MEMBRANE BIOREACTOR PRECEDED BY UASB REACTOR FOR TEXTILE EFFLUENT TREATMENT: COLOR AND COD REMOVAL

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ABSTRACT

The textile industry, both nationally and in the state of Santa Catarina, is of great economic importance, but faces environmental challenges due to the high consumption of billions of cubic meters of water per year. Adequate treatment of effluent is crucial because of the presence of dyes, particularly azo dyes, which are the most widely used and are known for being highly polluting due to their carcinogenic potential and the amount lost in the dyeing process and released into the effluent. Faced with this problem, a study was conducted to evaluate the treatment of textile effluent containing the azo dye Remazol Brilliant Violet 5R (RVB5R) in an anaerobic reactor (UASB - Upflow Anaerobic Sludge Reactor) followed by an aerobic reactor (MBR - Membrane Bioreactor). The reactors were operated continuously for 60 days, maintaining an unfavorable C:N ratio for the biological flocculation process, fixed at a ratio of 100:2.5. The performance of the treatment system was evaluated in terms of RVB5R dye removal and chemical oxygen demand (COD), showing average efficiencies of 83.6% and 97.9%, respectively. This represents superior advantages over conventional treatment systems, such as activated sludge, and is also a compact system with reduced sludge production.

Keywords: Textile Industry. Textile Wastewater. Textile Dyes. Biological Treatment.

1 INTRODUCTION

The State of Santa Catarina is one of the main reasons why Brazil is the largest producer of textiles and clothing in the western world[1], accounting for 26.7% of national production[2]. Despite its economic importance, the sector is one of the largest consumers of water resources, using 79 billion cubic meters annually[3].

The resulting effluent must be adequately treated due to its polluting potential caused by the presence of dyes. Azo dyes represent about 70% of those used in the industry, given their excellent cost-benefit ratio[4]. On the other hand, this dye is also one of the most polluting, primarily due to its carcinogenic potential. Additionally, it is estimated that between 15% to 50% of the total mass of dye used does not bind to the fabric during the dyeing process, and is therefore lost in the effluent during the process[5].

Considering the environmental issues inherent in the use of dyes, this study aimed to evaluate the treatment of textile effluent containing the azo dye Remazol Brilliant Violet 5R (RVB5R) in an anaerobic reactor (UASB - Upflow Anaerobic Sludge Reactor) followed by an aerobic reactor (MBR - Membrane Bioreactor). The treatment system provides a reductive stage, necessary for the cleavage of the azo dye molecule, followed by an oxidative stage, which acts on the oxidation of the by-products generated in the anaerobic stage, with an emphasis on aromatic amines. In the MBR, the presence of ultrafiltration membranes ensures complete retention of solids in the reactor, resulting in a final effluent with reduced turbidity. The advantages of this system include the compact size of the treatment units, reduced sludge production compared to conventional systems, and the high quality of the treated effluent, which encourages the practice of reuse for non-potable purposes[6,7].

2 MATERIAL & METHODS

The experimental unit of the study is schematically represented in Figure 1. The UASB reactor consists of a PVC cylinder with a working volume of 96.0L, equipped with a three-phase separator inside, which separates the liquid phase from the solid and gas phases. The MBR was made of acrylic, also in a cylindrical shape, with a working volume of 60L, in which a membrane module (9) was submerged, positioned above the aeration system (8). The experimental unit also includes: control panel (1), influent reservoir (2), nitrogen cylinder (3) for purging dissolved oxygen in the influent, peristaltic pumps (4), vacuum gauges (6), and permeate reservoir (10).

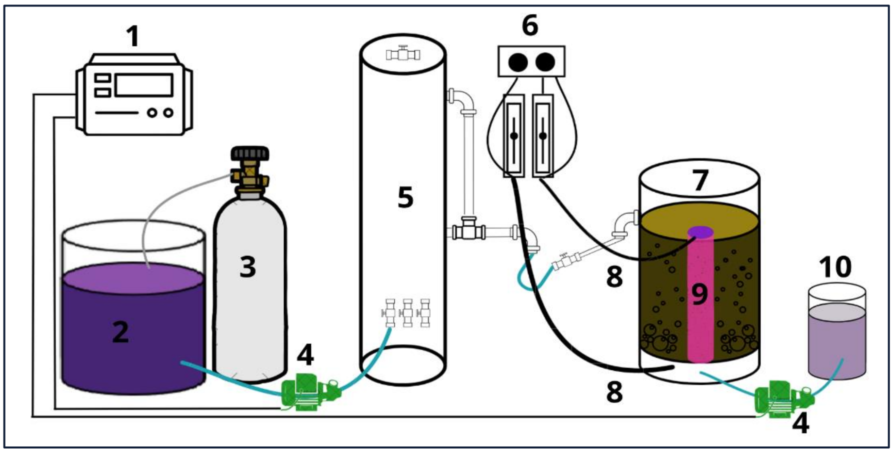

Figure 1 Representation of the Experimental Unit.

The start-up of the UASB reactor and the MBR reactor was carried out with the inoculation of sludge from the UASB reactor and Aerobic reactor of the Wastewater Treatment Plant located in the Lagoa da Conceição neighborhood, in Florianópolis/SC. The UASB reactor was inoculated with 50.0 liters of this sludge, which was directly inserted into the reactor. After a 140-day period reserved for biomass acclimation, the system was fed with synthetic effluent. The use of synthetic effluent aimed to maintain consistent loading on the system throughout the days of operation, thus avoiding the fluctuations that are common when using real effluents.

