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KINETIC STUDIES ON FLUIDIZED BED REACTOR FOR TREATING TEXTILE DYE EFFLUENT BY WHITE ROT FUNGI

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ABSTRACT

In the present study consortium of White Rot Fungal (WRF) species employed for the decolourization and biodegradation of synthetic textile dye effluent in a designed Fluidized Bed Reactor (FBR). Kinetic study was carried out with the results got from the operation of FBR to the varying Hydraulic loading rate (HLR) and Organic loading rate (OLR). Decolourization of 95%and 89% of Chemical oxygen demand (COD) removal were achieved through the study using the designed FBR. Kinetic study was carried out for the substrate removal using Modified Stover-kincannon model and First order substrate removal model to determine the constants and the correlation value for the effective treatment technology. From the result, it was observed that the Modified Stover-kincannon model fits to the satisfactory level when compared to First order model.

KEYWORDS: COD, FBR.HLR, OLR, Synthetic Dye Effluent, WRF

INTRODUCTION

Textile dyeing industries use synthetic dyes in large scale when compared to the natural dyes due for their ease and varieties of different colours. Over 7×10^5 tonnes of about 10, 000 different types of dyes and pigments are produced annually worldwide [1]. Colour, COD, alkalinity and Total dissolved solids (TDS) are the major pollutants from the textile dye industries affecting the aquatic ecosystem severely by their higher concentrations. The 10- 15% of the unfixed dyes from the textile dyeing industries is the reason for the colour pollution in the receiving streams in surface and subsurface levels. It is very difficult to decolourise the dyeing effluent due to the presence of the dyes which are complex in their chemical structure. Physicochemical treatment methods like flocculation, coagulation, oxidation, precipitation, irradiation, incineration and membrane adsorption have been employed for the treatment of dye-contaminated effluents [2], [3], [4], [5]. Sludge generation and high cost made the physicochemical methods less use in the treatment of textile dyeing industries. Biodegradation is an environment friendly and cost effective technology when compared for chemical decomposition [6]. WRF have been evaluated for their potential to treat coloured wastewaters [7] [8]. Research on WRF for the past decade for the decolourization and biodegradation of the textile dye effluent proved to be an effective technology in removal of COD and Colour by the degradation and mineralization of textile dye-stuffs by fungal species[7][8], [9]. This study aims for the evaluation of kinetic constants to the biodegradation of synthetic textile dye effluent in a designed fluidized bed reactor by the white rot fungal consortium along with the determination of decolourization.

MATERIALS AND METHODS

Experimental Set Up

The experimental setup consists of a fixed film aerobic fluidized bed reactor having an effective volume of $0.02 m^3$. The specification of the experimental set up is given in Table 1 and schematic is shown in Figure 1.

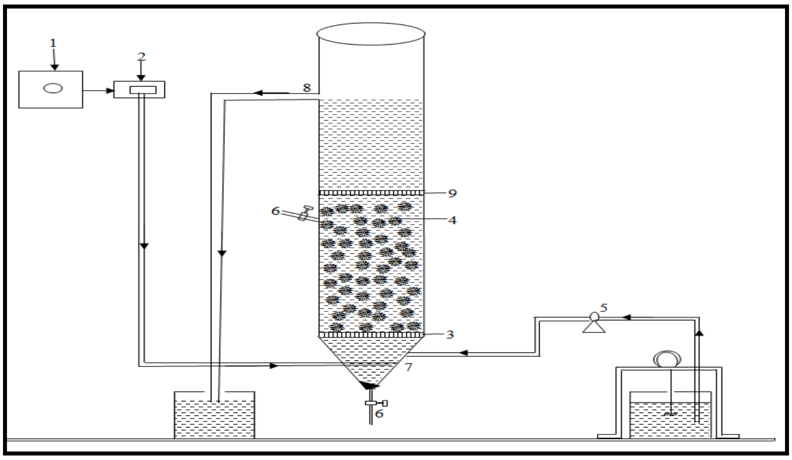
Preparation of Synthetic Waste Water

The synthetic wastewater was simulated towards the characteristics of a real textile dyeing effluent. Three different reactive dyes namely Drimarene Red X 6BN, Drimarene Blue X 3LR CDG and Drimarene Yellow X4RN were purchased from Colour Chemicals Pvt. Ltd. (Erode, India). Dyes were mixed in equal proportions with various chemicals like sodium chloride, sodium carbonate, soap oil, wetting agent, acids, alkalis and Hydrogen peroxide.

