Biodegradation of Azo-dye using Anaerobic Hybrid Reactor

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ARTICLE INFORMATION

ABSTRACT

The objective of this study was to assess the feasibility of anaerobic hybrid reactor, consisting of an Upflow Anaerobic Sludge Blanket (UASB) and anaerobic filter, for biodegradation of azo-dye (Acid orange 8) commonly present in textile industry effluent. The study was carried out in two phases. During the first phase, the reactor was feed with dilute neutralized acetic acid 500 mg/L for 20 days with hydraulic retention time (HRT) of 24 hours. During this period adequate nutrients were added to the system since acetate lack the necessary nutrients required by anaerobic bacteria. This was done to activate the methanogens. The chemical oxygen demand (COD) removal efficiency was continuously monitored. In the second phase of the study the synthetically prepared solution of dye of varying concentration from 10 ppm to 50 ppm was introduced along with acetic acid and the nutrients, the concentration of dye was increased after a regular interval of 10 days. The maximum dye removal efficiencies achieved at 10 ppm, 15 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm were 78 %, 70 %, 68 %, 64 %, 63 % and 54 % respectively. The maximum COD removal efficiency achieved during this phase was 80 %.

Keywords
Azo-dyes, Anaerobic, Chemical Oxygen Demand, Hybrid Reactor, Methanogens

1. Introduction

Colour is a visible pollutant and its presence not only hampers the aesthetic quality of surface waters but also affects and alters the aquatic ecosystem by reducing the penetration of light. The development of industries and improvement of human life, cause more and more use and need of dyes compounds (Shaylinda 2005.)

Dyes are coloured, ionising, aromatic organic compounds. A wide variety of dyes are used by industry and released into the environment as industrial effluents (Shaylinda 2005) Textiles are that industry that largely uses this product. A great number of dyes and other chemicals are used in textile wet processing. It is estimated that about 10-15% of dyes are released into processing water during this procedure (Fang et al. 2004, Steffana et al 2005, Khehraa et al. 2006, Asad et al 2007, Wijetunga et al. 2007). Being highly colored, dyes are readily apparent in wastewater, which is the reason that their breakdown is a priority before disposal into the environment (Zhao and Hardin 2007).

These dyes are highly stable in everyday use and resistant to microbial degradation. Azo-dyes, characterized by their typical azo bond (R1-N=N-R2), is responsible for imparting colour to wastewater (Mansour et al. 2007, Pajot et al. 2007). Azo-dyes are the largest class of dyes used in industries (Kim et al. 2005, Komaros and Lyberatos 2006, Kalyani et al 2007, Montano et al. 2007). They make up about a half of all known dyestuffs in the world, making them the largest group of synthetic colorants and the most
common synthetic dyes released into the environment (Zhao et al. 2007). In general, bacteria are not able to degrade Azo-dyes. However, some anaerobic bacteria in intestinal micro flora have been demonstrated to degrade a few Azo-dyes. Under these conditions the Azo-dyes can be toxic and potentially carcinogenic (Ong et al 2005).

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The objective of this study was to assess the performance of anaerobic hybrid reactor for the complete mineralization of azo-dyes. The attached as well as suspended anaerobic culture may result in the complete degradation of azo-dyes.

2. Material and Methods

In the present study, anaerobic hybrid reactor was employed for the biodegradation of azo-dyes. Synthetic solutions of different concentrations of azo dyes were prepared for the present study.

2.1 Reagents Used

2.1.1. Dye stock solution

An accurately weighed 10 grams of azo-dye (Acid orange 8) as dissolved in doubled distilled water to prepare a stock solution 10 g/L. Solutions of desired concentrations were obtained by successive dilution.

2.1.2. Neutralized Acetic Acid

Neutralized acetic acid was prepared by diluting 100 mL of concentrated acetic acid to 1000 mL then raising its pH to 7 by addition of NaOH. The pH was measured using pH meter.

COD was measured by closed reflux process as described in Standard Methods. Determination of dye concentration was carried out using Hatch Spectrophotometer DR 5000.

2.2. Experimental setup

The anaerobic hybrid reactor used in this study, was fabricated with Perspex material. The reactor was cylindrical in shape with an internal diameter of 0.05 m the total height of the reactor was 1.11 m. The lower portion of the reactor behaved like a UASB while the upper portion acted like a filter. The effective volume of the reactor was 1.77 L. The height of the UASB reactor was 0.45 m and that of anaerobic filter was 0.53 m. This was chosen so as to have equal HRT in both the reactors. Freeboard of 0.13 m was also provided. The media used for anaerobic filter was PVC pipe of inner diameter 0.25 m which has been cut into pieces nearly of length 0.0254 m.

2.3 Start up of the Reactor

The reactor was inoculated with the anaerobic sludge seed obtained from the anaerobic digester of a sewage treatment plant at
Okhla New Delhi. During the startup period, the reactor was fed with diluted neutralized acetic acid 500 mg/L for 20 days with HRT of 24 hours. During this period adequate nutrients were added to the system since acetate lacks the necessary nutrients required by the anaerobic bacteria. The nutrients supplemented to the system are shown in Table 1.