The reactors were operated continuously for a period of 60 days, during which the experimental unit was conducted under an unfavorable C:N ratio of the influent for the biological flocculation process, set at a proportion of 100:2.5. The performance of the treatment system was evaluated in terms of the removal of the RVB5R dye and chemical oxygen demand (COD).

During this period, physico-chemical analyses were conducted twice a week to determine the efficiency of COD and dye removal, following the APHA[8] methodology. There was also a daily monitoring of Oxidation-Reduction Potential (ORP), Dissolved Oxygen (DO), pH, and temperature using a multi-parameter probe.

3 RESULTS & DISCUSSION

As presented in Table 1, which shows the average concentrations of dye and COD at each treatment stage, the influent with industrial characteristics has both parameters elevated. Despite this, the treatment system demonstrated high performance in the removal of dye and COD, with average efficiencies of 83.6% and 97.9%, respectively.

Table 1 Average dye and COD concentrations with their respective standard deviations per processing step treatment and removal efficiency.

Parameter	Influent (mg/L)	UASB (mg/L)	MBR (mg/L)	Permeated (mg/L)	Efficiency (mg/L)
RVB5R	38.8 ± 0.7	4.4 ± 0.9	6.9 ± 1.7	6.3 ± 1.4	83.6 ± 3.7
COD	964.1 ± 3.3	410.1 ± 3.2	37.0 ± 2.1	20.4 ± 0.9	97.9 ± 1.0

The results in Table 1 highlight that dye removal occurs predominantly in the reductive environment, favored in the UASB reactor, where the anaerobic characteristic allows biological degradation to be more efficient due to the absence of alternative electron acceptors. In this reactor, the reduction in dye concentration compared to the influent was 88.2%. This occurs because in the anaerobic environment, dye molecules are cleaved into aromatic amines, which are biodegraded in the aerobic reactor.

Table 2 justifies the means of dye and COD removal. In the UASB reactor, there is a reductive environment characterized by a negative ORP value and a low DO concentration, below 0.5 mg/L, where the presence of anaerobic bacteria provides the degradation of organic matter and dye. In contrast, in the MBR, DO values were around 5.2 mg/L and ORP was above 200.0 mV, characterizing an oxidative aerobic system. These conditions indicate aerobic oxidative processes, such as the oxidation of aromatic amines formed by the cleavage of the azo dye in the UASB reactor.

Table 2 Average results of monitoring parameters for each reactor and their respective standard deviations.

UASB				MBR			
pH	Temp (°C)	DO (mg/L)	ORP (mV)	pH	Temp (°C)	DO (mg/L)	ORP (mV)
8.1 ± 0.3	30.4 ± 1.2	0.34 ± 0.04	-187.5 ± 4.3	8.4 ± 0.2	24.6 ± 1.6	5.27 ± 1.6	212.5 ± 3.8

In the aerobic reactor, a slight increase in dye concentration was observed, a result also obtained by previous studies[6]. This was associated with the oxidation of intermediate products formed in the previous stage. After the MBR, there was a reduction of approximately 2% in dye concentration due to the removal of its soluble form by the ultrafiltration membrane module. The overall efficiency of the system is extremely satisfactory, given the difficulty of dye removal.

The removal of COD occurred mostly in the non-aerated environment, similar to the results of previous studies[7,9], with the UASB reactor achieving an efficiency of 59%, where organic matter was mainly used for denitrification and azo dye reduction. A result that differs from previous studies is the high COD removal in the aerated phase, which is crucial to justify the need for the association of anaerobic and aerobic processes. It is noted that the 1.8% efficiency of the membrane module is due to the presence of soluble COD, and that the synthetic effluent contains only acetate as a carbon source, so the COD is equivalent to BOD, which justifies its highly efficient biological degradation, observed by the overall system efficiency of approximately 98%.

Another important result is to assess that the unfavorable C:N ratio did not compromise the treatment efficiency of the dye and COD, which was particularly high for COD, where the results were extremely similar to studies where the ratio was not unfavorable[6]. For dye removal, this ratio does not cause significant changes since the efficiency is mainly due to the UASB reactor, and the C:N ratio was calculated for the aerobic reactor.

Evaluating the treatment efficiency in relation to the discharge parameters of Brazil and the State of Santa Catarina, it is observed that the state legislation (Resolution 181/CONSEMA)[10] and the national legislation (Resolution 430/CONAMA)[11] do not address the COD parameter, emphasizing the BOD parameter for discharges into water bodies. In Santa Catarina, Resolution 181/CONSEMA establishes a limit of 60 mg/L for the final effluent of Sewage Treatment Plants (STPs). Therefore, it is possible to infer that the permeate from the MBR has an organic matter concentration below this limit, since the average COD (20.4 mg/L) is even lower than the BOD limit (60.0 mg/L). Regarding the color parameter, there is no mention in Brazilian environmental legislation, except in Resolution 357/CONAMA[12], which establishes that STP effluents should not alter the color of the receiving body in a way that affects its classification.

4 CONCLUSION

This research highlighted the importance of treating textile effluent due to the associated problems and also underscored the high efficiency of combining biological and treatments for this effluent, evaluating the removal of dye and COD.

Regarding dye removal, the effectiveness of the reducing environment stands out, with an efficiency of 88.2% compared to the influent concentration. The unfavorable C:N ratio did not alter the removal efficiency precisely because the process occurs predominantly in the UASB reactor. The lack of regulation for dyes highlights the importance of continuous monitoring and improvement of environmental policies to ensure the preservation of water resources.

The unfavorable ratio also did not affect the removal of COD, which was close to 98%, occurring in both reactors, although the UASB had a more significant role. Despite the effectiveness of the UASB, without subsequent aerobic treatment, the effluent would exceed the limit stipulated by legislation.

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