Microorganism and Culture Medium

Pure cultures of four different fungal species were obtained from the Microbial Type Culture Collection and Gene Bank (MTCC), Institute of Microbial Technology (IMTECH) Chandigarh, India. Species were Pleurotus *Ostreatus* MTCC No: 1804, *Pleurotus Sajor-Caju* MTCC No: 141, *Tremetus versicolour* MTCC No: 138 and *Tremetus Hirsuta* MTCC No: 136. The cultures were grown separately in the PDA (Potato Dextrose Agar) slants stored at 4^oC and subculture for every 25 days.

Start-Up Process



1. Air Blower 2. Flow Meter 3. Bottom Flow Distributor 4. Spiral Media
5. Miclin's Pump 6. Sample Port 7. Inlet 8. Outlet 9. Top Flow Distributor

Figure 1: Experiment Model of Aerobic Fluidized Bed Reactor

The experiment was initiated with the feeding of domestic wastewater and real textile dyeing wastewater for the acclimatization process. The nutrients supplied during the start-up process were in the ratio of COD: N: P as (100:5:1). After attaining the steady state condition within 14 days, the synthetic textile wastewater was fed into the reactor.

Table 1: Physical Features and Process Parameters

S.No.	Specifications	Details
1.	Volume of Reactor	$0.03 m^3$
2.	Effective volume of Reactor	$0.02 m^3$
3.	Diameter of Reactor	0.15m
4.	Height of Reactor	1.17m

Table 1: Contd.,

5.	Height of packed bed before fluidization	0.25m
6.	Flow Distributer	2 Nos.
7.	Pump used for the influent feed	Peristaltic Pump PP-30 model (Miclin's Product).
8.	Media Packed	Fujino Spirals, (PVC material)
9.	Specific area of filling media	$500m^2/m^3$
10.	Void ratio of the media	87%
11.	Expansion of bed Restricted by the top flow distributor	50% ie. 0.5m From the bottom Flow distributor
12.	Air blower	270 L/min
13.	Air Supply	0.025m/s
14.	Sample Port	2 Nos.

Experimental Run

The operational parameters were the HRT and OLR. The experiment was run for five different COD concentrations of 750mg/L, 1000mg/L, 1250mg/L, 1500mg/L and 2000mg/L. The operational parameters HRT was varied as 26 hrs, 20 hrs, 13 hrs and 10 hrs for each COD concentration subsequently. With respect to the COD concentrations and the influent flow rate the OLR is varied from 0.648 Kg. COD/ m3day to 4.816 Kg. COD/ m3day. Samples were collected regularly according to the HRT varying period from the inlet and outlet for the analysis. The evaluation is based on the %COD removal and %Colour removal.

MODELLING ASSAYS

First order model and Modified Stover-kincannon model were used for the evaluation of kinetics of the substrate removal in the designed FBR for the synthetic textile dye effluent by the selected WRF consortium for the treatment plant.

First-Order Substrate Removal Model

The rate of change in substrate concentration in the system, assuming that first order kinetics is can be expressed as Eq. (a):

$$-\frac{ds}{dt} = \frac{Q}{V} \times S_0 - \frac{Q}{V}S - k_1S \qquad \text{(a)}$$

Under steady-state conditions, the rate of change in substrate concentration (- dS/dt) is very less and the Eq. (a) Can be reduced to the Eq. (b):

$$\frac{S_0 - S}{t} = k_1 S \qquad \text{(b)}$$

The value of k_1 can be obtained by plotting (So - S /t) versus (S) in Eq. (b), which is obtained from Eq. (a). The value of k_1 can be obtained from the slope of the line on the graph. The **Figure 2** shows the plot between (S_0 - S) /t and k_1 was 0.37 per day with a correlation coefficient (R^2) was 0.684. The low value of this coefficient (R^2) clearly indicates that first order kinetics does not fit in the evaluation.

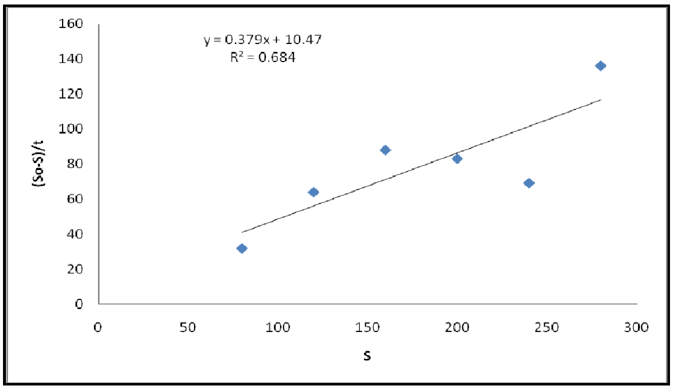


Figure 2: Determination of Constants by First Order Model

Modified Stover-Kicannon Model

Equation of the Stover-Kincannon model is expressed in Eq. (c).

