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Aerobic decolourization of the indigo dye-containing textile wastewater using continuous combined bioreactors

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Abstract

An aerobic bioprocess was applied to Indigo dye-containing textile wastewater treatment aiming at the colour elimination and biodegradation. A combined aerobic system using continuous stirred tank reactor (CSTR) and fixed film bioreactor (FFB) was continuously operated at constant temperature and fed with the textile wastewater (pH: 7.5 and total chemical oxygen demand (COD): 1185 mg l^{-1}). The CSTR is a 1 l continuous flow stirred tank reactor with a 700 ml working volume, and operated with a variable wastewater loading rate (WLR) from 0.92 to 3.7 g l^{-1} d^{-1}. The FFB is a 1.5 l continuous flow with three compartments packed with a rippled cylindrical polyethylene support, operated with a variable WLR between 0.09 and 0.73 g l^{-1} d^{-1}. The combined two bioreactors were inoculated by an acclimated microbial consortium and continuously operated with four total WLR. This system presented high COD elimination and colour removal efficiencies of 97.5% and 97.3%, respectively, obtained with a total hydraulic retention time (HRT) of 4 days and total WLR of 0.29 g l^{-1} d^{-1}. The effects of WLR on absorption phenomena on the yield of conversion of substrate on biomass ($R_{TSS/COD}$) and on the yield of conversion of substrate on active biomass ($R_{VVS/COD}$) are discussed. The increase of WLR and the decrease of HRT diminished the performances of this system in terms of decolourization and COD removal explained by the sloughing of biofilm, and the washout phenomena.

Keywords: Textile wastewater; Indigo; Aerobic; Microbial consortia; Decolourization

1. Introduction

Textile industries consume a considerable amount of water in their manufacturing processes. Considering both the volume and the effluent composition, the textile industry wastewater is rated as the most polluting among all industrial sectors. Important pollutants in textile effluents are mainly recalcitrant organics, colours, toxicants and inhibitory compounds, surfactants, chlorinated compounds (AOX), pH and salts [1]. Alterations to their chemical structures can result in the formation of new xenobiotic compounds which may be more or less toxic than the potential compounds [2]. It has been proven that some of those dyes and/or products are carcinogens and mutagens. Apart from the aesthetic deterioration of the natural water bodies, dyes also cause harm to the flora and fauna in the natural environment [3–5]. Therefore, industrial effluents, like textile wastewater containing dyes must be treated before their discharge into the environment. The dye wastewater from the textile is one of the most difficult wastewater to treat [6,7]. Because of their commercial importance, the impact and toxicity of dyes that are released in the environment have been extensively studied [8].

Colour can be removed from wastewater by chemical and physical methods including absorption, coagulation–flocculation, oxidation and electrochemical methods. These methods are quite expensive, have operational problems [9], and generate huge quantities of sludge [10]. Among low cost, viable alternatives, available for effluent treatment and decolourization, the biological systems are recognised, by their capacity to reduce biochemical oxygen demand (BOD) and chemical oxygen demand (COD) by conventional aerobic biodegradation [4,8,11].

Work on the use of combined bacterial process to treat textile wastewater has been carried out over the years by many research groups [8,12]. Recent study has used the combina-

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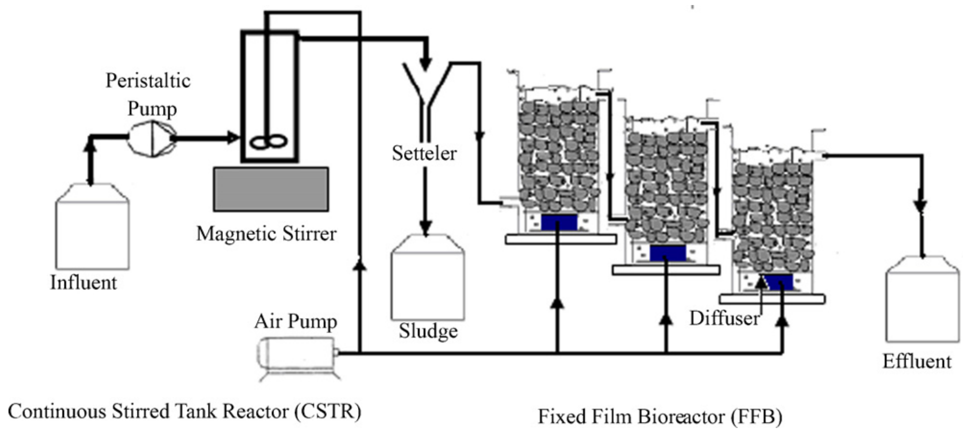

