization was calculated by

$$\%Decolorization = \frac{InitialOD - FinalOD}{InitialOD} \times 100 \quad (2)$$

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