$$\frac{ds}{dt} = \frac{R_{max} \times (Q \times S_0 / A)}{K_B \times (Q \times S_0 / A)} \quad (c)$$

Equation of the modified Stover-Kincannon model is expressed as in Eq. (d).

$$\frac{ds}{dt} = \frac{R_{max} \times (Q \times S_0 / V)}{K_B \times (Q \times S_0 / V)} \quad (d)$$

where dS/dt is defined in Eq. (e),

$$\frac{ds}{dt} = \frac{Q}{V} \times (S_0 - S) \quad (e)$$

Eq. (f) was obtained from linearization of Eq. (e) as,

$$\frac{V}{Q \times (S_0 - S)} = \frac{K_B}{R_{max}} \frac{V}{Q \times S_0} + \frac{1}{R_{max}} \quad (f)$$

Figure 3 Shows the graph plotted between reciprocal of total organic loading removal rate, $[V/ (Q (S_0-S)]$, against to the reciprocal of the total organic loading rate, $V/(Q \times S_0)$. The values of K_B/R_{max} and $1/R_{max}$ were found to be 1.995 and 0.113 from the plot with high correlation coefficients of (R^2) 0.935. The maximum substrate removal rate constant (R_{max}) is 8.83 g L^{-1} d^{-1} and the saturation value constant (K_B) is 17.62 g L^{-1} d^{-1} indicating the maximum substrate removed by the aerobic organisms versus time and the substrate removed by microorganisms during time respectively. From the above results it was clearly understood that the modified Stover-kincannon model fits very well for the designed FBR to treat the textile dye wastewater and can also be an effective tool for the evaluation of treatment technologies of the textile dye industries.

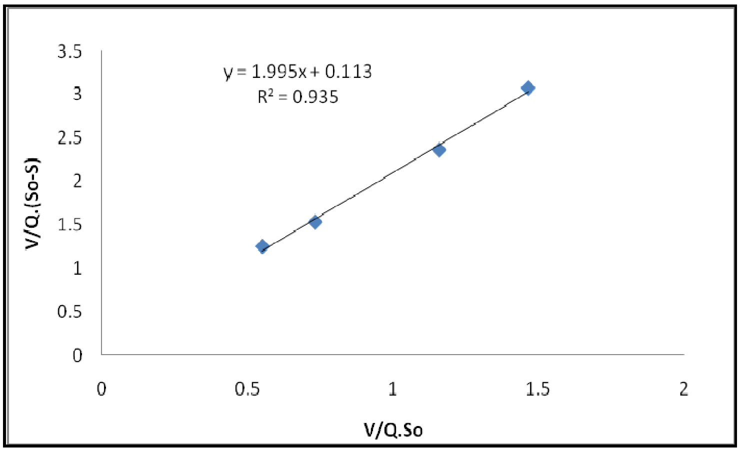


Figure 3: Determination of Constants by Stover-kincannon Model

RESULTS AND DISCUSSIONS

The results from the study of the determination of constants using First order model and Modified Stover-Kincannon model showed a greater influence in the substrate removal proving that the Modified Stover-kincannon model fits very well with the kinetic constants having a high correlation coefficient value of $R^2 = 0.935$. The (R_{max}) 8.83 g L−1 d−1 and (K_B) 17.62 g L−1 d−1 values obtained in this study were varying found by S.M.Borghei *et.al*, (2008) [11], S.Sandhya, *et.al*, (2008) [12] and Borghei and Hosseiny *et.al*, (2002) [13]. The variations of the similar operation and process experiments analyzed with the Modified Stover-kincannon model can be due to their varying wastewater characteristics, design of the reactor and the microorganisms involved in their process.

CONCLUSIONS

The fungal consortium of *Pleurotus Ostreatus, Pleurotus Sajor-Caju, Tremetus versicolour* and *Tremetus Hirsuta* with the designed FBR proved to be an excellent technique used for the biodegradation of textile dye effluent. First order model with $R^2 = 0.684$ does not fit in the evaluation of this technique and Modified Stover-kincannon (R_{max}) 8.83 g L−1 d−1 and (K_B) 17.62 g L−1 d−1 with the correlation coefficient $R^2 = 0.935$ made this technique viable for the treatment of textile dye effluent in an efficient manner.

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