Fig. 1. Schematic representation of the experimental set-up used for textile wastewater treatment.

tion of anaerobic and aerobic steps in an attempt to achieve not only decolourization but also mineralization of azo dyes. The use of exclusively aerobic processes to decolourize azo dye-containing wastewater was not common and rarely used; because dyes are difficult to remove by using the conventional wastewater treatment systems based on aerobic processes [13]. Aerobic processes have been recently used for the treatment of textile wastewater as standalone processes and it is confirmed that they are efficient, cost-effective for smaller molecules and that the aerobic reactor is an effective technique to treat industrial wastewater [5,10,14–19]; or in combination with anaerobic processes [12,19–22].

With this aim, the research investigated the aerobic biodegradability of the textile dye (Indigo) by a combination of two aerobic bioreactors (CSTR and FFB). The effects of HRT and WLR on the treatment efficiencies in terms of COD and colour removal efficiencies were investigated.

2. Materials and methods

2.1. Operational conditions of laboratory bioreactors

A laboratory scale aerobic bioprocess as shown in Fig. 1 was used in this study. The aerobic system used was a combined CSTR and FFB bioreactor. The system was operated continuously at a constant temperature of 30 °C using an external water bath. The continuous stirred tank reactor with a 700 ml working volume was used. Mixing was assured by the continuous rotation of the magnetic stirrer. The FFB is a 1.5 l continuous flow with three compartments packed with a rippled cylindrical polyethylene support. The coupled system was first inoculated with a microbial consortia obtained from a textile wastewater treatment plant. These inocula were selected because of the large variety of microorganisms that could be found in the biomass degrading dyes in textile wastewater, and because mixed cultures offer considerable advantages over the use of pure culture. In fact, individual strains may attack the dye molecules at different position or may use decomposition products produced by another strains for further decomposition.

Each bioreactor was operated in batch-wise until biofilm formation was realised in the FFB and the microbial consortia becomes stable in the CSTR bioreactor. In fact, it is mentioned that adaptation is important for successful decolourization, and as acclimation occurred, the decolourization time becomes constant [14].

The system was fed by a peristaltic pump with the textile effluent (containing the Indigo dye) obtained from textile wastewater plant in Ksar Hellal (Tunisia), and its pH was maintained at approximately 7.5. Air was provided from the bottom of the aeration of the combined bacterial process using diffusers and an air pump. Bioreactors operating conditions are depicted in Table 1.

2.2. Analytical methods

The effluent from each bioreactor was collected daily, centrifuged at 7000 rpm for 10 min and analysed for colour, COD, pH, total suspended solids (TSS), volatile suspended solids (VSS) and colonies forming units (CFU). COD and colour measurements were carried out on the clear supernatant. Colour was measured by an UV–vis spectrophotometer (Jenway UV visible spectrophotometer) at a wavelength of 620 nm in which maximum absorbance spectra was obtained. The total and soluble COD was measured following standard methods. Measured COD and absorbance values were used for calculation of biodegradation and decolourization efficiencies.

The TSS was determined by drying samples at 105 °C for 24 h. The VSS, which is assumed as active biomass, was measured by calculating the loss of the sludge before and after

Table 1
Bioreactors operating conditions

HRT (day)	WLR ($g\,l^{-1}\,d^{-1}$)
4	0.296
3	0.394
2	0.592
1	1.185

HRT: hydraulic retention time; WLR: wastewater loading rate.