Later on, synthetically prepared solution of dye (Acid orange 8) of 10 ppm concentration was introduced along with the acetic acid and the nutrients. The effluent samples were analyzed on alternate days using spectrophotometer. The conc. of dye was increased after regular interval of time.

Table 1. Nutrients used in the Start-up of the Reactor.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂BO₃</td>
<td>50</td>
</tr>
<tr>
<td>ZnCl₂</td>
<td>50</td>
</tr>
<tr>
<td>CuCl₂</td>
<td>30</td>
</tr>
<tr>
<td>MnSO₄·H₂O</td>
<td>50</td>
</tr>
<tr>
<td>(NH₄)₂MoO₇·2H₂O</td>
<td>50</td>
</tr>
<tr>
<td>Al₂(SO₄)₃·18H₂O</td>
<td>125</td>
</tr>
<tr>
<td>CoCl₂·6H₂O</td>
<td>50</td>
</tr>
<tr>
<td>NiCl₂</td>
<td>50</td>
</tr>
</tbody>
</table>

3. Results and Discussion

The objective of the study was to assess the performance of an anaerobic hybrid reactor for biodegradation of azo-dye (Acid orange 8). The parameters analyzed were pH, alkalinity, dye concentration, COD and volatile suspended solids.

During the entire course of the study the pH of effluent was found to be in the range of 7.2 to 7.5. The Alkalinity of effluent ranged from 600-1100 mg/L as CaCO₃. The volatile suspended solids concentration has increased from 1600 mg/L to 2490 mg/L. The colour and COD removal efficiency curves for different concentrations of dye are shown in figures 2 to 5.

Figure 2 shows the variation of influent and effluent COD with respect to time and COD removal efficiency during acclimatization phase. The influent COD concentration was kept constant and was around 500 mg/L. Initially the COD removal efficiency was less but as the start up of the reactor has occurred the methanogens have become active and the COD removal efficiency increased and was around 60%. At this time dye was introduced along with acetic acid. Figure 3 shows the results of the study after introduction of dye in the reactor. The maximum COD removal efficiency achieved during this phase was 80%.
Figure 4 shows the plots of influent dye concentration, effluent dye concentration, and percentage of dye removal with respect to time for the concentrations 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm. Figure 5 shows the maximum percentage dye removal at these concentrations. The maximum dye removal efficiencies achieved at 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm were 78 %, 70 %, 68 %, 64 %, 63 % and 54 % respectively. The dye Acid orange 8 degrade almost linearly with time at these concentration. It is depicted from Figure 4 that at concentration 10 ppm the dye degrades slowly and removal efficiency achieved on the sixth day was only 31 % after that it started degrading at a fast rate and on eighth day removal efficiency reached to 57 % and finally on the tenth day removal efficiency achieved was 78 %. After that the concentration was increased to 15 ppm. At concentration 15 ppm the degradation was almost linear and the removal efficiency achieved on the twentieth day was 53 % and on the twenty-second day it reached to 70 %. Then the dye concentration was further increased to 20 ppm on twenty forth day. At 20 ppm the degradation was quite fast and on the next day of enhanced feed concentration the removal efficiency achieved was 37 % and on twenty-eighth day it reaches to 50 % and on the thirty-fourth day 68 % removal efficiency was achieved. Then the concentration was increased to 30 ppm. At concentration of 30 ppm efficiency of degradation of dye was dropped to 13 % and then on forty-second day increased to 34 % on and on forty-sixth day 64 % removal efficiency was achieved. At concentration of 40 ppm there was a drop in the dye removal efficiency. However, the system regained it and on the fifty-eighth day the dye removal efficiency was 63 %. At concentration of 50 ppm the dye degraded at linearly at fast rate the removal efficiency on the sixty-second day was 27 % then it linearly increased to 52 % on eighth day and on seventieth day 54 % efficiency was achieved. It is seen that the dye removal efficiency dropped. However if the reactor was allowed to run for more time, microorganisms might have been acclimated to the higher concentration of dye. It was observed that the degradation efficiency dropped as and when the concentration of dye was increased. However, after six to seven days the dye removal efficiency was regained. This shows that nearly a week’s time is required to overcome the shock load of increased dye concentration. The study reveals that the wastewater containing dye can be treated provided a proper acclimatization time is provided to the microorganism to developed necessary enzymes for the degradation.

4. Conclusion
Anaerobic hybrid reactor was successfully used in the present study for the biodegradation of azo-dye (Acid orange 8). The reactor performed well over a wide range of dye concentration (10-50 ppm). The maximum dye removal efficiencies achieved at 10 ppm, 15 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm were 78 %, 70 %, 68 %, 64 %, 63 % and 54 % respectively. The maximum COD removal efficiency achieved was 80%. It can be concluded that there was no effect on the COD removal after the introduction of the dye the pH of effluent was found in the range 7.2 to 7.5. The Alkalinity of effluent ranges from 600-1100 mg/L as CaCO₃. The VSS has increased from 1600 mg/L to 2490 mg/L. The desired removal efficiency can be obtained by such reactors provided proper acclimatization period is provided.

5. References